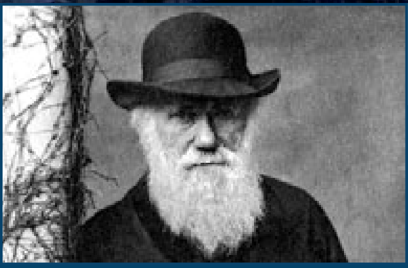
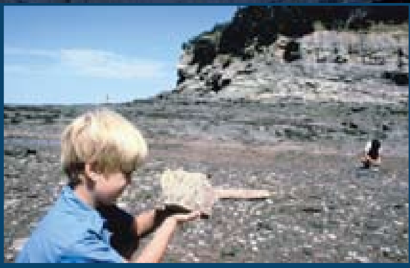




JOGGINS FOSSIL CLIFFS

Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List

January, 2007

Section of the cliffs of the South Joggins, nea

19.

Fig. 20.

Stigmaria in micaceous sandstone.

Nomination of the

The Joggins Fossil Cliffs

for Inscription
on the
World Heritage List

January, 2007

Nova Scotia

Foreword

The Joggins Fossil Cliffs are among the most significant natural earth science sites in the world. The coastal exposures at Joggins provides a near continuous, accessible sequence of rocks that document the "Coal Age" of earth's history. With careful observation and interpretation, visitors may discover 300 million year old fossils on the beach and in the cliffs.

The fossil cliffs of Joggins are located near the head of the Bay of Fundy, in an area where the tides are some of the highest in the world. This tidal action causes steady erosion of the towering cliffs. Given its outstanding significance, the province of Nova Scotia has protected this unique site through the *Special Places Protection Act.*

The Government of Canada has included The Joggins Fossil Cliffs as one of the eleven natural and cultural sites in its Tentative List of sites for future consideration as World Heritage sites. The cultural site of Old Town Lunenburg in Nova Scotia is one of only 13 sites in Canada that have been inscribed on the World Heritage List.

The successful development, protection and designation of The Joggins Fossil Cliffs has been a cooperative effort at the community, regional, provincial and national levels.

The province of Nova Scotia fully supports the nomination of The Joggins Fossil Cliffs for inscription on the World Heritage List, and will continue to be engaged as a partner in the ongoing management, protection and monitoring of the property.

Hon. Rodney MacDonald
Premier of Nova Scotia

Preface

The Joggins Fossil Cliffs is a special place and is recognized as such by both the international scientific community and local residents. For longer than a century, the people who lived in and around Joggins have played an important role in caring for and promoting The Joggins Fossil Cliffs. World Heritage Site status would provide a significant contribution to the long-term conservation of The Joggins Fossil Cliffs. Inscription on the World Heritage List would ensure that its earth science interests are properly recognized both in their own right and because of their important role within the region's history and culture.

As representatives of the people of Cumberland County, we are committed to working in partnership with the many organizations and individuals who own, manage, visit and value The Fossil Cliffs in order to continue to support effective protection, stewardship and public understanding so that this unique site will be conserved for future generations.

Increasing recognition of The Joggins Fossil Cliffs is helping to revitalize our communities. This is greatly assisting in the sensitive regeneration of an area which has suffered both economically and socially since the decline of the coal industry. Our proposals for the area have been developed through a wide partnership of stakeholders and in close consultation with local people.
We hope that this nomination for inscription on the World Heritage List will be looked upon favourably by the World Heritage Committee and provide international appreciation for The Joggins Fossil Cliffs.

Finally, we would like to thank The Joggins Fossil Cliffs Advisory Board, staff of the Cumberland Regional Economic Development Association and the Municipality of the County of Cumberland, the Nova Scotia Department of Natural Resources, Office of Economic Development and Department of Tourism, Culture and Heritage for their contribution in preparing this document.

Keith Hunter
Warden,
Municipality of the County of Cumberland

CUMBERLAND COUNTY MUNICIPALITY CORPORATION

Rhonda Kelly
Executive Director,
Cumberland Regional Economic Development Association

CREDA
CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

JARDIN BOTANICO DE CORDOBA
Información: 957 20 03 55 Fax: 957 29 53 33
Avda. de Linneo, s/n. - 14004-Córdoba (España)
Administración: 957 20 00 18 Dirección: 957 20 00 77
Area de Cultura: 939 00 11 30

Preamble

There is no doubt whatsoever that the coastal cliffs at Joggins, Nova Scotia, are not only of world renown and thus a standard reference in geological literature since the 1800s, but that the splendid outcrops contain a very significant record of fossil flora and fauna as well as the ecological conditions under which these terrestrial life forms occurred. It is difficult to overrate the importance of this very substantial section of beautifully exposed, well studied strata. There is no other site in the world that combines total exposure of a long section of Carboniferous ("Coal Age") strata with a palaeoecologically significant succession of *in situ* forests of well over 300 millions years ago, together with biostratigraphically important plant fossils, in context with palaeoecological and taphonomic evidence. Last but not least, it contains the most important record of early reptiles and their habitat.

The Joggins Fossil Cliffs is truly a site of outstanding universal value and can be regarded as unique and worthy of the international recognition which will ensure its promotion for educational and research purposes.

Dr. Robert H. Wagner

Reader in Geology (retired), Sheffield University, England, U.K.

Director Palaeobotanical Museum;
IMGEMA-Jardín Botánico de Córdoba, Spain

Profesor honorífico and Dr h.c., Universidad de Córdoba

Editor-in-Chief, *The Carboniferous of the World*

Executive Summary

State Party:	Canada
Province:	Nova Scotia
Name of Property:	The Joggins Fossil Cliffs
Geographical Co-ordinates to the Nearest Second:	45° 42′ 35″ N 64° 26′ 09″ W

Textual Description of the Boundaries of the Nominated Property:

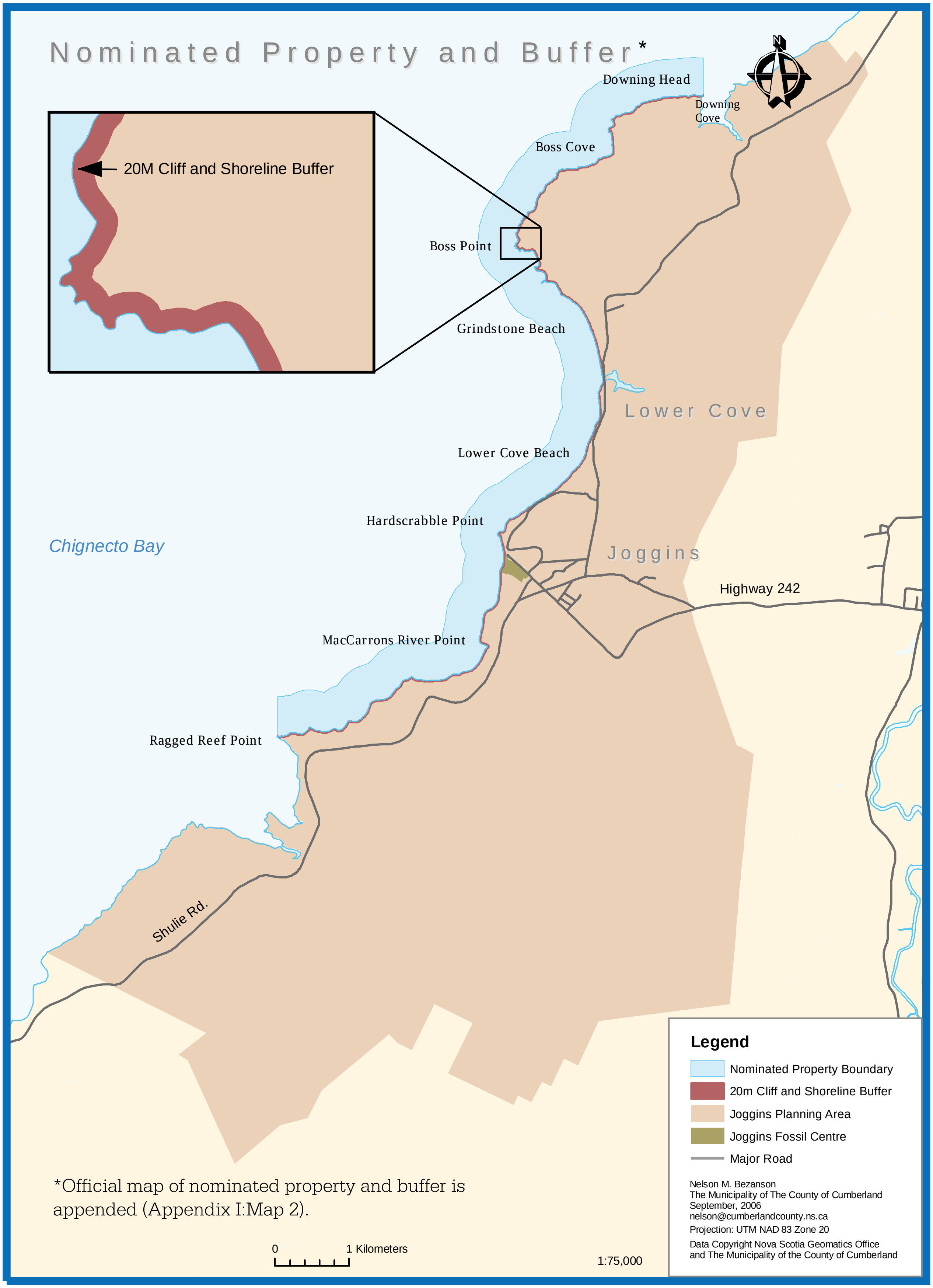
The nominated property comprises 14.7 kilometres of rugged coastal cliffs at Joggins, on Nova Scotia's Bay of Fundy, encompassing the entire Joggins Formation and both older and younger geological formations that together span 15 million years of earth history. The boundaries of the property include the continuous exposure of the Carboniferous strata within the coastal cliffs and foreshore, from which all known fossil discoveries from these beds have derived.

Due to the erosive action of the Bay of Fundy tides, the coast is highly dynamic and the profile of the cliffs and beaches is constantly changing. The boundary of the nominated property accommodates the natural processes of coastal erosion and as the cliff face migrates landward so too does the nominated property boundary. The boundary definition ensures that the property's integrity will be maintained in perpetuity. The boundary is defined by topographic features visible in the landscape and therefore ensures that they are clearly identifiable on the ground and ultimately useful for site management.

Protective legislation is in place and a comprehensive management plan for the property has been developed, ensuring its integrity for future generations. Complementary provincial and municipal legislation accords additional protection of future exposures in a buffer zone landward of the property. Goals of site stewardship, scientific research and education will be realized in part by the presence of the new Joggins Fossil Centre under construction adjacent to the nominated property.

Maps of the Nominated Property:

Figure (i) *Location of the nominated property.*



*Official map of nominated property and buffer is appended (Appendix I:Map 2).

Justification (Statement of Outstanding Universal Value):

The coastal cliffs at Joggins reveal the most complete fossil record in the world of terrestrial life in the Pennsylvanian "Coal Age" of earth history. Nowhere is this record of the evolution of life on land and biodiversity in the tropical "Coal Age"—encompassing plant, invertebrate and vertebrate life—rendered more evocatively. The magnificently exposed succession of sedimentary layers preserves the fossils *in situ*, providing environmental context that is unrivalled in the world. The fossil record includes the two defining, iconic elements of the "Coal Age": fossil forests of the "coal swamps" and the first reptiles, which as the earliest amniotes are the oldest known representatives of reptiles, birds and mammals. The origin of amniotes, the first vertebrates to achieve the capacity to reproduce on land, was one of the most significant events in the history of life on earth, an evolutionary milestone first recorded with certainty at Joggins. No other locality in the world has provided as much knowledge of the nature of early amniotes or more informative specimens for linking them to more primitive groups of Palaeozoic tetrapods, and to the world in which they lived. Through the power of the Bay of Fundy tides, which are unsurpassed in the world, ongoing discovery is ensured at this site of outstanding universal value.

This dramatic setting is home to what Sir Charles Lyell, founder of modern geology, described as "the finest exposure in the world" of the rocks and fossil record of the Pennsylvanian "Coal Age" of earth history. The fossil record of Joggins figured in the first debate on evolution, and remains pivotal to understanding the terrestrial origins of vertebrate life, including our own species. This uniquely representative chapter of the earth's history has been the subject of the research and writings of some of the world's most influential scientists since the mid-nineteenth century. Joggins has figured in such seminal works as *Principles of Geology* by Lyell and *The Origin of Species* by Charles Darwin, and has come to be known as a "Coal Age Galapagos."

Criteria under which Property is Nominated:

The coastal cliffs of Joggins are nominated for inscription to the World Heritage List under "criterion viii" of the Operational Guidelines for World Heritage (2005), which states that sites:

> be outstanding examples representing major stages of earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features.

Name and Contact Information of Official Local Institution:

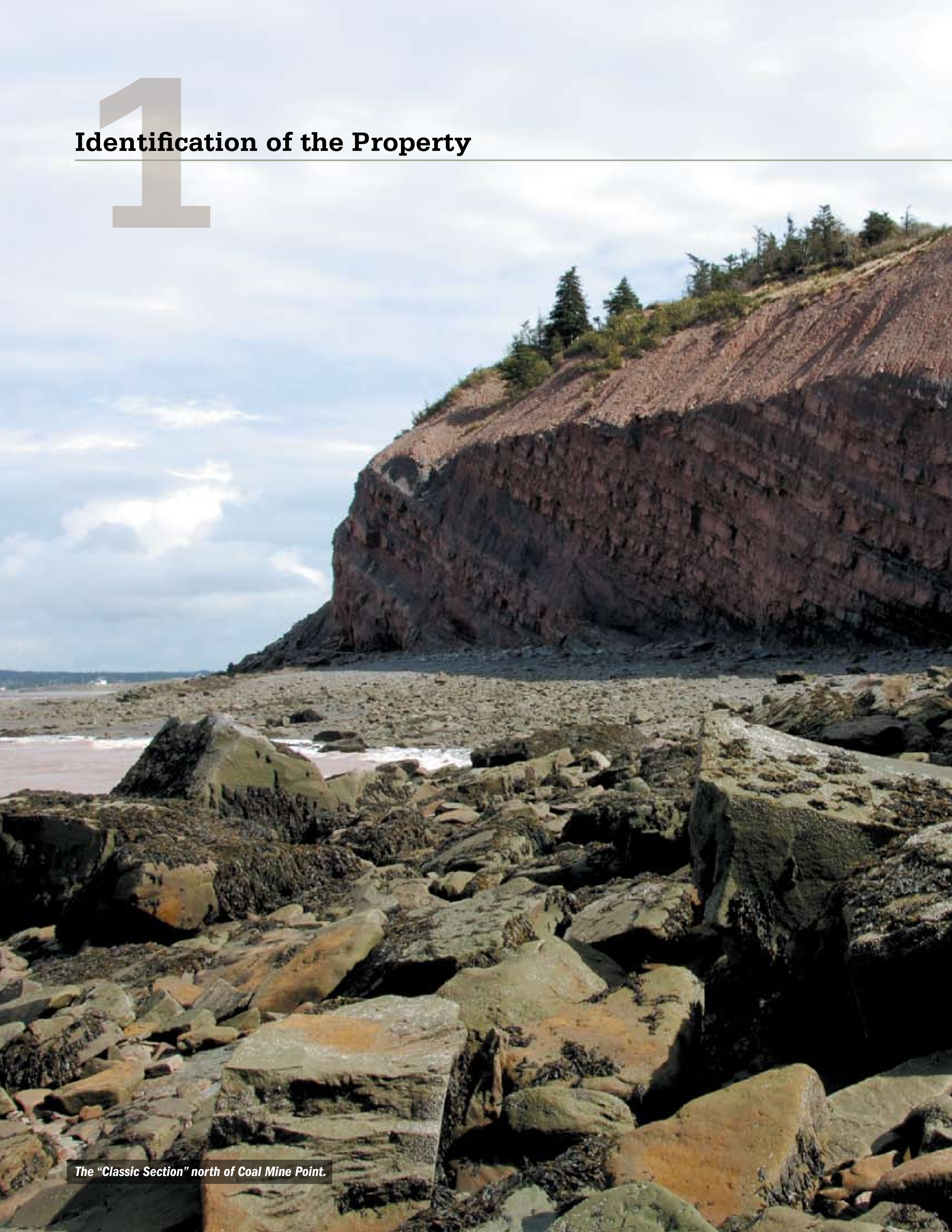
The official local institution responsible for the management of the nominated property is the Joggins Fossil Institute.

Organization Name:	Joggins Fossil Institute
Address:	35 Church Street, P.O. Box 546
City:	Amherst, Nova Scotia
Postal Code:	B4H 4A1
Tel:	(902) 667-6367
Fax:	(902) 667-2270
Email:	jboon@creda.net
Web Address:	www.jogginsfossilcliffs.net

JOGGINS FOSSIL CLIFFS

Table of Contents

1 Identification of the Property



The "Classic Section" north of Coal Mine Point.

1.A COUNTRY

The nominated property is located in Canada.

1.B PROVINCE

The nominated property is located in the province of Nova Scotia.

1.C NAME OF PROPERTY

The official name of the nominated property is the "The Joggins Fossil Cliffs."

1.D GEOGRAPHICAL COORDINATES

The geographical coordinates (to the nearest second) for the approximate centre of the property are:

LATITUDE	45° 42’ 35” North
LONGITUDE	64° 26’ 09” West

The Universal Transverse Mercator (UTM) coordinates (to the nearest 10 metres) for the approximate centre of the property are:

DATUM	North American Datum of 1983
ZONE	20
NORTHING	5,062,800 Metres
EASTING	388,220 Metres

1.E MAPS AND PLANS, SHOWING THE BOUNDARIES OF THE NOMINATED PROPERTY AND BUFFER ZONE

1.E (i) Property Boundary

The nominated property is situated in eastern Canada, in the province of Nova Scotia. The property comprises a 14.7-kilometre expanse of sea cliffs and beach on the eastern shore of Chignecto Bay, on the northern arm of the Bay of Fundy. The site extends north and south of the town of Joggins, County of Cumberland.

The northern extent of the property is defined by Downing Head (45° 45’ 07” N, 64° 25’ 05” W) and the southern extent is defined by Ragged Reef Point (45° 40’ 24” N, 64° 23’ 09” W). These boundaries coincide with the "Protected Site" designated under the *Special Places Protection Act* of the province of Nova Scotia.

The landward boundary of the nominated property has been defined as the top of the cliff-face, or in areas where cliffs are not present, the most landward point at the back the beach. The seaward boundary is 500 metres parallel to the top of the cliff or back of the beach. The nominated property includes the beach and inter-tidal area where bedrock "reefs" with embedded fossils extend from the cliffs. The legal description of the property boundary is described as:

BEGINNING at the north-eastern point at the top of the cliff or bank (in its natural state) on the eastward side of Chignecto Bay, on the west side of the mouth of Downing Cove; THENCE south-westerly and following the various courses of the top of the cliff or bank (in its natural state) and extending across the mouth of all tributaries on the eastward side of Chignecto Bay, to the north-western point of Ragged Reef Point; THENCE due grid north seaward to a point being located at a perpendicular distance of 500 metres northerly from the top of the cliff or bank, on the eastward side of Chignecto Bay; THENCE in a generally north-easterly direction remaining parallel to and 500 metres perpendicular distant from the top of the cliff or bank on the eastward side of Chignecto Bay, to a point being located due grid north from the PLACE OF BEGINNING; THENCE due grid south to the PLACE OF BEGINNING. CONTAINING an approximate area of 689 hectares. THE ABOVE DESCRIBED PARCEL having a seaward boundary lying 500 metres perpendicularly distant from the top of the cliff or bank and having a landward boundary that will follow parallel to the top of the cliff or bank, as its location varies over time.

The boundaries of the nominated property have been assigned to include the continuous exposure of the Carboniferous strata within the coastal cliffs and foreshore. Due to the erosive action of the Bay of Fundy tides, which are unsurpassed in the world, the coast is highly dynamic and the profile of the cliffs and beaches is constantly changing. The boundary of the nominated property accommodates the

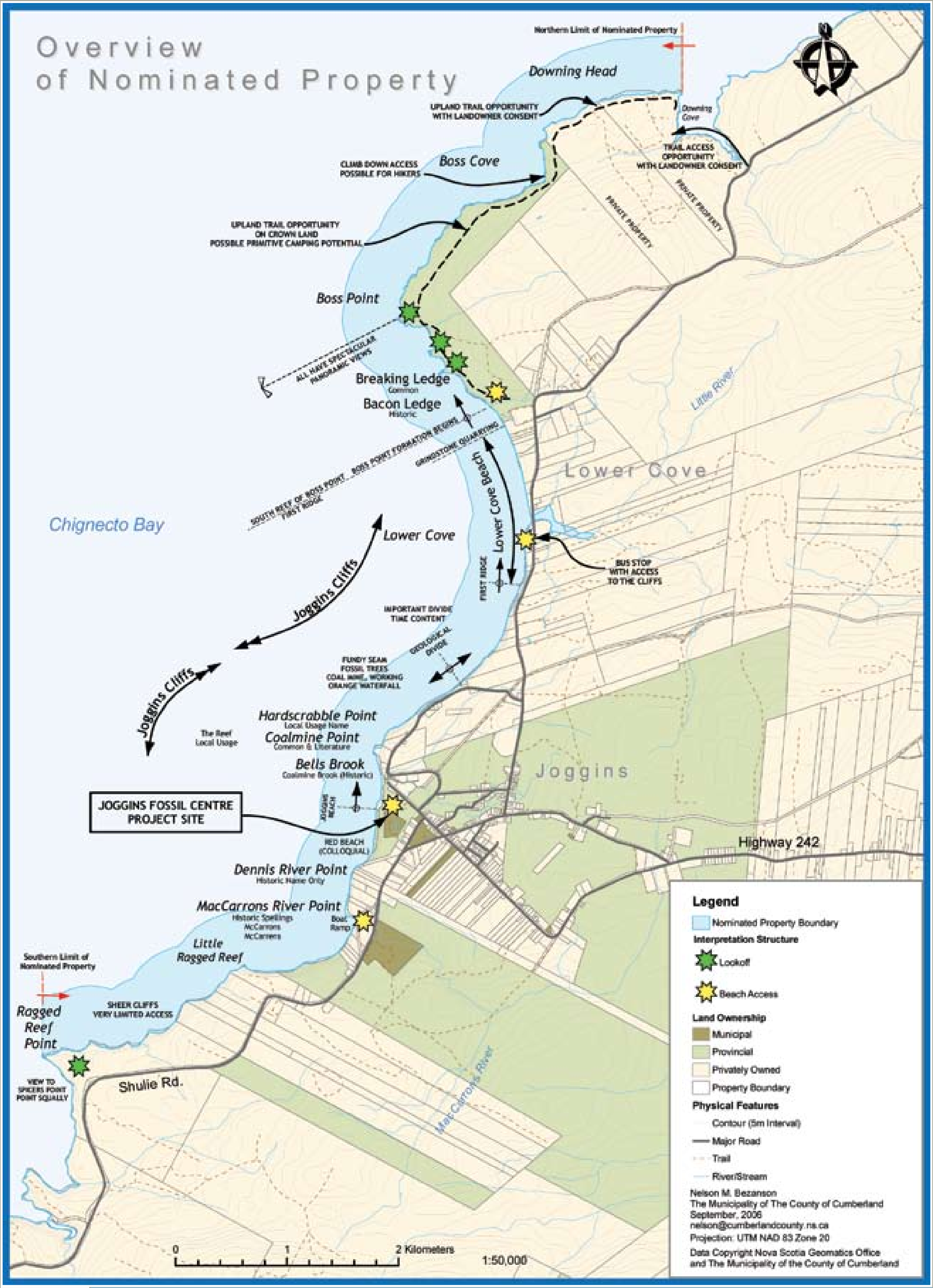


Figure 1 ***The nominated property.***

Figure 2 **Downing Head, northern property limit.**

Figure 3 **Ragged Reef Point, southern property limit.**

natural processes of coastal evolution—as the property boundary migrates landward with erosion of the cliff-face. The boundary definition ensures that the property's integrity will be maintained in perpetuity. The boundary is defined by topographic features visible in the landscape and therefore ensures that they are clearly identifiable on the ground and ultimately useful for site management.

1.E (ii) Buffer Zone

Paragraph 104 of the Operational Guidelines for the Implementation of the World Heritage Convention[1] makes provision for the identification of a buffer zone to protect World Heritage Sites from threats beyond their boundaries. In the case of the Joggins Fossil Cliffs, the integrity of the fossil heritage is naturally protected by the cliff, whose sheer face prevents development, and which is continually renewed by erosion. Nonetheless, four legislative controls including:

a) *the Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* (2006), through the *Municipal Government Act* (1998),
b) the *Beaches Act* and associated *Regulations* (1989),
c) the *Mineral Resources Act* (1990), and
d) the *Special Places Protection Act* (1989)

support the conservation of lands adjacent to the property and establishes a buffer to the nominated property (Appendix G). These legislative controls ensure the integrity of the nominated property for future generations (Map 2).

The Municipality of the County of Cumberland Secondary Planning Strategy and *Land Use Bylaw for the Joggins Planning Area* (Appendix G:4) contains planning policies and land use regulations that provide stringent protection to the lands adjacent to the nominated property, as contemplated by the Operational Guidelines.

Within the *Planning Strategy* and *Land Use Bylaw* there are two specific policies developed to protect lands immediately adjacent to the nominated property. These two policies include strict protection within 20 metres of the landward property boundary and encompass an area of 29.4 hectares (14,700 metres X 20 metres = 29.4 hectares).

Within this 20-metre buffer, the policy pertaining to "Cliffs and Shoreline Setbacks" includes restrictions to ensure that there will be no development and that environmental effects from human activities or land uses will not interfere with the natural erosion processes that regularly expose fossil resources at the cliffs or adversely affect the setting or views of the Joggins Fossil Cliffs or the aesthetic qualities of the views and natural vistas along the shoreline. Furthermore, the policy of "Prohibited Uses and Structures" includes restrictions within 20 metres of the cliffs that prohibit grading or alteration in elevation or contour of the land, the excavation and deposition of fill, defacing the cliffs, constructing permanent or temporary structures and outdoor storage of scrap or salvage material.

The definition of the boundary of this 20-metre buffer is contingent on the definition of the landward property boundary (the cliff), and as the cliffs erode the protection within the buffer migrates landward as well. Currently, at present rates of erosion, this 20-metre area equates to approximately 100 years of protection. Furthermore, the protection afforded to the property by these municipal policies extends in perpetuity as the cliffs and associated buffer move landward through erosion.

For the most scientifically important part of the nominated property, the beach and cliffs are protected 100 feet (30.48 metres) landward from the mean high-water mark. Within this buffer zone land use activities are restricted through the application of the *Beaches Act* and associated *Regulations* (Section 5 and Appendix G:2). The added protective measures governed under the *Beaches Act* and associated *Regulations* specifically apply to the "Classic Section" of the nominated property where the most important fossil discoveries and research have taken place and where visitation is highest.

In addition to the buffer zone, complementary planning and regulatory controls are in place, further contributing to conservation of the nominated property. The entire length of the property and adjacent lands are "closed" for mineral exploration through the application of the *Mineral Resources Act* (Appendix G:3 and Map 2). "Closures" under the *Mineral Resources Act* are created when land is withdrawn by the Minister of the provincial Department of Natural Resources from general application of the *Act* under Section 22. Therefore, the principles regarding acquisition of a mineral exploration licence do not apply to withdrawn ("closed") areas. *The Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw* for *The Joggins Planning Area* come into effect from as far away as seven kilometres. For the entire Planning Area, land use zoning has been established and policies pertaining to protection of views, outdoor lighting, health and safety, and traffic management are in place.

Additionally, the *Special Places Protection Act* (Appendix G:1) provides for the protection and conservation of heritage objects (fossils) for the entire province of Nova Scotia.

Further details related to municipal and provincial legislation, as it pertains to the property and adjacent lands, are provided in Section 5. Copies of the provincial legislation, municipal planning strategy, and land use bylaw are also appended (Appendix G).

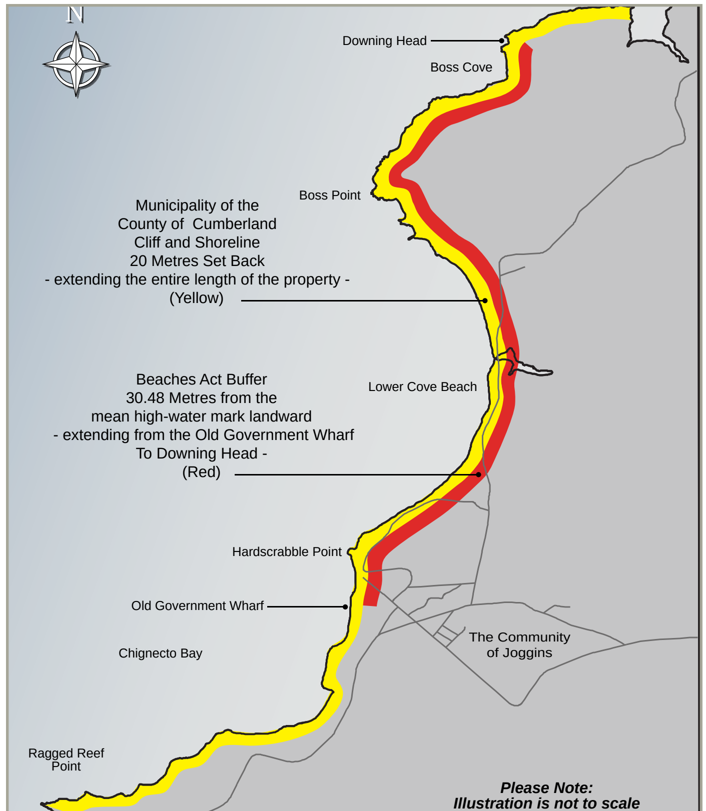


Figure 4a **Protective designations of the nominated coastline.**

1.F AREA OF NOMINATED PROPERTY

The area of property proposed for inscription is 689 hectares.

Within the Joggins Planning Area, a 20-metre buffer exists immediately adjacent to the landward boundary of the entire length (14.7 kilometres) of the nominated property. The area of this buffer is approximately 29.4 hectares.

Furthermore, the Lower Cove Beach (8.5 kilometres) that includes the "Classic Section" of the property has a buffer that extends 30.48 metres landward from the mean high-water mark. The area of this buffer is approximately 25.9 hectares.

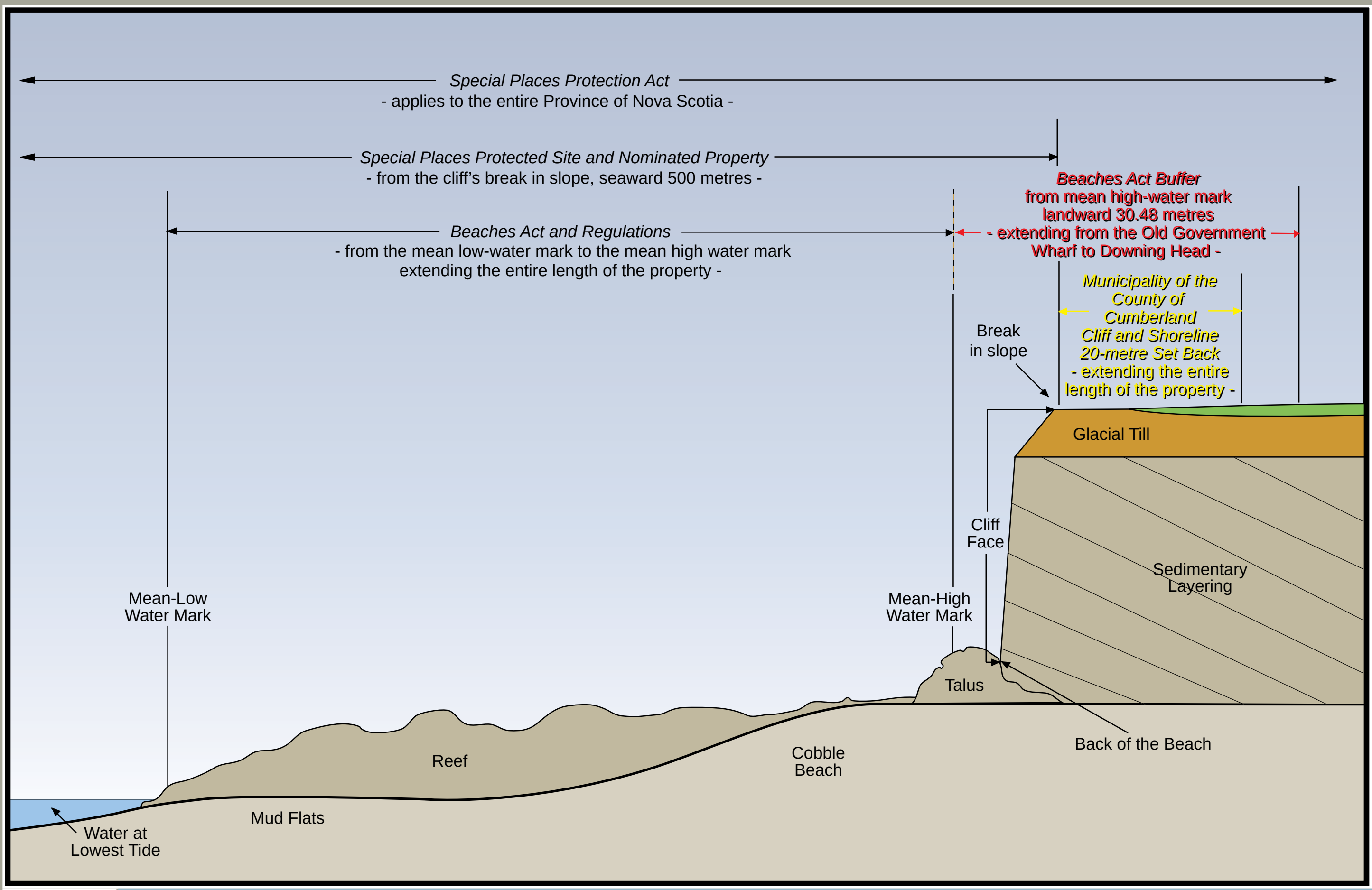


Figure 4b *Protected property and buffer zone.*

2 Description

An icon of Joggins: Sigillaria tree fossilized in situ.

" …the finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia."

~ Sir Charles Lyell, 1871

2.A DESCRIPTION OF PROPERTY

The nominated property at Joggins comprises 14.7 kilometres of coastline along the tumultuous Bay of Fundy. This magnificent setting is home to what Sir Charles Lyell, founder of modern geology, described as "the finest exposure in the world"[1] of the rocks and fossil record of the Pennsylvanian "Coal Age" of earth history, a record that has figured in the first debate on evolution, and remains pivotal to understanding the terrestrial origins of vertebrate life, including our own species.

Typically more than 30 metres in height, the alternating grey and reddish-brown cliff-faces drop abruptly to a rocky beach composed of cobbles and boulders calved from the cliffs above. This border of cliff and beach, periodically submerged by the ocean tides, is crossed in places by a series of bedrock ridges or reefs. These dark reefs are composed of more erosion-resistant rock layers and extend out into the intertidal zone. The Bay of Fundy tides, whose vertical range is surpassed nowhere else in the world, withdraw twice daily to expose hundreds of metres of shoreline that once again becomes submerged with the in-coming tidal waters.[2]

The nominated property includes the entire coastal exposure of the coal-bearing Joggins Formation.[3,4] It is from this "Classic Section"[5]

Figure 5

The cliffs and reefs of the nominated property at low tide.

Figure 6

The power of the Fundy tides.

Figure 7 ***The continuous exposure of the natural heritage at Joggins provides exceptional interpretive and research opportunities.***

that the world's most extensive fossil record of the tropical ecosystem of the Pennsylvanian "Coal Age" of earth history derives.[6,7] Adding to its paleontological significance is the intact nature of the fossil record within its sedimentary environment, which provides unequalled ecological and environmental context.[7] This uniquely representative "Coal Age" section has been the subject of the research and writings of some of the world's most influential scientists, including Sir Charles Lyell, Sir William Dawson and Charles Darwin during the nineteenth century.[8,9] Through the actions of the world's highest tides in the Bay of Fundy, the cliffs continue to yield important fossil discoveries.

The Fossil Record

The fossil record of biodiversity at Joggins, comprising nominally 195 species (Tables 2.1-2.4), offers the richest sampling of terrestrial life in the Pennsylvanian "Coal Age."[6] This record includes the plant life that gave rise to the vast coal deposits for which this period of earth history is named, as well as invertebrate and vertebrate fauna from both the aquatic and terrestrial realm, all preserved within their ecological context. Citing the work of Lyell and Dawson, Charles Darwin, in his seminal work *On the Origin of Species by Means of Natural Selection*, wrote that 68 horizons of standing trees occur in this celebrated section. The fossil record includes numerous taxa for which a species or higher taxonomic rank has been first defined (type specimens), some of which are found nowhere else on earth. Of the 63 fossil species of terrestrial fauna and their trackways, over half are type specimens, described first or found only at Joggins. The entire terrestrial record of tetrapods, encompassing 19 species of primitive "stem" tetrapods, amphibians and reptiles, comprises such type specimens. Most notably, these tetrapods include the earliest reptile *Hylonomus lyelli*, which is also the oldest known representative of the amniotes in the history of life on earth.[10,11,12] The amniotes, the group that comprises reptiles (including extinct groups such as the dinosaurs), birds and mammals, would eventually rise to dominate the terrestrial ecosystems of the world's biomes.

This fossil record represents a broad ecological spectrum, from the detail of guild to communities and still broader landscapes, including wetlands and seasonal drylands.[6,13,14] The entire food chain of the terrestrial "Coal Age" ecosystem is represented at Joggins, from the primary producers (plants) through detritivores (invertebrates) and ultimately to carnivores (tetrapods). The record of plant life, comprising 95 species and at least 187 plant microfossils (palynomorphs),[15] is represented most notably by standing lycopsid trees that constituted the ecological framework of the wetlands.[14] In marked contrast to the grand lycopsids is the delicate foliage of ferns and fern-like plants that grew beneath them or hung from them as vine-like lianas. Gymnospermous (seed-bearing) flora include the understorey vegetation of the wetland forests (pteridosperms or "seed ferns"), and enigmatic cordaite trees that inhabited river margins or uplands.[16] The ubiquitous *Calamites*, one of the only "Coal Age" plants to have a close living relative (horsetail or *Equisetum*), inhabited areas prone to floods and other disturbance.[14]

Figure 8 **A "Coal Age" tree, exposed after 310 million years.**

Figure 9a **Type specimen of Hylonomus lyelli, Natural History Museum, London.**

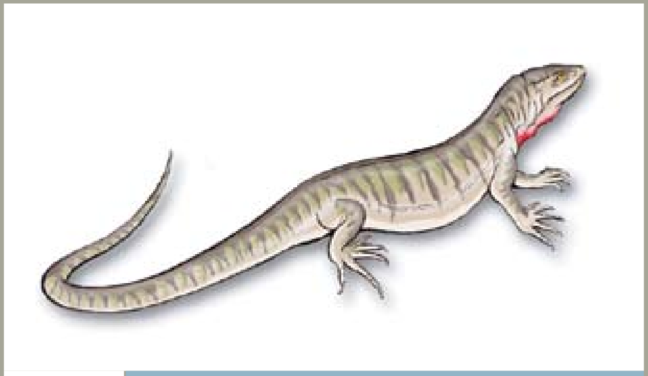


Figure 9b **Artist depiction of Hylonomus lyelli.**

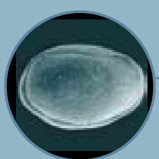
Table 2.1 The Faunal Record of Biodiversity at Joggins*

KINGDOM ANIMALIA

PHYLUM PROTISTA (single-celled organisms)
- Class SARCODINA
  - Order FORAMINIFERA
    - *Trochammina sp.*
    - *Ammobaculites sp.*
    - *Ammotium sp.*

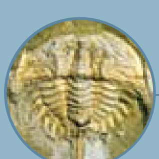
PHYLUM ANNELIDA (segmented worms)
- Class POLYCHAETA
  - *Spirorbis carbonarius*

PHYLUM ARTHROPODA (jointed-leg invertebrates)
- Subphylum CRUSTACEA
  - Class OSTRACODA



    - *Carbonita altilis*
    - *C. elongata*
    - *C. fabulina*
    - *C. humilis*
    - *C. pungens*
    - *C. rankiniana*
    - *C. secans*
    - *Hilboldtina rugulosa*
    - *Candona bairdiodes*
    - *C. salteriana*
    - *Velatomorpha sp.*
  - Class MALACOSTRACA (soft-shelled: cray-fish *et al.*)
  - Superorder EOCARIDA
    - Order PYGOCEPHALOMORPHA

      - *Pygocephalus (Anthrapalaemon) dubius*
- Subphylum CHELICERATA (pincer-bearing)
  - Class MEROSTOMATA
    - Order XIPHOSURIDA (sword-tailed: horseshoe crabs *et al.*)



      - *Belinurus sp.*
    - Subclass EURYPTERIDA (wing-like legs)
      - indet. cuticle, *cf. Hibbertopterus/ Mycterops*
  - Class ARACHNIDA (spiders, scorpions)
    - Order ANTHRACOMARTIDA
      - *Coryphomartus triangularis*
    - Order PHRYNICHIDA (whip spiders)

      - *Graeophonus carbonarius*
    - Order SCORPIONIDA
      - *indet. cuticle*
- Subphylum MYRIAPODA
  - Class DIPLOPODA (millipedes)
    - Order EURYSTERNA
      - *Xyloiulus (Xylobius) sigillariae*
      - *Archiulus xylobioides*
      - *Incertae sedis*
    - ARTHROPLEURIDA
      - *Arthropleura sp.*
- Subphylum INSECTA
  - Class PTERYGOTA (winged insects)
    - Order MEGASECOPTERA
      - *incertae familiae*

PHYLUM MOLLUSCA
- Class BIVALVIA (Pelecypoda: clams)
  - Order UNIONOIDA
    - *Archanodon (Asthenodonta) westonis*
  - Order PTERIOIDA [Dysodonta]

    - *Naiadites carbonarius*
    - *N. longus*
    - *Curvirimula sp.*
- Class GASTROPODA (snails)
- Subclass PULMONATA (Stylommatophora) (land snails)
  - Order ORTHURETHRA

    - *Dendropupa vetusta*
    - *Pupa bigsbii*
  - Incertae sedis
    - *Zonites priscus*

PHYLUM CHORDATA
- Subphylum VERTEBRATA
- Superclass PISCES
  - Class ACANTHODII
    - *incertae sedis*
    - GYRACANTHIDAE
      - *Gyracanthus duplicatus*
  - Class CHONDRICHTYES (cartilaginous fishes)
    - *incertae sedis*
    - *Ageleodus (Callopristodus) pectinatus*
  - Subclass ELASMOBRANCHII (sharks)
    - Order XENACANTHIDA
      - *Xenacanthus sp.*

Order CTENACANTHIFORMES

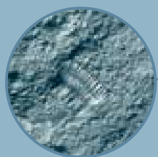
Ctenacanthus sp.

Subclass HOLOCEPHALI

Order CHIMAERIDA

Helodus sp.

Incertae sedis 'PETALODONTIDA' (ray-like fishes)



Ctenoptychius cristatus

Class OSTEICHTHYES (bony fishes)

Subclass ACTINOPTERYGII (ray-finned fishes)

Order PALAEONISCIFORMES

Haplolepis cf. corrugata

H. cf. canadensis

Subclass SARCOPTERYGII (lobe fins)

[Order ACTINISTIA]

Order CROSSOPTERYGII

Rhizodopsis/ Strepsodus sp.

Megalichthys sp.

Suborder COELACANTHINI

(indet. scales)

Superfamily DIPNOI (lungfish)

Ctenodus (Conchodus) plicatus

Sagenodus cristatus

S. plicatus

Superclass TETRAPODA

incertae sedis

Hylonomus ociedentatus

Hylonomus wymani

Class NEOTETRAPODA

Order BAPHETOIDEA

Family BAPHETIDAE

'Baphetes minor'

Class AMPHIBIA

Subclass BATRACHOMORPHA (true amphibians)

Order TEMNOSPONDYLI

Dendrerpeton acadianum

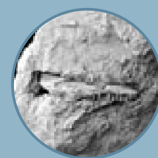
Dendrerpeton confusum

Dendrepeton helogenes

indeterminate Cochleosauridae

Order MICROSAURIA

Asaphestera (Hylerpeton) intermedium



Hylerpeton dawsoni

Leiocephalikon problematicum

Ricnodon sp.

Subclass REPTILIOMORPHA

Order ANTHRACOSAURIA (EMBOLOMERI)

Calligenethlon watsoni

Class REPTILIA

Subclass ANAPSIDA

Order CAPTORHINOMORPHA

(protorothyrids & captorhinids)

Hylonomus lyelli

Archerpeton anthracos

Subclass SYNAPSIDA

Order PELYCOSAURIA

Protoclepsydrops haplous

Incertae sedis

Novascoticus (Hylonomus) multidens

[*"Eosaurus acadiensis"*= exotic ichthyosaur?]

* Note that systematic taxonomy for many of these groups in the fossil record is problematic, and many variations exist, particularly for the vertebrates.

Table 2.2 The Record of Vertebrate Trace Fossils of The Joggins Fossil Cliffs

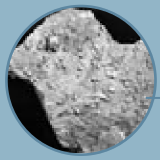
KINGDOM ANIMALIA

PHYLUM Chordata
Subphylum VERTEBRATA
Superclass TETRAPODA Goodrich, 1930
Class AMPHIBIA
Order MICROSAURIA

Barillopus arctus Matthew, 1905
B. confusus Matthew, 1905
B. (Baropus) unguifer Matthew, 1903
Salichnium (Ornithoides) adamsii (Matthew, 1905) Haubold, 1970
Ornithoides (Hylopus) trifudus (Dawson, 1895) Matthew, 1903
Dromillopus quadrifidus Matthew, 1905
D. (Dromopus) celer (Matthew, 1903) Matthew, 1905

Order TEMNOSPONDYLLI (Edopoidea, Eryopoidea)

Anthichnium (Nanopus) obtusum (Matthew, 1905) Haubold, 1970
A. (Nanopus) *quadratum* (Matthew, 1905) *Haubold, 1970*
Baropezia (Sauropus) sydnensis (Dawson 1863)
Cursipes dawsoni Matthew, 1903b
*Hylopus mino*r Matthew, 1905

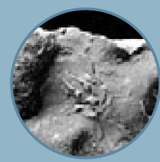


Limnopus (Theranopus?) mcnaughtoni (Matthew, 1903c) Haubold, 1970

Amphibia indet.

Matthewichnus (Dromopus) velox (Matthew, 1905) Haubold, 1970
Quadropedia (Cursipes) levis (Matthew, 1905) Haubold, 1970

Class REPTILIA
Order CAPTORHINOMORPHA



Asperipes avipes (Matthew, 1903c)
A. flexilis Matthew, 1905
Pseudobradypus (Sauropus) caudifer (Dawson, 1882) Haubold, 1971

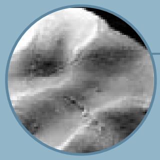
Familiae incertae

**Pseudobradypus (Sauropus) unguifer* (Dawson, 1872) Matthew 1903

Table 2.3 The Fossil Record of Invertebrate Traces of the Joggins Fossil Cliffs

KINGDOM ANIMALIA

PHYLUM Annelida



Arenicolites Salter, 1857
Haplotichnus Miller, 1889
Cochlichnus Hitchcock,1858
Laevicyclus sp.
Planolites montanus
Planolites beverlexensis
Skolithos linearis
Treptichnus pollardi Miller, 1880
Taenidium barretti Heer, 1877
Taenidium annulata

PHYLUM Arthropoda

Protichnites Owen, 1852

Subphylum CHELICERATA
Class MEROSTOMATA
Order XIPHOSURIDA

Kouphichnium Nopsca,1923
cf. Limulocubichnus

Subphylum MYRIAPODA
Order ARTHROPLEURIDA

Diplichnites Dawson, 1873

Indeterminate

Fuershichnus sp.
Palaeophycus hebrati
Palaeophycus tekularis
Rhizocorallium jenese

Table 2.4 The Fossil Macrofloral Record of Joggins, Incorporating Revised Taxonomy of R.H. Wagner, Jardin Botanico de Córdoba

KINGDOM PLANTAE

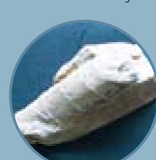
PHYLUM Tracheophyta
- Class PROGYMNOSPERMOPSIDA
  - Order CORDAITALES
    - *Artisia transversa*
    - *Cordaites principalis* (Germar) Geinitz
    - *Cordaites palmaeformis* (Göppert) Weiss
    - *Cordaianthus sp.*
  - wood
    - *Cordiaxylon cf. C. dumusum* Rothwell & Warner
    - *Dadoxylon sp.*
    - *Mesoxylon cf. sutcliffi*
  - seeds
    - *Cordaicarpus dawsoni*
    - *Samaropsis sp.* Goeppert

  - Order NOEGGERATHIALES?
    - *Adiantites adiantoides* (Lindley and Hutton) Kidston
    - *Pseudadiantites rhomboideus* (Ettingshausen) Wagner

- Class CYCADOPSIDA Barnard & Long
  - Order TRIGONOCARPALES Seward
  - Family POTONIEACEAE
    - *Paripteris pseudogigantea* (Potonié) Gothan
  - Family TRIGONOCARPACEAE
    - *Alethopteris discrepans* Dawson
    - *Alethopteris urophylla* Brongniart
    - *Alethopteris decurrens* (Artis) Zeiller
    - *Karinopteris (Mariopteris)* grandepinnata (Huth) Boersma
    - *Karinopteris tennesseana* (White) Gastaldo and Boersma
    - *Mariopteris abnormis* Gothan
    - *Mariopteris comata* Bell
    - *Mariopteris disjuncta* Bell
    - *Neuropteris cf. blissi* Lesquereux
    - *Neuropteris cf. hollandica* Stockmans
    - *Neuropteris obliqua* (Brongniart) Zeiller
    - *Neuropteris* (Laveineopteris) *tenuifolia* (Schlotheim) Brongniart
    - *Neuralethopteris schlehanii* (Stur) Cremer
    - *Sphenopteris valida* (Dawson) Stopes
    - *Holcospermum sp.* Nathorst
    - *Trigonocarpus parkinsoni* Brongniart

  - Family LAGENOSTOMACEAE
    - *Eusphenopteris obtusiloba* (Brong niart) Novik
    - *Eusphenopteris trigonophylla* (Behrend) Van Amerom
    - *Palmatopteris furcata* (Brongniart) Potonié
    - *Palmatopteris alata* (Brongniart) Potonié
- Class FILICOPSIDA
  - Order BOTRYOPTERIDALES
  - Family TEDELACEAE
    - *Senftenbergia plumosa* (Artis) Stur
  - Family URNATOPTERIDACEAE
    - *Zeilleria delicatula* (Sternberg) Kidston
    - *Zeilleria frenzlii* (Stur) Kidston
    - *Zeilleria hymenophylloides* Kidston
    - *Zeilleria pilosa* (Dawson) Wagner
    - *Zeilleria schaumburg-lippeana* (Stur) Zeiller
    - *Renaultia crepinii* (Stur) Zeiller
    - *Renaultia gracilis* (Brongniart) Zeiller
    - *Renaultia footneri* (Marrat) Kidston
    - *Renaultia rotundifolia* (Andrae) Zeiller
    - *Renaultia schatzlarensis* (Stur) Zeiller
    - *Sphenopteris (Renaultia) schwerinii* (Stur) Zeiller
    - cf. *Boweria schatzlarensis* Kidston
    - *Oligocarpia brongniartii* Stur
    - *Sphenopteris deltiformis* Kidston
    - *Sphenopteris dixonii* Kidston
    - *Sphenopteris effusa* Kidston
    - *Sphenopteris fletcheri* Bell
    - *Sphenopteris moyseyi* Kidston
    - *Sphenopteris sp.* indet
    - *Sphenopteris sp.*
    - *Sturia amoena**

  - Order COENOPTERIDALES
  - Family CORYNEPTERIDACEAe
    - *Corynepteris angustissima* (Sternberg) Nemejc
- Class SPHENOPSIDA (Equisetopsida)
  - Order EQUISETALES
  - Family CALAMOSTACHYACEAE
    - *Calamites carinatus* Sternberg
    - *Calamites suckowi* Brongniart
    - *Calamites cf. goeppertii* Ettingshausen
    - *Calamites (Calamitina)* sp.



  - rhizome
    - C. group *varians* of Bell
  - roots
    - *Pinnularia* sp.
  - foliage
    - *Annularia aculeata* Bell

Table 2.4 The Fossil Macrofloral Record of Joggins, Incorporating Revised Taxonomy of R.H. Wagner, Jardin Botanico de Córdoba (continued)

Annularia asteris Bell
Annularia latifolia (Dawson) Kidston
Annularia acicularis (Dawson) Matthew
Annularia cf. stellata (Schlotheim) Wood
Asterophyllites charaeformis (Sternberg) Göppert
Asterophyllites grandis (Sternberg) Göppert
Asterophyllites equisetiformis (Schlotheim) Brongniart

cones

Palaeostachya sp. Weiss

Order BOWMANITALES

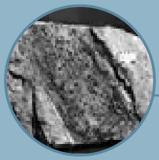
Family BOWMANITACEAE

Sphenophyllum cf. kidstonii Hemingway

Class LYCOPSIDA

Order LEPIDOCARPALES

cf. *Bothrodendron punctatum* Lindley and Hutton
Diaphorodendron sp. DiMichele



Lepidodendron aculeatum Sternberg
"Lepidodendron" bretonense Bell
Lepidodendron cf. fusiforme Corda
Lepidodendron lycopodioides Sternberg
Lepidodendron cf. obovatum Sternberg
Lepidodendron worthenii Lesquereux
Lepidophloios laricinus Sternberg
Sigillaria cf. laevigata Brongniart
Sigillaria mamillaris Brongniart

Sigillaria cf. rayosa
Sigillaria scutellata Brongniart
Sigillaria cf. scutellata Brongniart
sp. indet.

branch scar

Ulodendron Lindley and Hutton

decorticated stem

Syringodendron sp.

Cyperites sp. Lindley and Hutton

cones and bracts

Lepidostrobus ornatus Brongniart
Lepidostrobus olryi Zeiller
Lepidostrobophyllum lanceolatum (Lindley & Hutton) Bell
Lepidostrobophyllum majus (Brongniart) Hirmer
Lepidostrobophyllum morrisianum (Lesquereux) Tenchov

Sigillariostrobus sp. Schimper

rootstock

Stigmaria ficoides Sternberg

Order ISOETALES

Omphalophloios sp.?

The Geological Record

The coastal section that comprises the nominated property spans approximately 15 million years of the Carboniferous System of earth history (International Union of Geological Sciences Timescale of Gradstein and Ogg, 2000).[17] The rock record is divided, following geologic convention, into units of similar rock type. These units include, from oldest to youngest, the Shepody, Claremont, Boss Point, Little River, Joggins, Springhill Mines, and Ragged Reef Formations.[13,14,15]

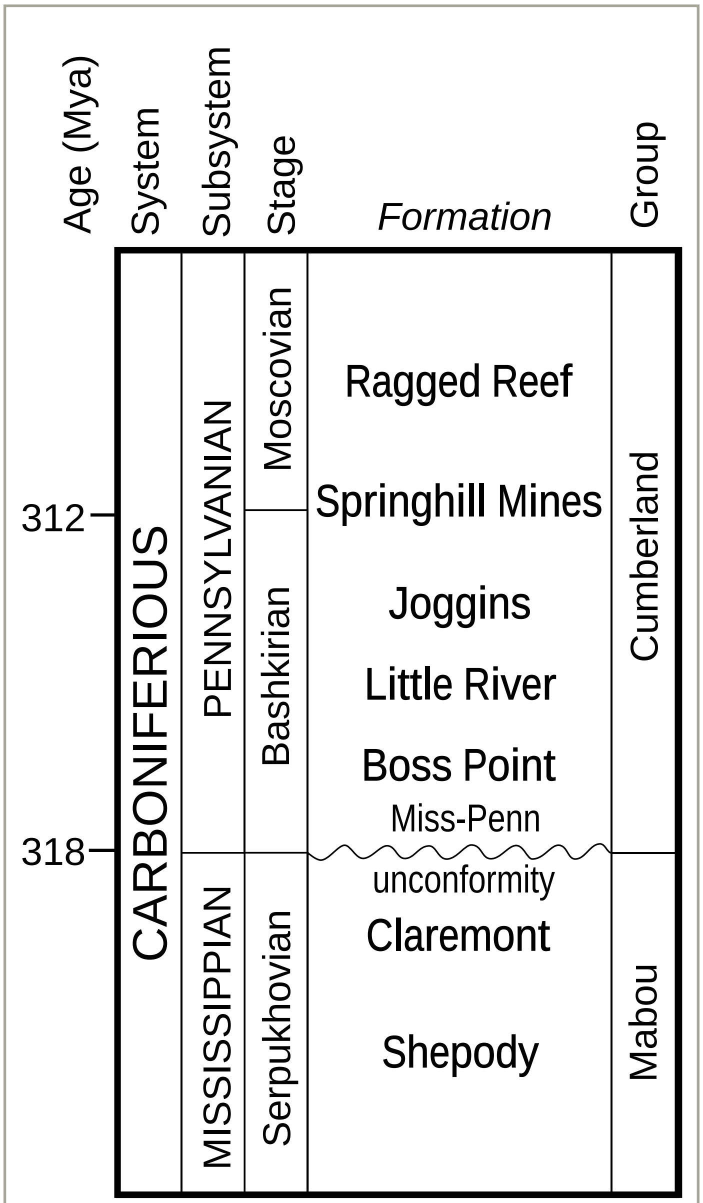


Figure 10 *The stratigraphic column, depicting the geological formations represented in the nominated property, and their corresponding age, according to the IUGS timescale.*

The total thickness of sedimentary beds exposed in the coastal cliffs measures 4,442 metres, making the Joggins Fossil Cliffs the thickest sedimentary succession found in any Carboniferous coal basin worldwide. The sedimentary succession itself is considered outstanding in its own right.[1,4,5,18] The "Coal Measures" (coal-bearing rocks/strata) are represented in their entirety by the Joggins and Springhill Mines Formations. No fewer than 67 coal beds have been enumerated in these formations.[19] Virtually all of the historic fossil discoveries derive from the Joggins Formation (the "Classic Section", as it is commonly known), which totals 915.5 metres in thickness and is exposed in its entirety along a 2.8-kilometre section of the cliffs. The nominated property includes the entire exposure of the Joggins Formation, but also several younger and older geological formations both above and below it which are exposed for a total distance of 14.7 kilometres. This extensive record provides broader context to the Joggins Formation from the standpoint of earth history, while at the same time providing an important geological buffer to the "Classic Section."

Figure 11 *The sedimentary succession recorded in this "marvellous chapter of the big volume."*

Overlying the Joggins Formation is the Springhill Mines Formation, as well as a portion of the succeeding Ragged Reef Formation,[20,21] which serve as a geological buffer to the "Classic Section" in the south. The even larger geological buffer for the underlying (older) rocks in the north addresses the important fact that discoveries in these strata have potential to become the oldest known examples of certain fossil taxa. These geological buffer units include, in order of increasing age, the Little River and Boss Point Formations of the Cumberland Group, and Claremont and Shepody Formations of the Mabou Group.[3,20,21] The coastal exposures of red beds (reddish brown coloured rocks) of the Mabou Group in particular have been used to establish the Mississippian component of the global timescale of polar reversals in the earth's magnetic field, central to reconstructing the global position of the continents.[22]

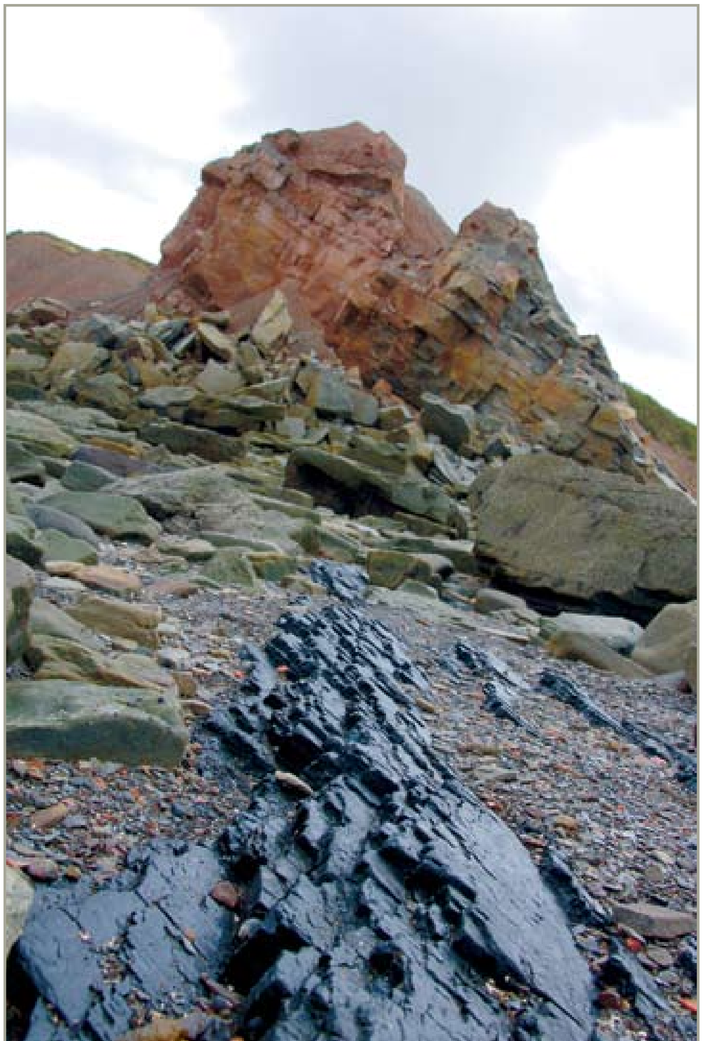


Figure 12 *"Coal bed 15" of Logan (1845), one of the 67 or more coal beds that drew the attention of the first explorers to Joggins.*

Figure 13 *Mississippian rocks (in the background, at left) of the Claremont Formation and Pennsylvanian rocks (foreground) of the Boss Point Formation, on either side of the globally significant Mississippian-Pennsylvanian unconformity at Boss Cove.*

The geological contact at the base of the Boss Point Formation represents the base of the Pennsylvanian Subsystem in the section, and the Boss Point-Claremont contact coincides with the globally significant Mississippian-Pennsylvanian unconformity (abbreviated regularly as "Miss-Penn," and referring to a time gap in the rock record). This time witnessed the collision of Gondwana (specifically northwest Africa) with Laurentia (North America) as the land masses assembled to form the supercontinent Pangea and heralded the marked global change that ushered in the Pennsylvanian "Coal Age" (See Section 2.B (i)).[23,24] The geological formations of the nominated property provide outstanding examples of this profound change that distinguishes the rocks of the two Carboniferous Sub-Systems, the Mississippian and the Pennsylvanian.[25]

Physical Description of the Property

The topographical character of the property—the cliffs and intertidal shore—varies with the nature of the rock formations, from areas of low, receding bluffs to sheer cliffs that attain heights in excess of 30 metres. Sandstone beds that are resistant to erosion form headlands and promontories along the coast and form grey or dark ochre reefs that are exposed at low tide across the intertidal zone (all the land exposed at low tide and submerged at high tide). The character of the shore changes from the cliff-face seaward: large boulders (talus) newly fallen from the cliff-face sit atop the upper beach whose cobbles are rounded continually by the waves. Farthest from the cliffs, mudflats sprawl in areas of low relief between the reefs.

The tides of the Bay of Fundy, which at 16.8 metres in the Minas Basin are the highest in the world,[2] shape the Bay and cliffs. The tides dictate times and duration of visitation as well as action in the stewardship of the fossil heritage of the property (see Sections 4, 5 and 6). At Joggins, this relentless tidal action ensures continuing exposure of the "Coal Age" beds and their superb fossil record.

The northern end of the nominated property has been established at Downing Head, a broad promontory buttressed by the sandstone and conglomerates of the Shepody Formation. Proceeding south from Downing Head, the weak, brick-red granule conglomerates of the Claremont Formation have been eroded more severely, forming an embayment at Boss Cove. The prominent headland of Boss

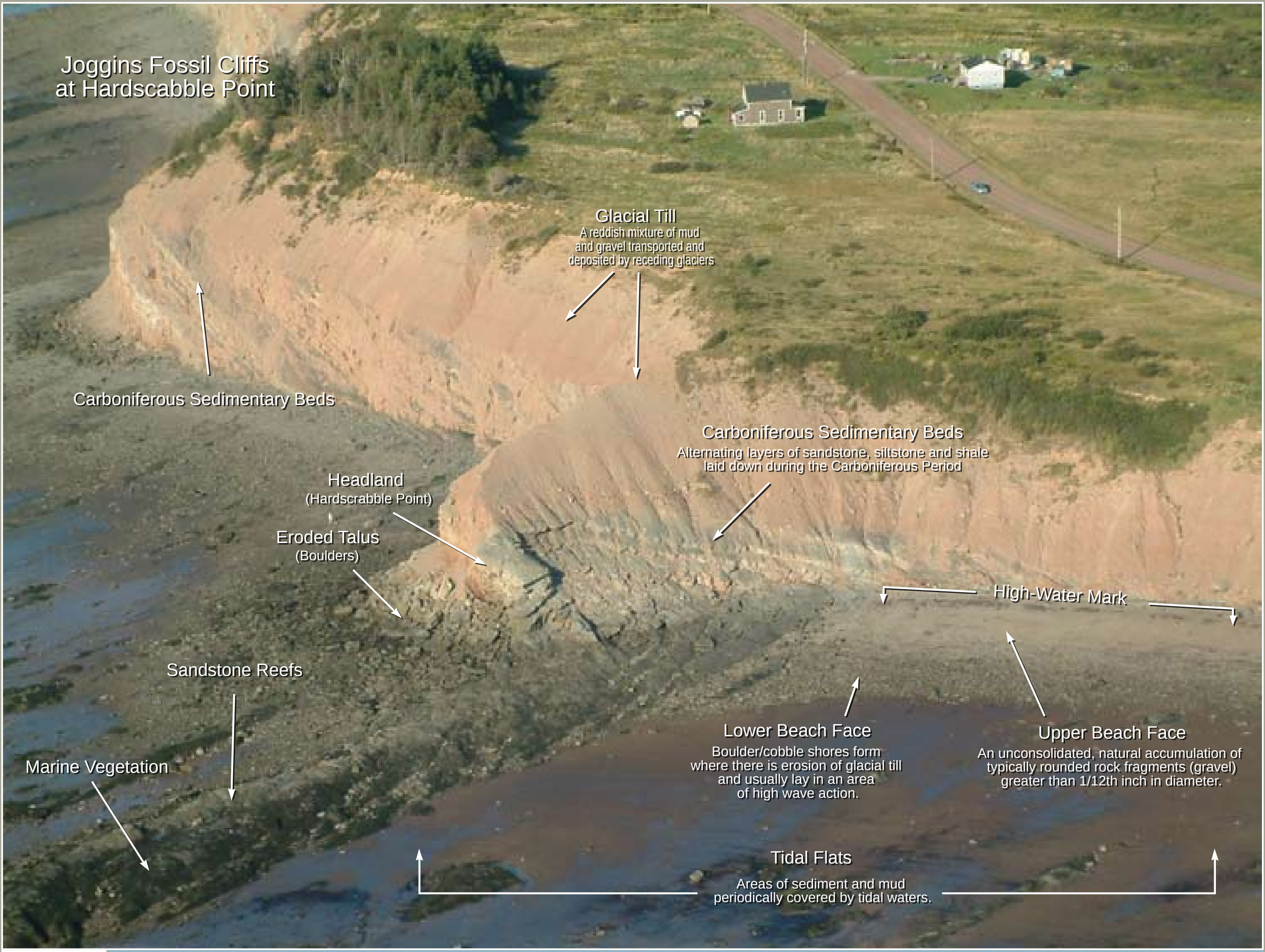


Figure 14 ***Coal Mine Point, looking north: geomorphic features of the nominated coastline.***

Figure 15 ***Intertidal zone: reefs and mudflats.***

Figure 16 ***The fossil-bearing coal measures of the Joggins Formation.***

Figure 17 ***Downing Head, the northernmost point of the nominated property.***

Figure 18 ***Boss Point sandstones.***

Figure 19 ***The windswept bluffs of Lower Cove.***

Figure 20 ***The "Classic Section" of the Joggins Formation.***

Figure 21 ***A majestic standing tree fossil. One of the hallmarks of the Joggins Fossil Cliffs.***

Point lends its name to the formation of exceptionally thick, well-sorted sandstone bodies long prized for grindstones and building stones.[26] From the buff-coloured cliffs of Boss Point, the coast sweeps gradually south in a broad arc through Lower Cove and the confluence of Little River. This two-kilometre section of the property is characterized by low bluffs topped by windswept cranberry barrens.

South of Lower Cove, the cliffs gradually rise to form a dramatic exposure of the coal-bearing rocks of the Joggins Formation. From Lower Cove south past Coal Mine (Hardscrabble) Point and Bell's Brook, standing fossil trees preserved to heights of seven metres[14,27] are exposed perpendicular to the sandstone, mudrock and coal beds which dip consistently south at an average of 20 degrees from horizontal.[20] Wooden pit props and iron rails, historic signs of past coal mining, protrude from centuries-old collieries exposed by erosion. Ochre staining by groundwater, that consistently runs from workings on the old Fundy Mine, marks the northernmost and stratigraphically lowest, mine workings. Coal Mine Point is a landmark of historic paleontological significance,[28,29,8,9] and its sandstone reef is the most prominent south of Boss Point. The reef acts as a natural breakwater against waves driven by the prevailing south-westerly winds of Chignecto Bay.

Figure 22 ***Pit props and chains bear witness to nineteenth century coal mines, long since abandoned.***

Figure 23 ***Coal Mine Point, site of the historic discovery of "Coal Age" reptiles and amphibians by Lyell and Dawson.***

Between Coal Mine Point and Bell's Brook, the cliffs of Carboniferous strata are partly masked by deposits of glacial till—boulders and clay left behind by the melting Laurentide ice sheet of the Quaternary Period between 18,000 and 10,500 years ago. It is this reddish clay that washes down over the cliff-face and Carboniferous strata below. To the south, the glacial till section is renowned for its record of successive advances and retreats of the ice sheet.[30,31] Along the entire expanse of the cliffs of the nominated property, the Carboniferous rocks are truncated at the clifftop in a strikingly planar fashion that records a previous wave-cut platform produced when the earth's crust was depressed some 30 metres by the weight of glacial ice.[32,33] This ancient wave-cut platform is clearly visible along the entire cliff section when viewed from the distant vantage point offered at low tide.

The remains of the historic coal-loading wharf at the site of the Joggins seam mark the southernmost coal seam to have been mined underground and (atop the cliffs) the future site of the new Joggins Fossil Centre, a major interpretation, education and research facility from which the property will be managed as of its opening in summer 2007. The coal-bearing strata continue south past the headland of MacCarron's River, but without the fossiliferous limestone beds that distinguish the Joggins Formation.[3,4,18] The thin coal beds of the Springhill Mines Formation persist south of MacCarron's River, but are succeeded by sandstones and conglomerate beds of the Ragged Reef Formation, named after the headland and sheer cliffs that demarcate the southern end of the nominated property. Beyond Ragged Reef,

Figure 24 **Panorama of the Pennsylvanian rocks and Quaternary glacial till overlying the ancient wave-cut platform.**

Figure 25 **Remnant pilings of the coal-loading wharf at the Joggins seam.**

Figure 26 **Ragged Reef Point, the southernmost point of the nominated property.**

the cliff section continues 40 kilometres south to Spicer's Cove at Cape Chignecto Provincial Park (www.capechignecto.net), where the Carboniferous section abuts against the older, crystalline rocks of the ancient Cobequid highlands massif that formed a natural border to the basin during the Carboniferous Period.[34]

2.B HISTORY AND DEVELOPMENT

2.B (i) Geological History

As a natural property, Joggins has a history that extends far deeper into time than the narrow timeframe of human experience. The coastal section of Joggins was born in the heart of the equatorial wetland biome that gave rise to the iconic Pennsylvanian "Coal Age" of earth history.[23,6,7] The rock record bears witness to the assembly of the earth's land masses into the supercontinent named Pangea ("One Earth") by Alfred Wegener, pioneer of the theory of Continental Drift.[35]

Figure 27 **Dramatic cliff exposures of Carboniferous rocks south of the nominated property at Spicer's Cove, Cape Chignecto Provincial Park.**

The geological formations that comprise the property date from about 325 to 310 million years ago,[17] spanning the Mississippian-Pennsylvanian boundary of the Carboniferous System.[25] The oldest rocks in the nominated section, the Shepody and Claremont Formations, crop out in the north at Downing Head. The varied older rocks incorporated in these beds record periodic tectonic upheaval along faults at the basin margin with the Caledonia Highlands of southern New Brunswick. These gritty rocks, turned brick-red by oxidation, also record the arid conditions that marked the paleoclimate of the tropics during the first half of the Carboniferous System, known as the Mississippian Subsystem.

A profound change from the Mississippian to the Pennsylvanian Subsystem, described briefly in Section 2A, is recorded in the rock record at Boss Cove as far-travelled rivers swept through the basin.[36,24] This globally significant change coincides with the continental collision of Gondwana (comprising the southern continents of Africa, South America, India, Australia and Antarctica) and Laurentia (North America and Europe) during the assembly of the supercontinent Pangea. This continental collision gave rise to the Mauritanide-Atlas Mountains of northwestern Africa and to the Appalachian Mountains of eastern North America, where the event is known as the Alleghenian Orogeny. A marked, global change in climate coincided with this event,[24] ushering in the

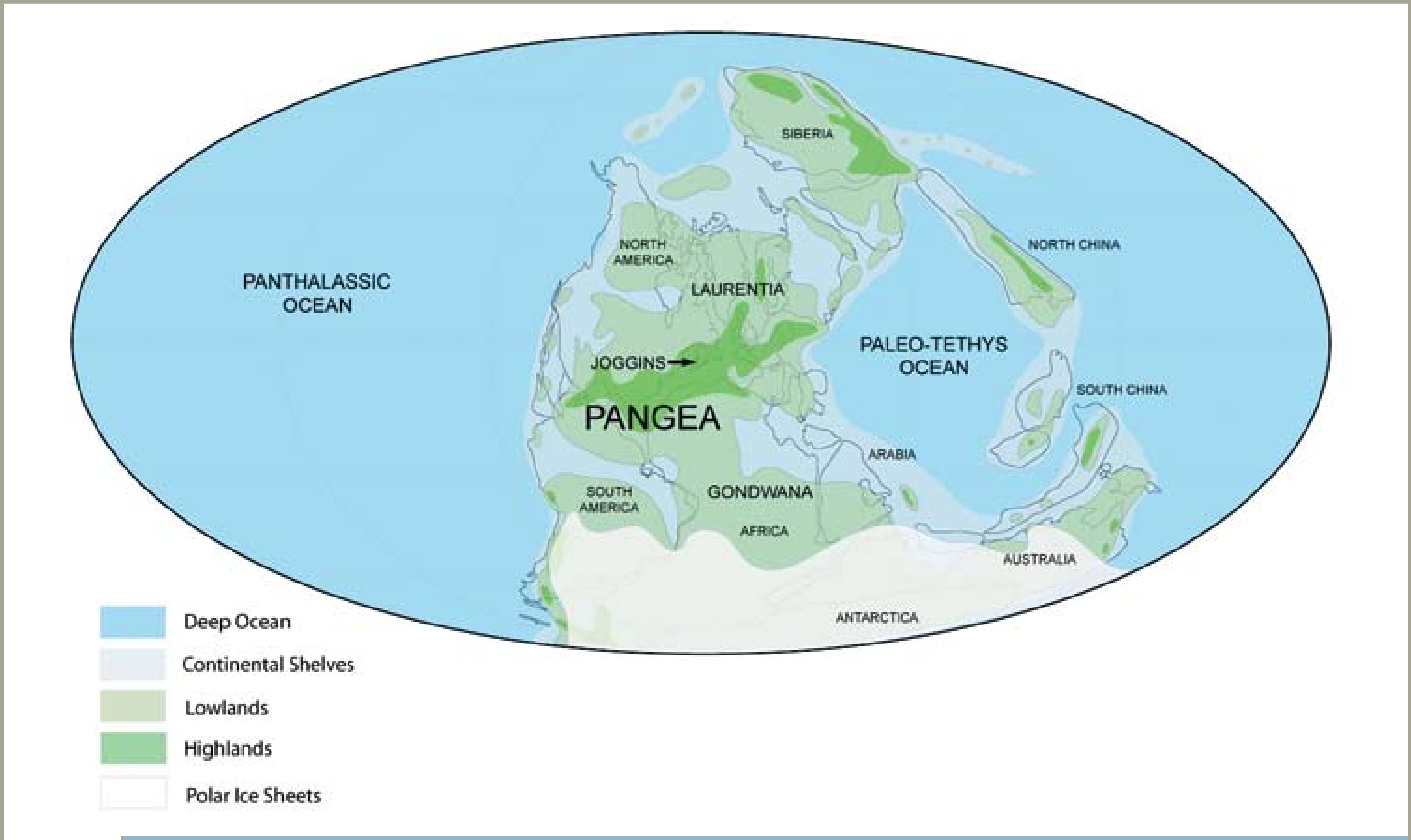


Figure 28 ***The supercontinent Pangea and the southern polar ice cap over Gondwana.***

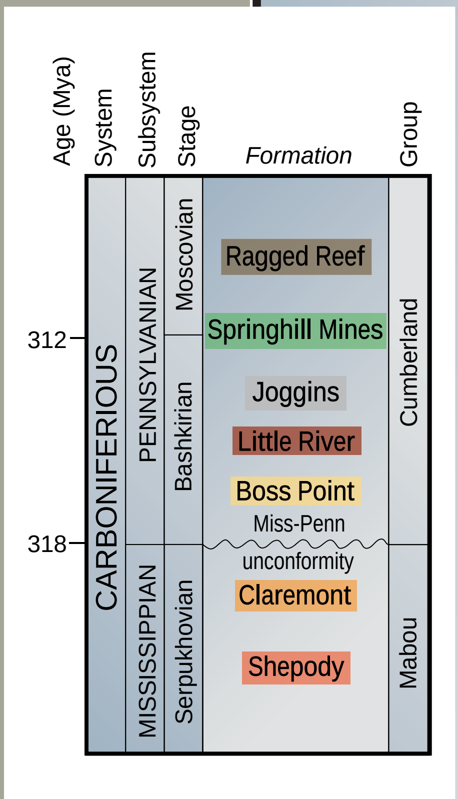


Figure 29 **Stratigraphic column of geological formations.**

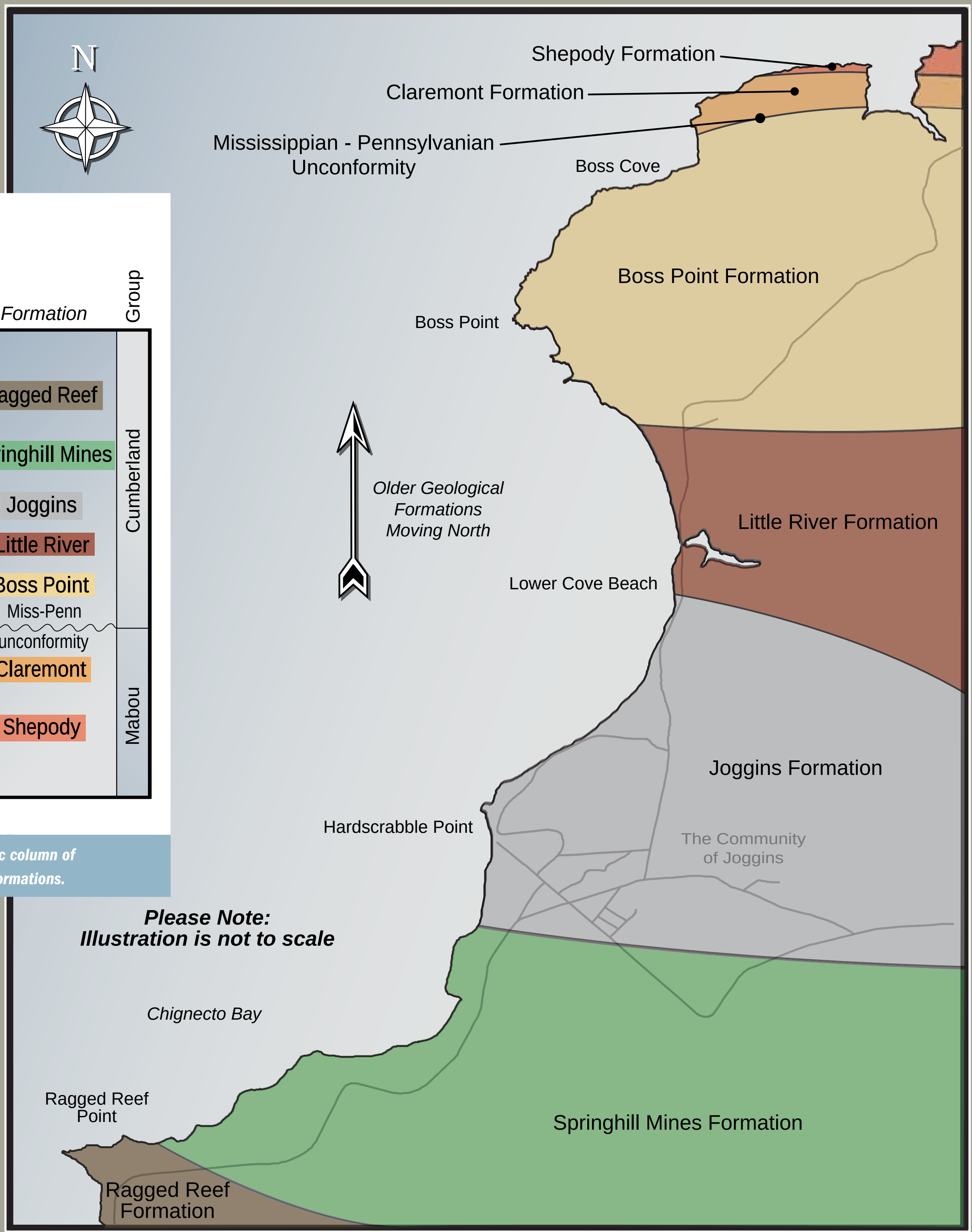


Figure 30 **Geological formations exposed in the nominated property.**

Figure 31 **Red beds of the Claremont Formation at Boss Cove, formed during the arid conditions of the Mississippian Subsystem.**

humid conditions of Pennsylvanian "Coal Age." As in the modern Himalayas, great river systems were born in the rising mountain belts,[37] in this case recorded in the thick sandstone beds of the Boss Point Formation. Swept along by these great rivers as they flowed east towards Europe were the great *Cordaites* trees of the uplands, which have been preserved as huge permineralized logs.[16] The long-travelled, well-sorted sand grains of the Boss Point Formation sandstones favoured their historic use as grindstones and building stones (see Section 2.B (v)).

As the flow of the rivers slowed or was diverted, conditions in the valleys and basins grew increasingly wetter as the basin floors subsided, recorded in the change from the seasonal drylands of the Little River Formation[3] to the wetlands of the Joggins Formation.[4,18] Conditions rife for the development of wetlands forested by enigmatic lycopsid trees became widespread across the equatorial regions of the world.[38,39,40,41] These forest swamps sheltered the first reptiles on earth—found only at Joggins—and whose amniotic egg has been described as the most significant evolutionary innovation in the history of the vertebrates.[40,42,11,12]

Within the equatorial wetlands formed vast peat deposits of accumulating plant remains that would gradually transform into the coal deposits of eastern North America and western Europe[23,38] that lend their name to this geologic period: the Carboniferous. The combination of carbon stored as peat and oxygen respired by the luxuriant tropical forests contributed to the lowest atmospheric carbon dioxide and highest oxygen levels in earth history.[43] As a consequence, this period of lush tropical forests was also an

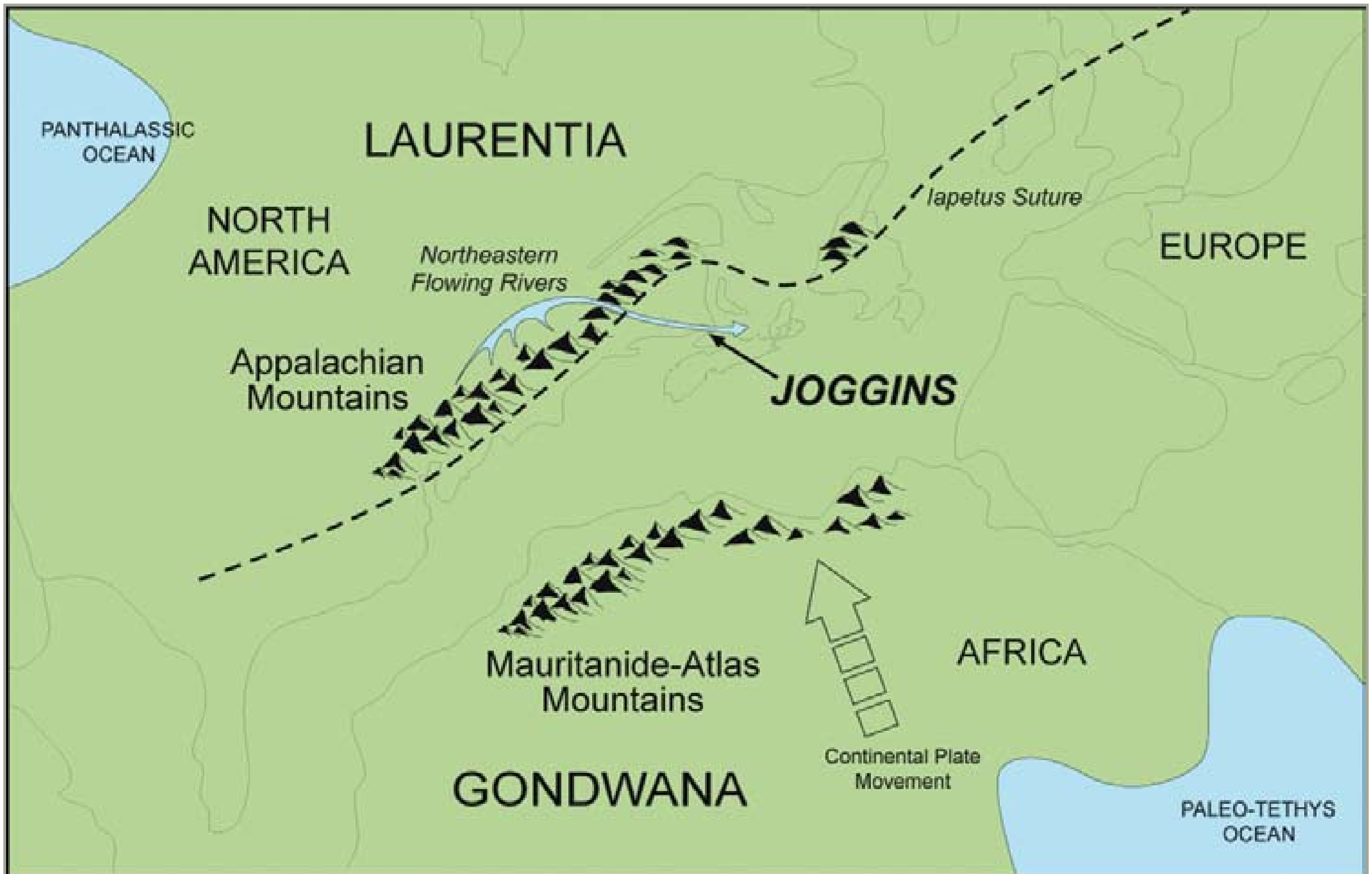


Figure 32 **The mountains of central Pangea that arose as a result of the continental collisions that accompanied the assembly of the supercontinent.**

"Icehouse" world, with a continental ice sheet over the south polar regions of the ancient continental landmass of Gondwana (represented today by South America, Africa, Australia, India and Antarctica). The Carboniferous was the last period of earth history before today's world to experience polar ice, and such equator-to-pole temperature extremes, and as such offers the most direct lessons for global change occurring today.[44]

These coal deposits would draw the attention of humans—descendants of the first amniotes—some 300 million years later, and would serve as the fuel for their Industrial Revolution. The coal beds, first reptiles and evidence of early mining are exposed in the cliffs of Joggins, testament to the linked geologic and human history of this remarkable place.

The coastal cliffs that expose these deposits of the "Coal Age" tropics were carved by the erosive power of the Bay of Fundy tides that developed following the retreat of the last continental ice sheet during the Pleistocene Epoch of the Quaternary Period, approximately 10,500 years ago.[31] Glacial deposits left behind in their wake are exposed atop the cliffs and record the successive advance and retreat of the ice sheets.[30,31] Between Coal Mine Point and Bell's Brook, the cliffs are partly masked by deposits of glacial till—boulders plucked by the advancing Laurentide ice sheet during the last "Ice Age" of earth history, and unceremoniously dumped in clay as the ice melted. South of MacCarron's River, the glacial till section is renowned for its record of successive advances and retreats of the ice sheet. The Carboniferous rocks that comprise the cliffs are truncated above by the Pleistocene wave-cut platform formed when the earth's crust was depressed approximately 30 metres by the weight of the glacial ice.[32,33]

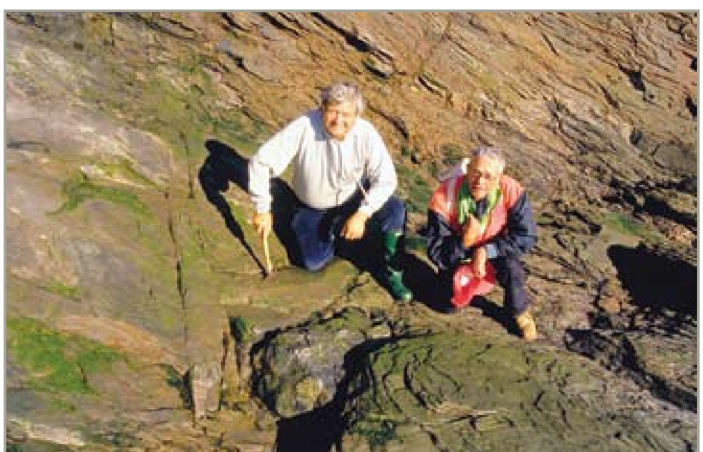


Figure 33 *Permineralized Cordaites trunk in Boss Point Formation sandstone.*

Today, as global sea levels continue to rise with the melting of the earth's polar ice caps, sea levels bordering the property in the Bay of Fundy rise also, witnessed by submerged forests at nearby Amherst Head and Aulac, New Brunswick, described more than 150 years ago by Dawson.[45] These partially buried, standing trees

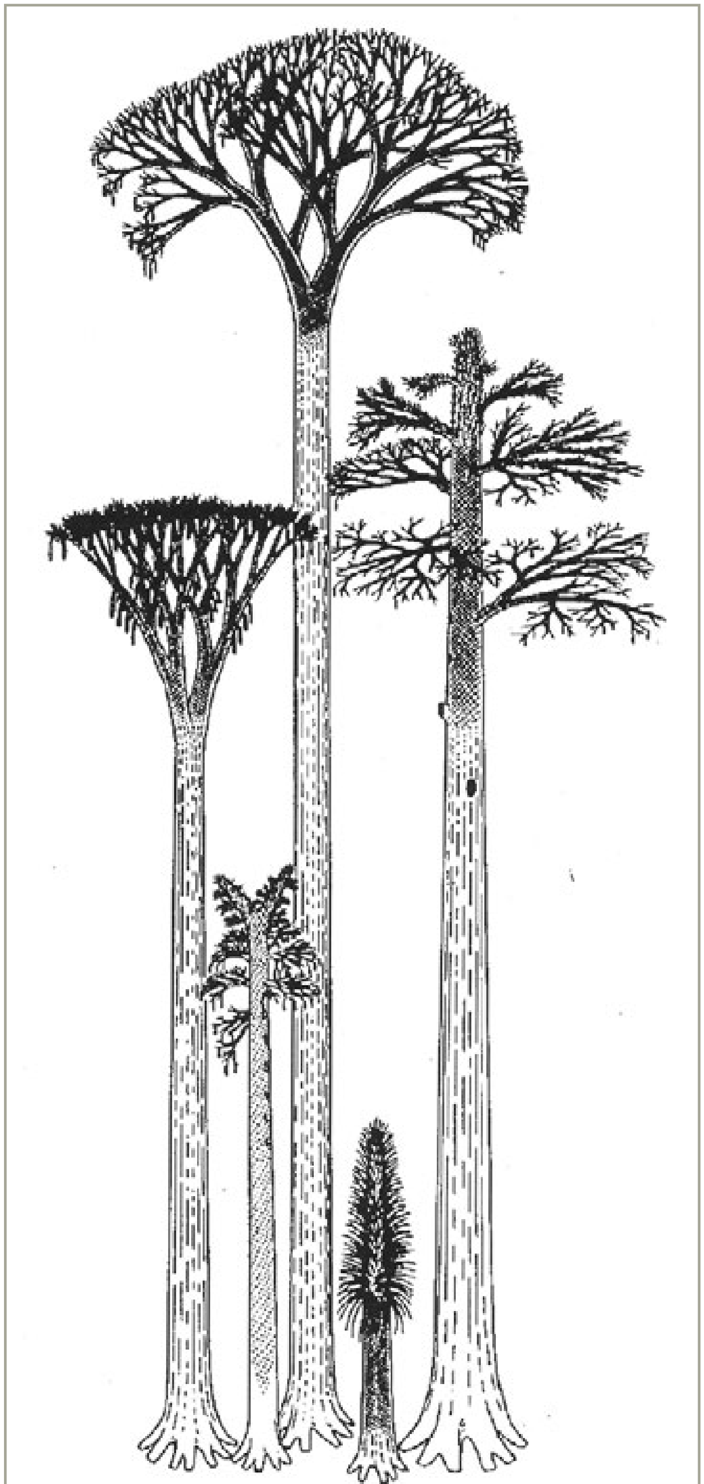


Figure 34 *Enigmatic lycopsid trees, framework of the Coal Age ecosystem, preserved in standing position in the Joggins cliffs (after DiMichele and DeMaris, 1987).*

Figure 35 **Coal-bearing rocks of the Carboniferous Period.**

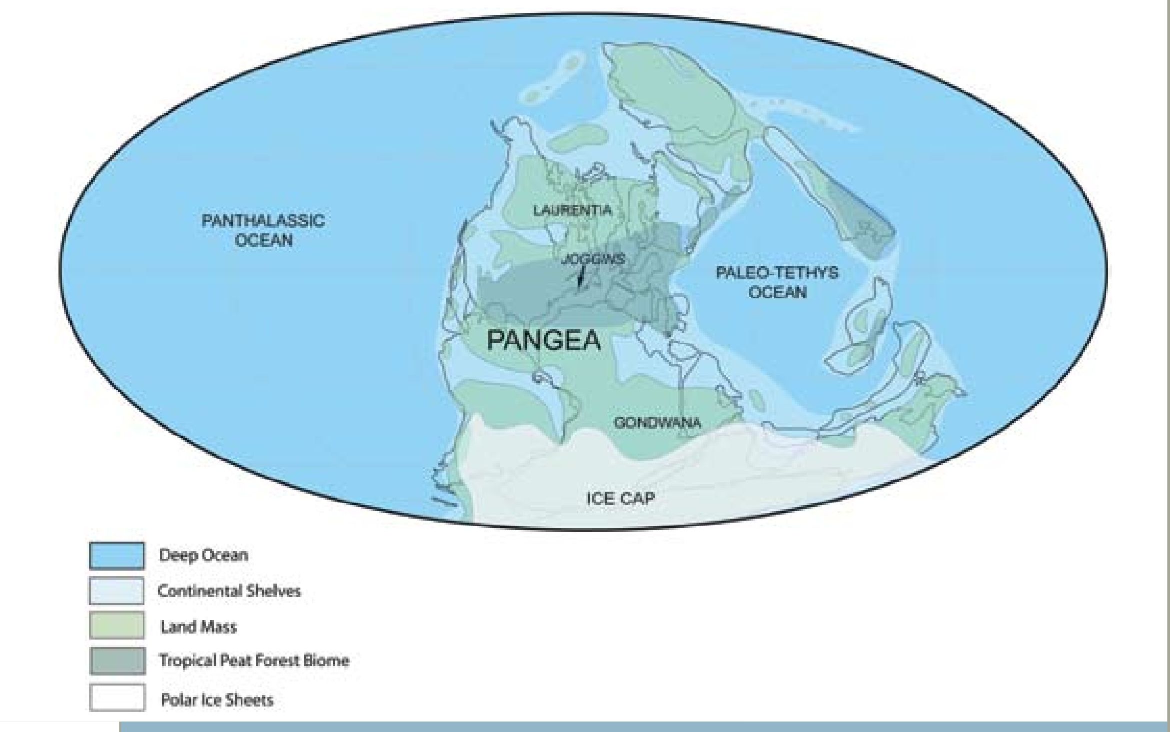


Figure 36 **Reconstruction of the continents during the Pennsylvanian "Coal Age," showing the extent of the tropical wetland forest biome of Pangea that gave rise to the coal deposits of the Carboniferous Period.**

offer a modern counterpoint to the standing trees of 300 million years ago exposed in the cliffs of Joggins (see Question 8, Section 3.C (i)).

2.B (ii) Human History: Beginnings

Long before the beginnings of the science of geology, the Mi'kmaq first people named this place. The earliest record of their place name appears on the 1735 map of George Mitchell and Edward Amhurst[46] as "Grand Nyjagon."[47] The place name has been interpreted since as Chegoggin, "place of the fishing weirs,"[48] or Chegoggins," the great encampment."[49,50] The name eventually became construed as "The Joggins," and later, in the time of the earliest geological visitors, to "The South Joggins" ("The North Joggins" being across Chignecto Bay at Cape Maringouin, New Brunswick,[51] the twin names likely coming from the quarrymen working both shores for grindstones).

Figure 37 *Contemporary wood-cut engraving of a Mi'kmaq person, from Dawson's Acadian Geology.*

Figure 38 *The 1735 map of Mitchell and Amhurst.*

2.B (iii) "Coal Age Galapagos": Scientific Investigation at Joggins

The following account is drawn primarily from "Coal Age Galapagos: Joggins and the Lions of Nineteenth Century Geology,"[8] a history of scientific work at Joggins. This paper is appended in full under Appendix K.

Fully one century prior to the adoption by UNESCO of the World Heritage Convention, Sir Charles Lyell, founder of modern geology and author of *Principles of Geology,* first proclaimed the superlative natural heritage value of the Joggins Fossil Cliffs:

> " …the finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia."[1]

Accounts of the geology of the celebrated coastal section at Joggins first appear in the published literature in 1828—1829, by Americans C.T. Jackson and F. Alger,[52] and by R. Brown and R. Smith, managers for the General Mining Association in the Sydney and Pictou coal-fields.[53] Brown and Smith's astute account is the first stratigraphic reconstruction of the section and the first to document the standing fossil trees and their implications for subsidence of the earth's surface.[8,24] In 1836, Abraham Gesner, inventor of a process to distil kerosene from coal oil, described Joggins as "...the place where the delicate herbage of a former world is now transmuted in stone."[54]

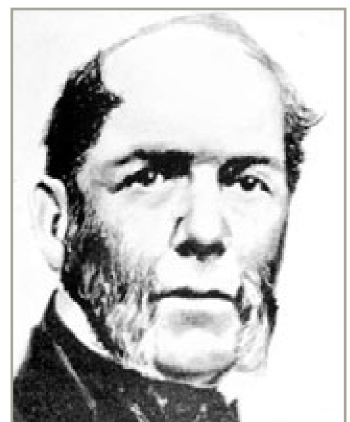


Figure 39 *Abraham Gesner.*

In 1842, Gesner accompanied Sir Charles Lyell on his first trip to Joggins. Lyell was drawn to the fossil forests of Joggins not out of singular interest in the trees, but for their implications for his theory on the terrestrial origin of coals and principles of basin subsidence,[55] which is still very much the subject of current research.[56] The detailed ecological context provided by fossils of invertebrate and vertebrate life and the plant life with which they cohabitated, all preserved *in situ* in the environments where they once lived, continues to be one of the most outstanding attributes of the Joggins fossil record.[7]

Figure 40 Sir Charles Lyell.

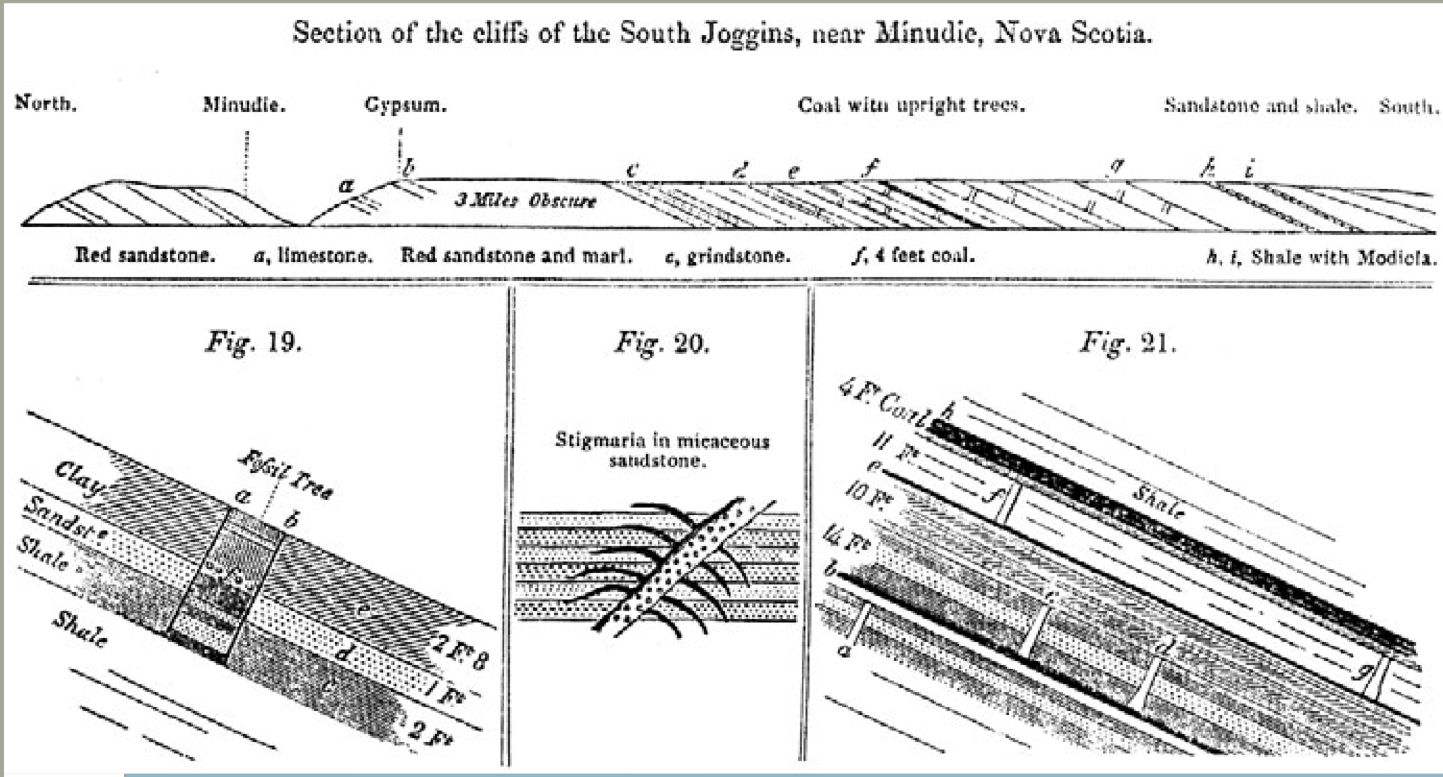


Figure 41 Lyell's sections depicting the Joggins cliffs, from his 1843 paper read before the Geological Society in London.

Lyell was not to be disappointed: in a letter to his sister,[27] he wrote,

> My dear Marianne, --- We have just returned from an expedition ... whither I went to see a forest of fossil coal-trees --- the most wonderful phenomenon perhaps that I have seen.

Soon after, Lyell alerted Darwin of his forthcoming paper on the erect trees of Joggins, to be read before the meeting of the Geological Society in London. Darwin would take note, in the pages of *The Origin of Species*.

Logan and the First Field Projects of the Geological Survey of Canada

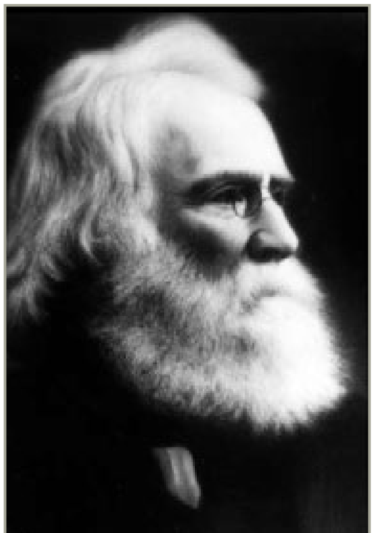


Figure 42 *Sir William Logan.*

In 1843, the year following Lyell's arrival at Joggins, Sir William Logan undertook the daunting bed-by-bed measurement of the entire Joggins coastal section, measuring a succession of sedimentary beds that by his account totalled 14,570 feet, 11 inches (4,441.22 metres).[57,58] Logan's impressive achievement served as the reference section for Joggins for 150 years, superseded only in 2006, with publication of detailed logs of Davies *et al.*, which form the basis for the record of fossil discoveries in the "Classic Section" of the nominated property (Appendix J).[3,4,5] His work comprised the first field project of the nascent Geological Survey of Canada, with Logan as its first Director. The great succession of strata represents the thickest section of Pennsylvanian strata known anywhere in the world.

> My Dear Sir, - I have visited the Joggins, on the Bay of Fundy, and I never before saw such a magnificent section as is there displayed. The rocks along the coast are laid bare for thirty miles, and every stratum can be touched and examined in nearly the whole distance.
>
> ~ William Logan, Gaspé, 10 July, 1843

Lyell, Dawson and Tree Stump Fauna

In 1852, on his third trip to America, Lyell made his second excursion to the Joggins Fossil Cliffs, this time accompanied in the field by thirty-two-year-old J. William Dawson, who would dedicate much of his remaining life to the study of the Joggins fossil record. Their goal was to investigate "the

Figure 43 *A page in Logan's field notebook of 1843, from his epic measurement of the Joggins cliffs.*

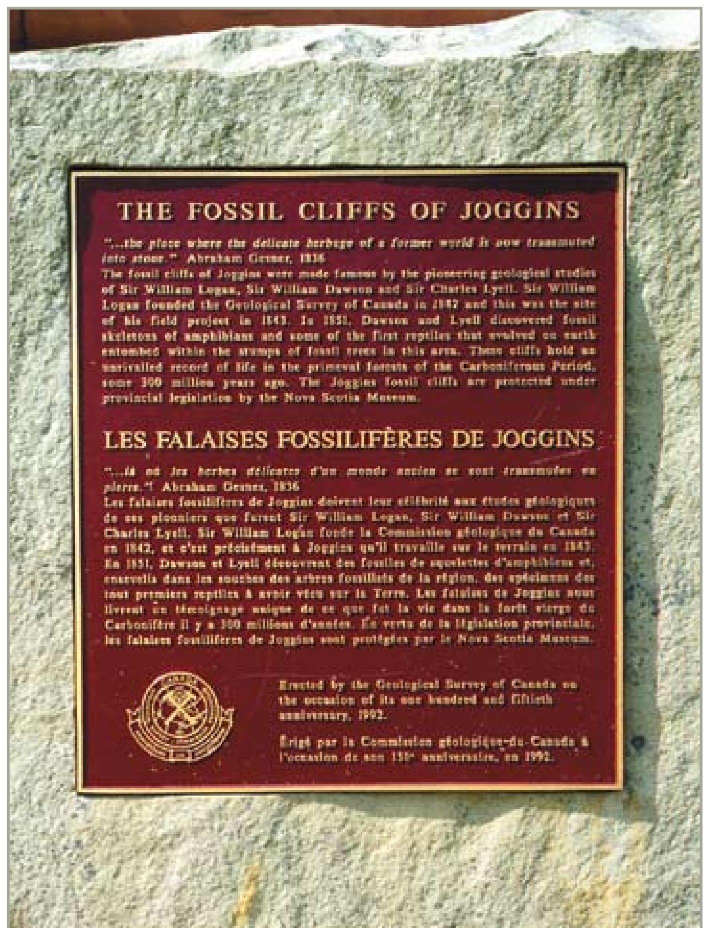


Figure 44 *Plaque commemorating the 150th anniversary of the first field project of the Geological Survey of Canada at Joggins.*

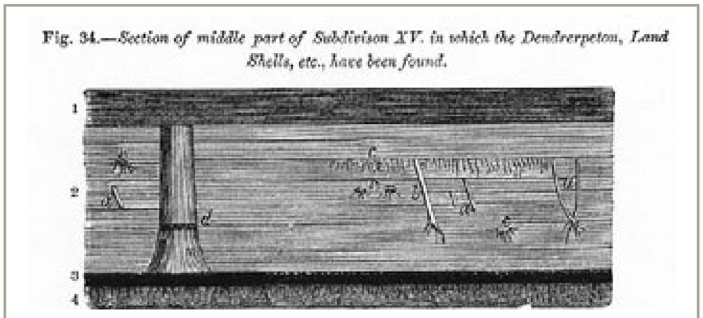


Figure 45 *A woodcut depicting a standing lycopsid tree and erect Calamites, both in growth position, from Lyell and Dawson's 1852 study of the "Classic Section."*

Figure 46 *The early millipede Xyloiulus sigillariae, first found by Lyell and Dawson entombed in a fossil lycopsid tree.*

peculiar circumstances which favoured the preservation of so many fossil trees."[59] In a letter, once again to his sister,[55] Lyell wrote,

> Dawson and I set to work and measured foot by foot many hundred yards of the cliffs, where the forests of erect trees and calamites most abound....I never enjoyed the reading of a marvellous chapter of the big volume more.

Dawson and Lyell re-described sedimentary beds that totalled 2,800 feet (853.44 metres), including the entire "Coal Measures" of Logan's Division IV that comprise the "Classic Section" of the property. At Joggins, Dawson and Lyell would also make one of the most famous of fossil discoveries: tetrapods (including amphibians and later, by Dawson alone, reptiles) within the erect fossil trees, together with millipedes and the earliest land snails.[59] Dawson later recounted Lyell's excitement at their discovery, in the company of a Joggins resident:

> I well remember how, after we had disinterred the bones of Dendrerpeton from the interior of a large tree on the Joggins shore, [Lyell's] thoughts ran rapidly over all the strange circumstances of the burial of the animal, its geological age, and its possible relations to reptiles and other animals, and he enlarged enthusiastically on these points, till, suddenly observing the astonishment of a man who accompanied us, he abruptly turned to me and whispered, 'The man will think us mad if I run on in this way.'[60]

In a letter to Dawson written 6 November 1852,[27] Lyell related the growing sense of the significance of their discovery as it was pored over by Professors Wyman and Agassiz at Harvard:

> My dear Sir, --- I have very good news to tell you. … you will be delighted to hear that in the same stone Wyman

Figure 47 *Artist's rendition of the famous discovery at Coal Mine Point by Lyell and Dawson, in 1852 (Judi Pennanen, from* **The Last Billion Years***).*

Figure 48 Skeletal remains of *Dendrerpeton acadianum* from Lyell and Dawson, 1853.

> has worked out part of a vertebral column, … belonging to a distinct creature, and which he at once pronounced a salamander from the articulating surface of the ball-and-socket joints. Afterwards, when it was shown to Agassiz, he exclaimed, 'This is more reptilian than anything I ever saw in the coal!'
> Latest intelligence. --- Dr. Wyman has just been here with great news. The first bone which we found is clearly not the hyoid bone of a fish, but the iliac bone of a reptile. Do not say anything about it, as every hour he is advancing ....
> Believe me, my dear sir, ever truly yours, Charles Lyell


Figure 49 Sir Richard Owen.

Lyell and Dawson's discovery was first announced through the "Lowell Lectures" given by Lyell a few weeks later in 1852, in Boston,[61] and in early 1853 was christened *Dendrerpeton acadianum* ("Tree reptile of Acadia") in a paper read before the Geological Society of London, not by the discoverers, but to Dawson's chagrin by the overly zealous Keeper of the British Museum, Richard Owen.

O.C. Marsh and *Eosaurus acadianus*

One of the first scientists to be drawn to Joggins by its growing fame was O.C. Marsh, the zealous "dinosaur hunter" of later years, who in 1855 was a wealthy young man of twenty-four just entering Yale University. Marsh's report of two large *vertebrael centrae* was proclaimed "*Eosaurus acadianus*."[62] Mystery surrounds the purported discovery to this day, as subsequent vertebrate paleontologists[63,64,65] now hold the vertebrae to be those of an ichthyosaur from Lyme Regis, Dorset, United Kingdom, home to the seaside fossil shop of Mary Anning.


Figure 50 O.C. Marsh.

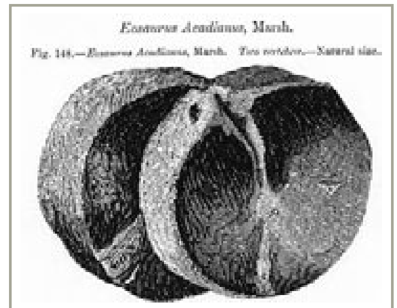


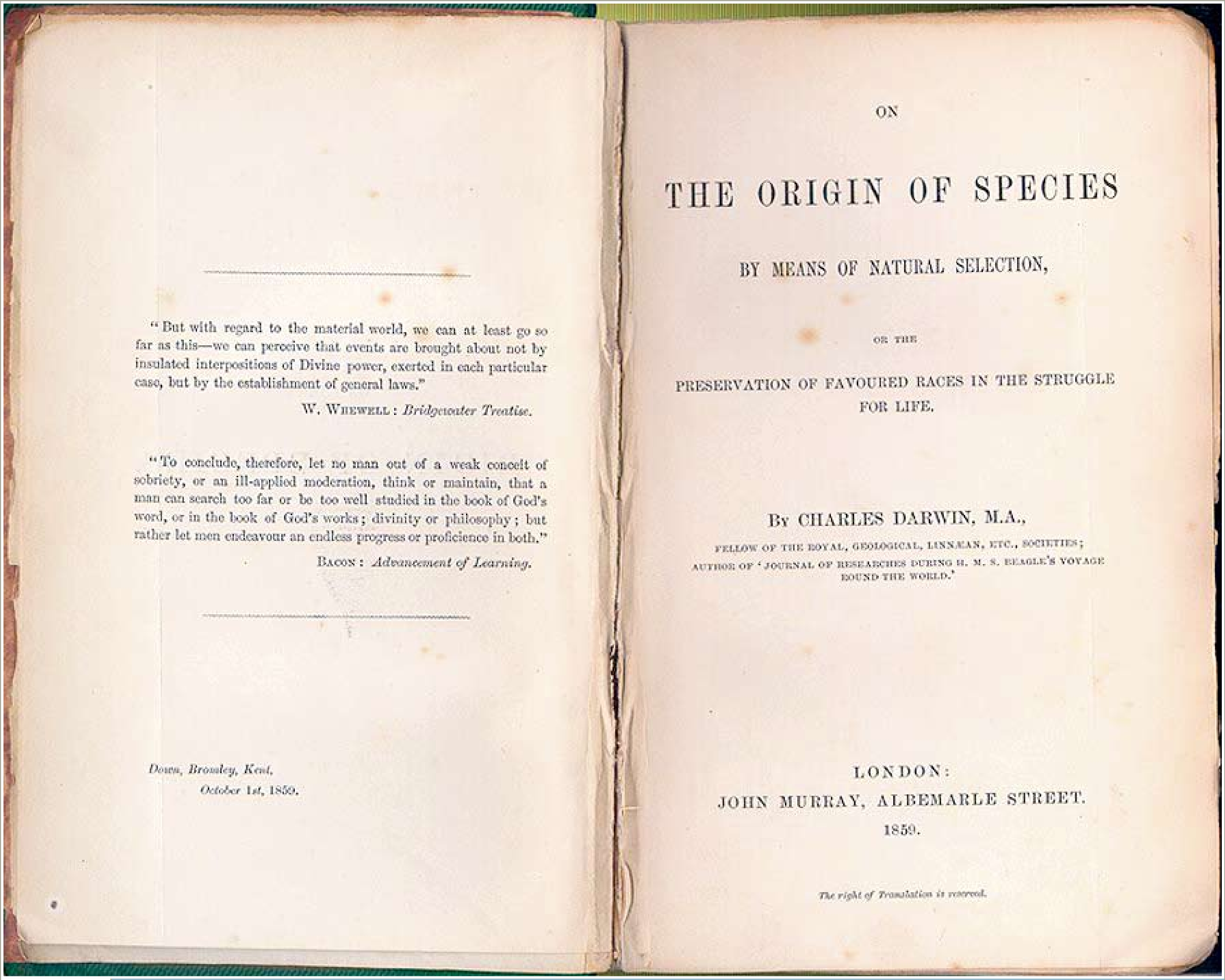
Figure 51 Vertebrae of the dubious *Eosaurus acadianum*.

The Big Picture: Lyell, Darwin and Dawson on Evolution

Lyell was delighted with his discovery with Dawson of "Coal Age reptiles" largely because it provided him with evidence in his long-standing campaign against the proponents of catastrophism, who argued that reptiles succeeded fishes in the Mesozoic Era.[66] The true significance of these earliest reptiles at Joggins has only grown with the passage of time and development of evolutionary biology and paleontology.

With the publication of *The Origin of Species* in 1859, Charles Darwin drew on the completeness of exposure at Joggins and the recurrence of the fossil forests to illustrate that the fossil record is inherently incomplete.[67] What at first may seem a paradox was, in fact, a shrewd, pre-emptive argument against critics of gradual and progressive evolution. Darwin argued that even in the unrivalled exposures at Joggins,[67] where fossil forests appear at no less than 68 horizons, the intervening beds theoretically could hide "the fine intermediary gradations which must on my theory have existed between them," with the result that the fossil record generally gives the misleading appearance of "abrupt, though perhaps very slight, changes of form."[67]

Dawson continued to argue the case for Lyell, his close friend, mentor and benefactor. In 1863, Dawson published *Air-Breathers of the Coal Period*, (subtitled *A Descriptive Account of the Remains of Land Animals Found in the Coal Formation of Nova Scotia With Remarks on their Bearing on Theories of the Formation of Coal and of the Origin of the Species*),[68] which, as the complete title reveals, was in part a counterpoint to Darwin's *The Origin of Species*. Dawson advocated that the discovery of essentially modern, conservative forms such as the land snail *Dendropupa*, virtually unchanged over millions of years, argued against Darwinian progressive change—imperfections in the geological record aside. Bishop Samuel Wilberforce, in his review and criticism of *The Origin of Species* had already taken obvious pleasure in chiding Darwin about "this miserable little *Dendropupa*."[69] In all his work, Dawson was a careful observer and documenter of geologic phenomena. His observation that conservative forms such as *Dendropupa* persist unchanged for long expanses of time presaged



"But with regard to the material world, we can at least go so far as this—we can perceive that events are brought about not by insulated interpositions of Divine power, exerted in each particular case, but by the establishment of general laws."

W. WHEWELL: *Bridgewater Treatise.*

"To conclude, therefore, let no man out of a weak conceit of sobriety, or an ill-applied moderation, think or maintain, that a man can search too far or be too well studied in the book of God's word, or in the book of God's works; divinity or philosophy; but rather let men endeavour an endless progress or proficience in both."

BACON: *Advancement of Learning.*

Down, Bromley, Kent,
October 1st, 1859.

ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

BY CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

Figure 52 ***Frontispiece of*** **The Origin of Species.**

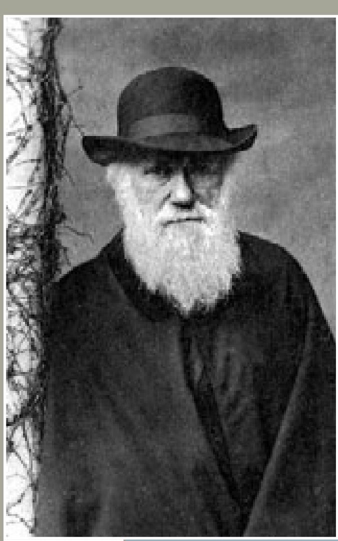


Figure 53 ***Charles Darwin.***

Figure 54 ***Contemporary caricature of Bishop Sam Wilberforce, by Carlo Pelligrini, in Vanity Fair, 1869.***

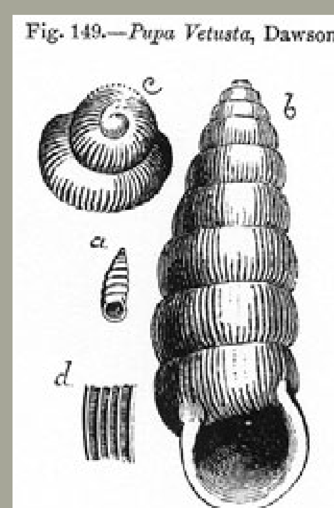


Figure 55 ***The earliest land snail Dendropupa vetusta.***

later modification to evolutionary theory expressed in the "tempo and mode" of Simpson (1941)[70] and "punctuated equilibria" of Gould and Eldredge (1977),[71] but which would have to await the passage of a century for wide acceptance.[72,73]

The Contentious Origin of Coal

In the middle of the nineteenth century, as coal fuelled the Industrial Revolution, Charles Darwin wrote emphatically about the then-unresolved and highly disputed origins of coal, stating: "I shall never rest easy in Down church-yard, without the problem be solved by someone before I die."[74] Debate on the origin of coal, the fuel of the Industrial Revolution, revolved very much around the Joggins section.[29] Lyell cited this coal mystery as one of his main reasons for first visiting the cliffs in 1842, and it was the subject of one his Lowell Lectures delivered in Boston and repeated in New York and Philadelphia during his first trip to America.[61] Coal beds remained enigmatic to many scientists of the day,[75] some of whom, including Darwin (correspondence of 19 May 1846),[76] speculated that their great areal extent necessitated a submarine origin. Logan, Lyell and Dawson all begged to differ[77,78,79,80] based on field observations of standing tress rooted in place atop the coals, to which Dawson added his prowess in microscopy.[81]

For Darwin, it was the discovery of terrestrial fauna within the upright trees at Joggins[82] that finally persuaded him of the terrestrial origin of coal (essentially a fossil peat) and of the fossil trees: in a letter of 22 May 1860 to Lyell,[83] he exclaimed "What a fact about the Coal Land Shells!!!" Thanks in part to Joggins, Darwin may now rest easy.

Figure 56 **Coal No. 15, as enumerated by Sir William Logan.**

Dawson's Journey to the "Coal Age" World

Throughout his long career, Sir William Dawson repeatedly revisited Joggins, the site of his discovery with Lyell of *Dendrerpeton*, and in 1859[82] reported to the Geological Society yet another discovery, the significance of which has continued to grow with time. *Hylonomus lyelli*, meaning "forest dweller", named in honour of his mentor and friend, Sir Charles Lyell, a century-and-a-half later was proclaimed Nova Scotia's provincial fossil and remains the earliest known amniote in the fossil record.[11,12,84,85] *Hylonomus* was briefly usurped by *Westlothiana lizzeae*, an older tetrapod known from the Visean of Scotland, but which is now widely considered to represent a more primitive, stem amniote.[11,12]

Figure 57 **Sir William Dawson**

In 1877, armed with a grant of £50 from the Royal Society in London, and with the assistance—and explosives—of the mining company at Joggins, Dawson[12] exposed an entire fossil forest horizon comprising twenty-five lycopsid trees entombed in the "Lesser Reef of Coal Mine Point."[28] Incredibly, fifteen entombed trees—more than half of those examined—were productive, yielding more than 100 individual tetrapods from this one concentrated Lagerstätten, which remains the most significant single collection of Paleozoic terrestrial tetrapods in the world.[86] The curious circumstances of the entombment of these denizens of the "Coal Age" forests have continued to enthral scientists and the public. Lyell and Dawson[61] originally ascribed their occurrence to denning, pitfall, or the possibility that the animals had been washed into the buried hollow trees. Dawson ultimately came to favour the pitfall theory, which has been figured in countless texts on the history of life, although recent research[13] points to another of Lyell and Dawson's original hypotheses: denning.

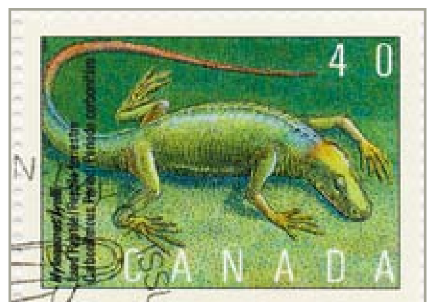


Figure 58 ***Hylonomus lyelli*, Provincial Fossil of Nova Scotia.**

Much of our knowledge of the fossil record at Joggins derives from the lifelong work of Dawson. Lyell once wrote, "I never travelled in any country where my scientific pursuits seemed to be better understood, or were more zealously forwarded, than in Nova Scotia."[55] No one would prove to be a more "zealous" advocate than Dawson.

Dawson was a pioneer in the field of terrestrial paleoecology.[87] In a letter written in 1868,[88] Dawson commiserated with Lyell on the lack of field investigation that typified and hobbled paleontologists of the day, offering that advances would come by careful study of "... plants as they stand in the cliffs at Sydney and the Joggins,

Figure 59 ***Hylonomus lyelli* in the primeval forest, by John Sibbick, from** **Prehistoric Life.**

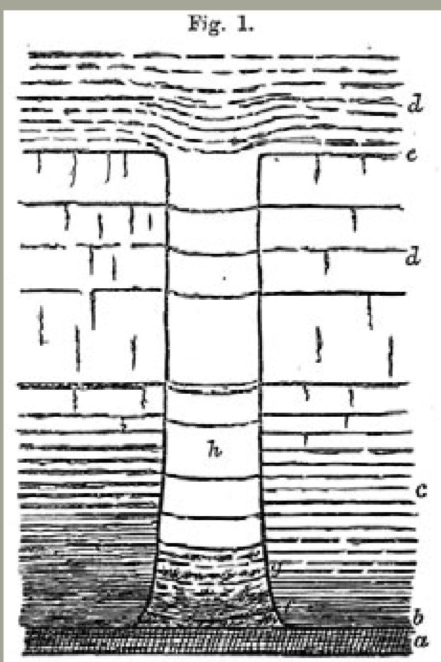


Figure 60 ***A tetrapod-bearing fossil tree from Dawson (1882).***

Figure 61 ***"Airbreathers of the Coal Period," 1863.***

Figure 62 **Acadian Geology, *Sir William Dawson's 1855 opus updated in editions of 1868, 1878 and 1891.***

Figure 63 ***"Old Joggins" ~ a wood block etching from Dawson's* Acadian Geology.**

instead of on the shelves of the British Museum." The breadth of Dawson's work and his careful observations of the relationships of fossils and their entombing sediments,[87] coupled with observations by Lyell and others of modern environments,[89] enabled him to draw astute inferences of the ancient Joggins landscape and its paleoecology:

> These beds carry our thoughts back to a period when the district was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades, or the Delta of the Mississippi.[90]

His historic diorama of the terrestrial environment and fauna at Joggins for the frontispiece of *Air Breathers of the Coal Period* (1863)[68] is one of the earliest for the Paleozoic. Dawson's publications stemming from Joggins, spanning 44 years, are summarized eloquently in his opus *Acadian Geology* (1855, updated editions of 1868, 1878 and 1891).[90]

Joggins: New Centuries Dawn

Late in his life, Dawson recalled his first visit to Joggins in the early 1840s, a memory evocative to many who have followed in his footsteps:

> The tide favoured my expedition, and the day was fine, though small banks of fog drifted up the bay from time to time, dissolving as they touched the cliffs, warmed by the sun. I returned in the evening to the quarrymen's shanty, thoroughly fatigued, but loaded with fossils, delighted with the knowledge I had acquired, and with my enthusiasm for geology raised to a higher point than ever before. Such was my first visit to the celebrated coast-section of the Joggins, on which I have spent so many pleasant and profitable days.[60]

As the nineteenth century drew to a close and the twentieth began, the momentum of Dawson's work carried paleontology forward at Joggins. In 1893, T.C. Weston of the Geological Survey of Canada discovered one of the few taxa to escape Dawson's eye, the large and enigmatic bivalve *Archanodon*, originally described as *Asthenodonta* by Whiteaves,[91] who the year before had described fauna from the Burgess Shale. George Frederic Matthew, founder of the New Brunswick Museum, pursued the trackways of Lyell and Dawson's tetrapods in a series of keynote papers[92,93] that remain definitive works in tetrapod ichnology.

Research at Joggins in the twentieth century reflected the pragmatism and geopolitical divide of a world conflicted, with attention focussing on characterizing the coal beds that continued to be strategically important. The year 1911 drew two notable but very different paleobotantists separately to Joggins: British activist Marie Stopes, who was questioning the paleobotanical assessment by Dawson of the Fern Ledges across the Bay of Fundy in New Brunswick,[94] and the retiring young Canadian Walter A. Bell of the Geological Survey of Canada. Bell, one of the delegates to the International Geological Congress of 1913 and future Director of the Geological Survey of Canada, pursued paleobotanical studies at Joggins[95,96,97] and elsewhere in the Carboniferous rocks of eastern Canada. Bell's interest in the fossil plants lay chiefly in their utility in correlating the rocks of eastern Canada with those

Figure 64 *Field trip of the International Geological Congress of 1913.*

Figure 65

Redpath Museum, McGill University, Montréal, half-scale version of the Musée de l'Histoire Naturalle, Paris, and built to house the collections of Principal Sir William Dawson, which remains home to the most important collection of Dawson's tetrapod fossils.

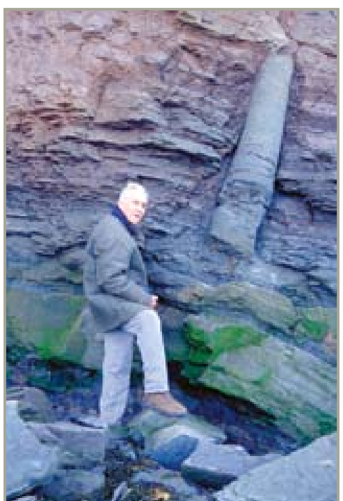


Figure 66 ***Dr. Robert H Wagner.***

of the European coal measures. An important re-evaluation of the Joggins macroflora was undertaken in the 1990s and 2000s by Robert Wagner, of the Jardin Botanico de Córdoba, who drew together the works of American and European paleobotanists—including that of Stopes—in revising the floral record. Complementing this work has been an exhaustive analysis of the microscopic record of plants throughout the entire sedimentary succession comprising the nominated property by palynologists John Utting of the Geological Survey of Canada and Graham Dolby, Calgary.[15,98]

Research on the tetrapod record, which remains the richest known from the terrestrial realm of the Carboniferous, continued in the twentieth century. This research centred on restudy of Dawson's collection,[99,100,101,102] now largely housed at the Redpath Museum of McGill University, Montréal, but was supplemented by important new discoveries.[103,104] A consequence of these studies led by Robert Carroll and his students and colleagues (Godfrey, Holmes, Milner, Reisz, and others) was an even greater significance for the tetrapod record at Joggins, the most significant element of which has been recognition of the

Figure 67 ***Dr. Robert L. Carroll.***

earliest reptiles (and amniotes) in the fossil record of life. Adding to the significance of the earliest amniote *Hylonomus*, which as an anapsid reptile is ancestor of dinosaurs, birds, and lizards, is the presence of *Protoclepsydrops*, equivocally the earliest representative of the other main amniote lineage, the diapsids, which gave rise ultimately to mammals[10,11,12,105] (Section 3.C (v)). The earliest fossil reptiles found by Lyell and Dawson a-century-and-a-half earlier now figure prominently in emerging fields of evolutionary study, including the "molecular clock."[105,106]

The record in footprints of the terrestrial vertebrate community first described systematically by Matthews in the early twentieth century continues to serve as the gold standard in tetrapod ichnology,[107,108,109] not only because of the richness of the footprint record itself, but also due to the exceptionally rich skeletal records of the trackmakers. In the past decade, the number of discoveries of tetrapod trackways has grown exponentially, reflecting the close collaboration between the scientists and resident stewards skilled in the recognition of footprints. At the time of submission of this nomination, a comprehensive treatment of the tetrapod trackway record of Joggins, including type specimens in world museums,

Figure 68 ***Type specimen of Barillopus arctus (microsaur footprints), Redpath Museum.***

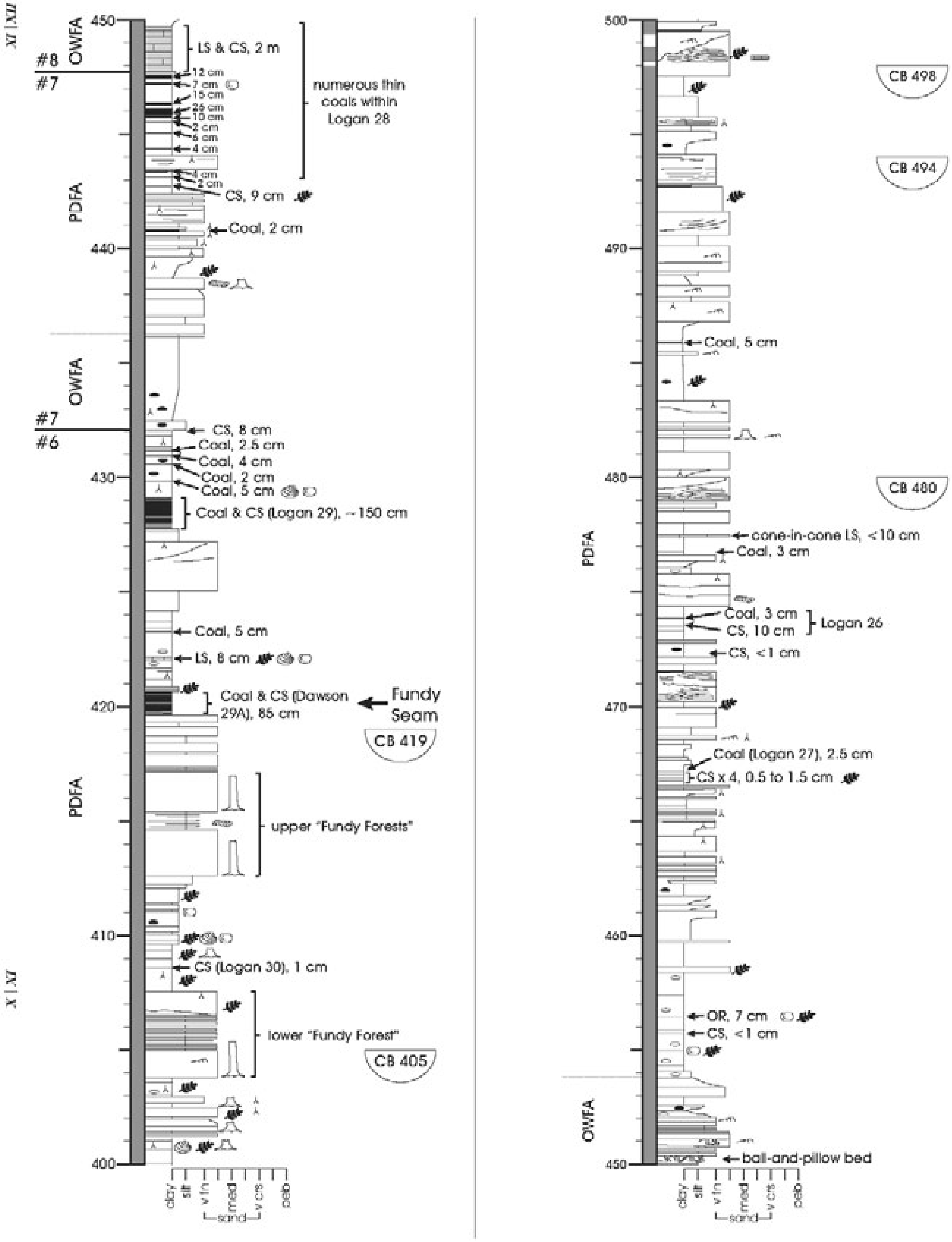


Figure 69 ***A portion of the detailed sedimentological log that forms the new reference for paleontological discoveries from the section.***

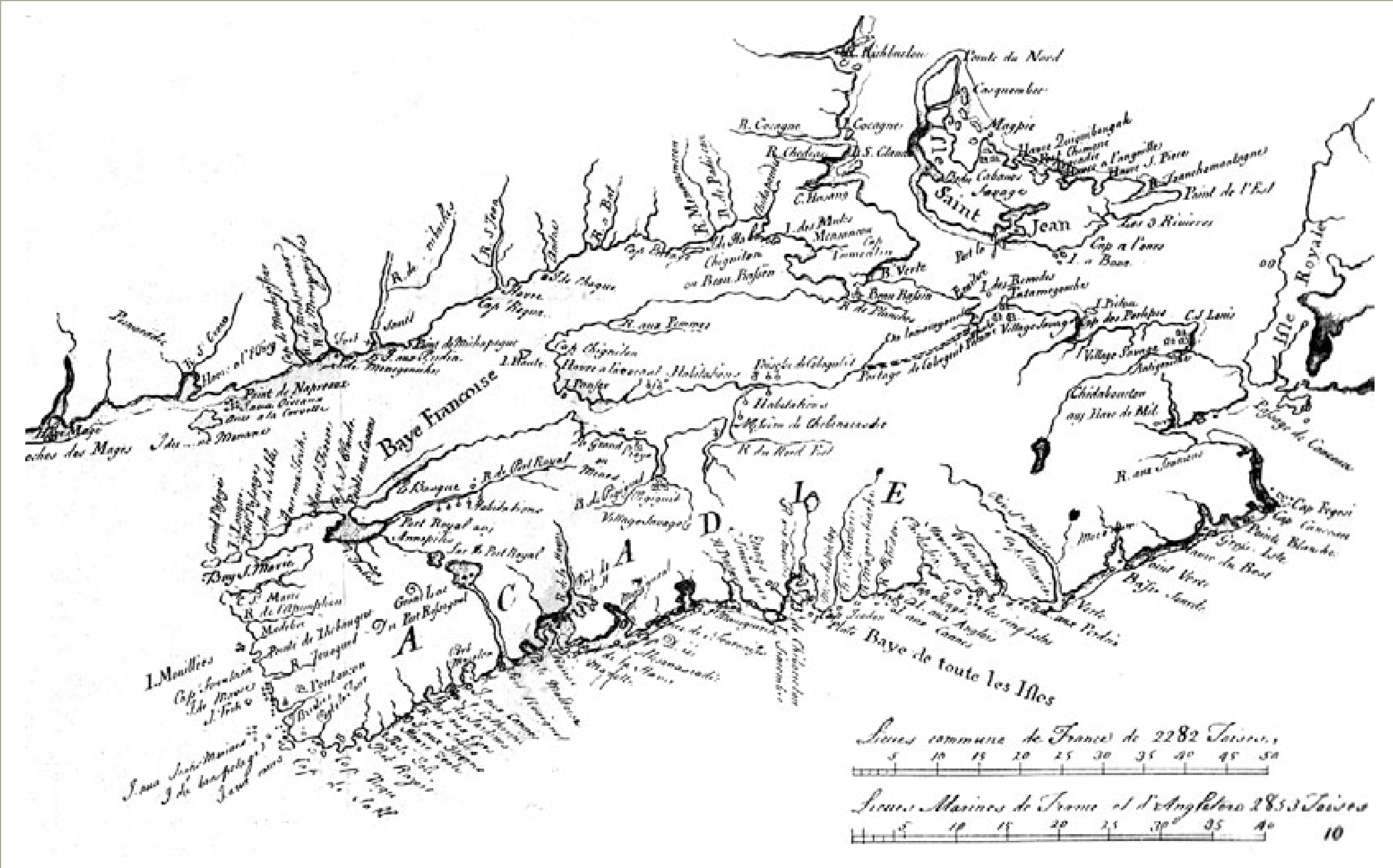


Figure 70 *Seventeenth century map of Samuel de Champlain, depicting Acadia and the Bay of Fundy.*

was being undertaken by two world leaders in the subject, Spencer Lucas and Adrian Hunt of the New Mexico Museum of Natural History.

A resurgence in scientific publication at Joggins to rival that of the nineteenth century[8,9] has waited for the passage of a century since the work of the so-called "lions"[7] such as Lyell and Dawson, and has required the collective wisdom and efforts of an informal working group drawn, as in their day, from both sides of the Atlantic (see references to Calder, Davies, Falcon-Lang, Gibling, Rygel and Scott among others, in Section 7.E, Bibliography). Just as in the mid-nineteenth century, this work was made possible only with the return to careful, bed-by-bed scrutiny of this daunting section.[3,4] The graphic logs derived from this work (Appendix J) serve as the new reference section for specimens collected from this most outstanding exposure of the "Coal Age." The work by contemporary authors has returned to interpreting the paleoenvironment and sedimentary record of Joggins that provides the fossil record its all-important context. An important advance has been to consider the record and influence of global change in the fossil record of Joggins. A full account of the scientific literature derived from the fossil record at Joggins is presented in Section 7.E, Bibliography.

2.B (iv) Mining: Harvesting the Energy of the Coal Age Sun

Coal was mined from the cliffs of Joggins by French explorers long before any written reference to its geology was recorded in English. Archaeological investigations at Port Royal, roughly 100 kilometres farther down the Bay of Fundy, suggest that the first forges of the New World in North America were fuelled by the coal beds of Joggins in the earliest years of the seventeenth century.[8,110] Over a century later, the fires of the French garrison at Fort Beausejour at the head of the Bay continued to be stoked by coal worked from the Joggins cliffs.

Coal was first mined from the cliff-face, then by following the seams inland for a distance of 30 kilometres (Appendix I: Map 4). The operations of at least 83 underground collieries are recorded, primarily on the Fundy, Forty Brine, Kimberley, Queen and Joggins seams and their inland equivalents.[20,111] The Joggins Fossil Centre will be situated on the site of the former Joggins No. 7 colliery,[111] which pursued the Joggins seam beneath the waters of Chignecto Bay, earning it the distinction of being one of the first (if not the first) submarine colliery in the world. From the first operation of the General Mining Association in 1847 until the closure of the last underground colliery at River Hebert in 1980, more than 13 million tonnes were hard won from the thin coal seams of the Joggins Formation.[111]

Evidence of past mining can be seen in the pit props revealed by erosion of the cliff-face, and in the remains of the main coal loading wharf at the Joggins seam. Coal was transported onto the wharf along an excavated decline known locally as "the dugway," which still exists south of the new Centre. Stairs that access the beach at the Centre are situated where "the dugway" met the loading wharf, the remains of which can be seen clearly on the foreshore at low tide (Section 4.A (ii)). A similar loading wharf existed at the Fundy Seam in the mid-nineteenth century, but was abandoned earlier.

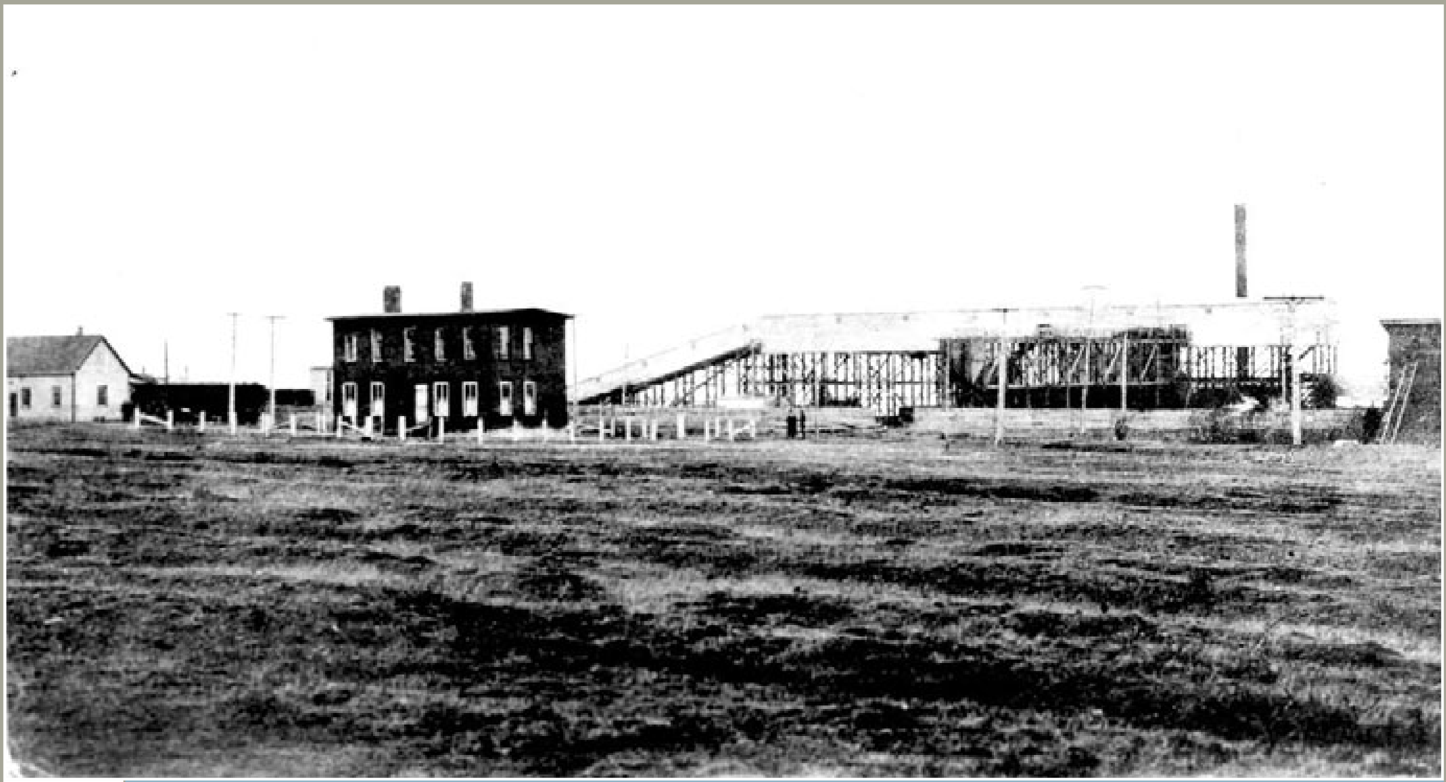


Figure 71 ***Joggins No. 7 Colliery, which operated in the early nineteenth century at the site of what is now the Joggins Fossil Centre.***

Figure 72 ***The breakwater at the Joggins seam, completed in 1872.***

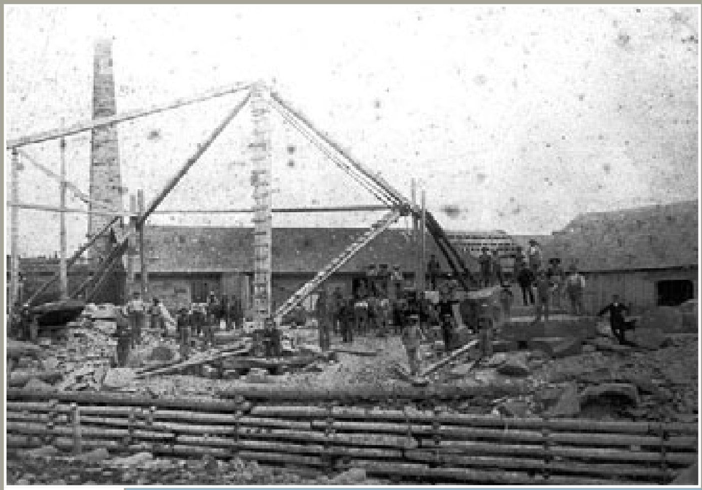


Figure 73 ***Stone-cutters at Lower Cove, late nineteenth century.***

Figure 74 A grindstone lies where it was abandoned by stone-cutters in the nineteenth century at Lower Cove.

Figure 75 Fishing weir at low tide.

2.B (v) Grindstone Works at Lower Cove

Innovative quarrying of sandstones of the Boss Point Formation at Lower Cove, and smaller operations at Ragged Reef, produced vast numbers of grindstones and millstones in the eighteenth, nineteenth and early twentieth centuries.[112] The stones were highly prized, with the largest market being the eastern seaboard of the United States. In the mid-nineteenth century, the number of men toiling at the stone works at Lower Cove swelled in summer months to 500. In the year 1847 alone, 33,075 grindstones were exported from Cumberland County, mostly from Lower Cove, at a value of 2 shillings, sixpence each.[26]

The large mill grindstones, called waterstones, were cut from stone in the intertidal zone, as described by Gesner:[19]

> During the recess of the tide, the strata are broken near the low-water mark, and large masses of rock are secured between boats, which, at high-water, are lifted up and hauled to the shore, where the stone is cut into grindstones from four to six feet in diameter, and from ten to eighteen inches in thickness.[26]

Operations adjacent the shore, called the "Bank Quarry," produced smaller grindstones some 60 centimetres in diameter and 10 centimetres in thickness that were highly prized in America and England:

> A peculiar stratum at this place, called the 'blue grit,' is covered by 30 feet of gravel. The drift has been removed at much cost, and the stratum has been followed 200 yards by a level, and a railway running into the bank. After the rock has been blasted, it is removed to the cutting house, where it is speedily fashioned into grindstones, by the workmen.[26]

Old quarries and foundations of the stone works are still evident at Lower Cove, and directly across the Bay at Cape Maringouin, New Brunswick. Large nineteenth-century millstones, damaged near completion, lie abandoned between reefs at Lower Cove. A small grindstone museum is operated by the community at nearby Minudie, home of the operation's owner, "King" Amos Seaman.

Figure 76 Amos "King" Seaman, proprietor of the grindstone works at Lower Cove.

2.B (vi) "The Place of the Fishing Weirs"

One of the earliest place names for Joggins can be translated as the "Place of the Fishing Weirs,"[113] and fishing doubtless was undertaken here since the arrival of the first people. Although few details of fishing operations are recorded in contemporary literature, fishing practises of the Mi'kmaq First Nation certainly were adopted by European immigrants. In 1898, the MacCarron's River Fishing Co. was established to develop fish weirs along the Joggins shore and drying racks at MacCarron's River.[114] Nets are still set by

Figure 77 A local workman excavating a fossil tree from the Joggins cliffs, from Acadian Geology (1855), by J.W. Dawson.

Figure 78 Donald Reid, "Keeper of the Cliffs."

fishers today between reefs at Joggins and Lower Cove.

2.B (vii) Community Stewardship

Members of the Joggins and surrounding communities have played a role in site investigations since the very first geological investigations. In the mid-nineteenth century, Sir William Logan was accompanied in the field by a Mi'kmaq guide who by Logan's account was an invaluable companion.[115] Coal miners and officials from the Joggins Mines accompanied Lyell and Dawson, including the day in 1852 when they made their famous discovery of the hollow tree fauna. Dawson employed coal miners to scale the cliffs in excavating fossil trees, and during his years as Principal of McGill University in Montréal, had a long-term relationship with P.W. McNaughton, who is credited with discovery in 1893 of the single most productive tetrapod-bearing tree.[116]

In the 1950s—1970s, Harry Burke operated the former Fundy Museum in Joggins, which was routinely visited by palaeontologist Donald Baird of Princeton and later Yale. For approximately the last

Figure 79 Brian Hebert of Lower Cove, who discovered a unique fossil assemblage from the Joggins Formation.

20 years, a privately operated fossil centre displayed the collections of Donald Reid and family, which served as an important census of the biodiversity of the site. Reid's altruistic collaboration with scientists earned from them the title "Keeper of the Cliffs." The fossil centre filled an important gateway to the site for scientists and casual visitors during the years 1992-2006. This strong sense of community stewardship has inspired younger generations, some of whom have made significant paleontological discoveries in their own right[117] at this magnificent archive of earth history.

The Cliffs in the Heart of the Community

The former mining town of Joggins is very much a community rooted in coal, and the cliffs and their fossil heritage touch deeply the lives of the people who live there. The cliffs inform their art and very sense of being.

Figure 80 The Joggins Fossil Cliffs have inspired resident artists with their wild beauty.

2.B (viii) Recent Conservation History

The cliffs of Joggins have been protected under law since 1970, when legislation of the province of Nova Scotia was drafted by Dr. J. Lynton Martin, first Director of the Nova Scotia Museum, specifically to address the significance of Joggins and to ensure its protection and stewardship. The *Historical Objects Protection Act* was superseded in 1989 by the *Special Places Protection Act*. A review of the protective designation was undertaken in 1988 by Dr. Laing Ferguson, Mount Allison University.[118] In 1994, the *Act* was revised to give even greater strength to the protection of fossil heritage. Measures for managing the fossil resource, and the legislation involved, are summarized in Section 5: Protection and Management of the Property. The full management plan and relevant legislation are appended (Appendix C and G).

Figure 81 Dr. Laing Ferguson.

3 Justification for Inscription

The earliest repitile, Hylonomus lyelli, in the "Coal Age" forest of Joggins, as depicted by Doug Henderson.

3.A CRITERIA UNDER WHICH INSCRIPTION IS PROPOSED (AND JUSTIFICATION FOR INSCRIPTION UNDER THESE CRITERIA)

The coastal cliffs at Joggins reveal the most complete fossil record of terrestrial life in the iconic “Coal Age” forests, including the most pivotal event in the evolution of vertebrate life on land. The Joggins Fossil Cliffs therefore are nominated for inscription to the World Heritage List under “criterion viii,” which states that properties:

> be outstanding examples representing major stages of earth’s history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features.

With its combined record of biodiversity, paleoecological integrity and evolutionary milestones, the Joggins Fossil Cliffs is the one natural site in the world for this period of earth history that best meets the criteria for fossil sites established by UNESCO and the IUCN (see Tables 3.1 and 3.2).[1,2]

The enduring significance of Joggins can be ascribed to four pillars:

i) the grand exposure of the coastal cliffs;
ii) the fossil record that is contained in the cliffs;
iii) the sedimentary succession that provides the fossil record its ecological context; and
iv) the role that the cliffs and their fossil record have played in the history of science.

The magnificently exposed succession of sedimentary rocks at Joggins[3] contains an unrivalled fossil record of the terrestrial tropical biome and ecosystem that is preserved in its environmental context, representing what Sir Charles Lyell described as “the finest example in the world”[4] of the Pennsylvanian “Coal Age” of the earth’s history. The sedimentary strata provide environmental context to the fossil record that is unparalleled in the world. This fossil record of biodiversity, preserved *in situ*, contains the two defining elements of the Pennsylvanian “Coal Age”[5]: fossil forests and the first reptiles, which as the earliest amniotes are the oldest known representatives of reptiles, birds and mammals.[6,7,8,9,10] The evocative nature of this fossil record is expressed no better than by the world’s first reptiles entombed within once-hollow trees, an image reproduced in virtually all major texts of the history of life.

The fossil record includes numerous taxa for which a species or higher taxonomic rank has been first defined (type specimens), some of which are found nowhere else on earth. Of the 63 fossil species of terrestrial fauna and their trackways, over half are type specimens, described first or found only at Joggins. The entire terrestrial record of tetrapods, encompassing 19 species of primitive “stem” tetrapods, amphibians and reptiles, comprises such type specimens.

One of the most significant events in the history of life was the origin of reptiles (or, more generally, amniotes) that achieved the capacity to reproduce on land, an evolutionary milestone first observed at Joggins. Modern amniotes have come to dominate the terrestrial environment over the past 300 million years, but their ancestry remains enigmatic. No other locality in the world has provided as much knowledge of the nature of early amniotes, or has provided more informative specimens for linking them to their more primitive ancestors.[11]

Joggins has played a vital historic role in the development of seminal geological and evolutionary principles, including those of Sir Charles Lyell and Charles Darwin, for which it has been called the “Coal Age Galapagos.”[12] These principles are as varied as ongoing subsidence of the earth’s crust, the origin of coal, the inherent nature of the fossil record as it informs evolutionary theory, and recently, molecular sequencing of amniote origins.

Unequivocal endorsement for the nomination of Joggins as a World Heritage Site has been received from leading scientists and institutions worldwide. Ongoing discovery and research at this dramatic natural site, hewn and freshly exposed by the world’s highest tides, ensure that this history will continue.

3.B PROPOSED STATEMENT OF OUTSTANDING UNIVERSAL VALUE

The coastal cliffs at Joggins reveal the most complete fossil record in the world of terrestrial life in the Pennsylvanian "Coal Age" of earth history. Nowhere is this record of the evolution of life on land and biodiversity in the tropical "Coal Age"—encompassing plant, invertebrate and vertebrate life—rendered more evocatively. The magnificently exposed succession of sedimentary layers preserves the fossils *in situ*, providing environmental context that is unrivalled in the world. The fossil record includes the two defining, iconic elements of the "Coal Age": fossil forests of the "coal swamps" and the first reptiles, which as the earliest amniotes are the oldest known representatives of reptiles, birds and mammals. The origin of amniotes, the first vertebrates to achieve the capacity to reproduce on land, was one of the most significant events in the history of life on earth, an evolutionary milestone first recorded with certainty at Joggins. No other locality in the world has provided as much knowledge of the nature of early amniotes or more informative specimens for linking them to more primitive groups of Palaeozoic tetrapods, and to the world in which they lived. The fossil record includes species first defined at Joggins, some of which are found nowhere else on earth: of the 63 fossil species of terrestrial fauna and their trackways, over half are such type specimens. Through the power of the Bay of Fundy tides, which are unsurpassed in the world, ongoing discovery is ensured at this site of outstanding universal value.

This dramatic setting is home to what Sir Charles Lyell, father of modern geology, described as "the finest exposure in the world" of the rocks and fossil record of the Pennsylvanian "Coal Age" of earth history. The fossil record of Joggins has figured in the first debate on evolution, and remains pivotal to understanding the terrestrial origins of vertebrate life, including our own species. This uniquely representative chapter of the earth's history has been the subject of the research and writings of some of the world's most influential scientists since the mid-nineteenth century. Joggins has figured in such seminal works as *Principles of Geology* by Lyell and *The Origin of Species* by Charles Darwin, and has come to be known as the "Coal Age Galapagos."

Figure 82 *Artist's depiction of Hylonomus lyelli within a hollow lycopsid tree as a wildfire passes through the wetland forest (Stephen Greb).*

3.C COMPARATIVE ANALYSIS (INCLUDING STATE OF CONSERVATION OF SIMILAR PROPERTIES)

Only eleven properties are inscribed on the World Heritage List primarily in recognition of their outstanding fossil values (ten natural sites, and one cultural). In addition, several other sites include fossil heritage as a component of their statements of outstanding universal value. The eleven fossil sites are:

- Australian Fossil Mammal Sites (Riversleigh/Naracoorte), Australia (Quaternary)
- Lake Turkana National Parks, Kenya (Quaternary)
- Fossil Hominid Sites, South Africa (Quaternary)
- Wadi Al-Hitan (Whale Valley), Egypt (Paleogene)
- Messel Pit Fossil Site, Germany (Tertiary)
- Dinosaur Provincial Park, Canada (Cretaceous)
- Dorset and East Devon Coast, United Kingdom (Triassic-Cretaceous)
- Monte San Giorgio, Switzerland (Triassic)
- Ischigualasto-Talampaya Natural Parks, Argentina (Triassic)
- Miguasha National Park, Canada (Devonian), and
- Burgess Shale, as part of Canadian Rocky Mountain Parks, Canada (Cambrian).

A representative selection of international scientists in support of the outstanding universal value of the Joggins Fossil Cliffs.

M. Marius Aresnault
Director (Retired)
Parc Nationale de Miguasha, Canada

Dr. Robert L. Carroll
Vertebrate Paleontologist
Redpath Museum, Canada

Dr. Aureal T. Cross
Scientist Emeritus
University of Michigan, USA

Dr. Phillip Currie
Vertebrate Paleontologist
Royal Tyrell Museum of Paleontology, Canada

Dr. William A. DiMichele
Paleobotanist
National Museum of Natural History, Smithsonian Institution, USA

Dr. Laing Ferguson
Professor Emeritus
Mount Allison University, Canada

Dr. Howard J. Falcon-Lang
Palaeobotanist
University of Bristol, UK

Dr. Robert A. Gastaldo
Professor of Geology
Colby College, USA

Dr. Richard A. Grieve
Chief Geoscientist
Geological Survey of Canada

Dr. Paul Johnston
Curator of Invertebrate Paleontology
Royal Tyrrell Museum of Paleontology, Canada

Dr. Elizabeth C. Kosters
Past President
Royal Netherlands Geological Society

Dr. Andrew C. Milner
Palaeontologist Emeritus
Natural History Museum, UK

Dr. Martin J.S. Rudwick
Historian of Science
Cambridge, UK

Dr. A.C. Scott
Reader in Palaeobotany
Royal Holloway University of London, UK

Dr. Susan Turner
Vertebrate Paleontologist
The University of Queensland, Australia

Dr. Peter von Bitter
Head of Paleobiology
Royal Ontario Museum, Canada

Dr. Robert H. Wagner
Editor-in-Chief, Carboniferous of the World
Jardin Botanico de Córdoba, Spain

Dr. Peter A. Hacquebard
Founding Member,
International Committee for Coal Petrology

Figure 83 ***Signatures and affiliations of scientists.***

Eon	Era	Period	Millions of Years Ago	UNESCO World Heritage Sites
Phanerozoic	Cenozoic	Quaternary	3	• **Australian Fossil Mammal Sites**: ~ 1 mya "Australian Marsupials" • **Lake Turkana National Parks,** Kenya: ~ 3 mya "Early Hominid and Mammal Sites" • **Fossil Hominid Sites,** South Africa: ~ 3.3 mya "Australopithecus Discovery Site"
		Neogene	23	
		Paleogene	66	• **Wadi Al-Hitan (Whale Valley),** Egypt: ~ 40 mya (Paleogene Epoch) "Evolution of Whales" • **Messel Pit Fossil Site,** Germany: ~ 50 mya (Eocene Epoch) "Tertiary Mammals"
	Mesozoic	Cretaceous	146	• **Dinosaur Provincial Park**, Canada: ~ 100 mya "Acme of the Dinosaurs"
		Jurassic	200	• **Dorset and East Devon Coast,** United Kingdom: ~ 174 mya marine life & geology of the "Dinosaur Era"
		Triassic	251	• **Monte San Giorgio,** Switzerland-Italy: ~ 240 mya "Marine Reptiles" • **Ischigualasto-Talampaya National Parks,** Argentina: : ~ 248 to 208 mya "Terrestrial Life"
	Paleozoic	Permian	299	
		Carboniferous – Pennsylvanian	318	○ **The Joggins Fossil Cliffs, Canada: Pennsylvanian ~ 310 mya "Coal Age" swamps and first reptiles**
		Carboniferous – Mississippian	359	
		Devonian	416	• **Miguasha National Park,** Canada: ~ 370 mya "Age of Fish" evolution of limbs, preparing for life on land
		Silurian	444	
		Ordovician	488	
		Cambrian	542	• **Burgess Shale,** Canada: ~ 535 mya "Explosion of Multicellular Life"
Proterozoic		Vendian	600	
			2500	
Archean			4000	
Pre-geological Earth			4600	

Figure 84 *The geological timescale, showing fossil sites inscribed on the World Heritage list, and the nominated candidate for the Carboniferous "Coal Age," Joggins.*

Natural sites are under represented in the World Heritage list, as recognized by the Global Strategy (Paragraphs 54-58 of the Operational Guidelines, 2005). Within the natural category, other imbalances are even more profound: fossil sites that record the history of life on earth represent just over one percent of sites inscribed on the World Heritage List. Of these, the record of the Paleozoic Era is further under-represented, and no site represents either Subsystem of the Carboniferous Period.

Each of these sites illustrates a different period of geological history from the Pennsylvanian Subsystem of the Carboniferous time period that is illustrated by Joggins. As such, they do not serve as appropriate references for direct comparison of their fossil records. They do however provide benchmarks for the state of conservation of such sites, which Joggins matches or exceeds (see Section 3.C (iv), below).

There are currently no fossil sites of the Pennsylvanian "Coal Age" Period of earth history inscribed on the World Heritage List.

3.C (i) IUCN Criteria for the Evaluation of Palaeontological Sites Nominated for Inscription on the World Heritage List[1]

The IUCN has undertaken major contextual studies in 1994[1] and 1996[2], that establish guiding principles for the evaluation of fossil sites that may have potential to be inscribed on the World Heritage List as sites of outstanding universal value. The resulting questions and recommendations provide broad evaluation criteria, whereas a comparative analysis provides detailed assessment of the significance of a site in the context of contemporary localities from the same period of earth history.

These recommendations stress the breadth of biodiversity demonstrated by the fossil record of a property and the significance of evolutionary events, expressed in the context of the tree of life. The argument for inscription of Joggins is compelling in the context of these guiding principles, which are confirmed by a comparative analysis of contemporary sites from the Pennsylvanian "Coal Age" of the Carboniferous Period of earth history.

Specific response to the IUCN guidelines of 1994 and subsequent recommendations of 1996 is provided below:

Question 1. Does the site provide fossils which cover an extended period of geological time (i.e., how wide is the geological window)?

> Nowhere else in the world is there so magnificent, or so instructive an exposure of the coal-measures as that of the Joggins. Imagine a thickness of three miles of strata, tilted up so that almost every successive bed is brought to view! What a history is there contained!
>
> -- B.J. Harrington, Biographer of Sir Wm. Logan, 1883[13]

Yes, the Joggins Fossil Cliffs record a geological window that spans at least 15 million years of earth history,[13] from the late Mississippian Subsystem (Serpukhovian stage) through early Pennsylvanian Subsystem (Bashkirian to Moscovian stages) of the Carboniferous System, as defined by the International Commission on Stratigraphy and International Union of Geological Sciences (Section 2.A).[14]

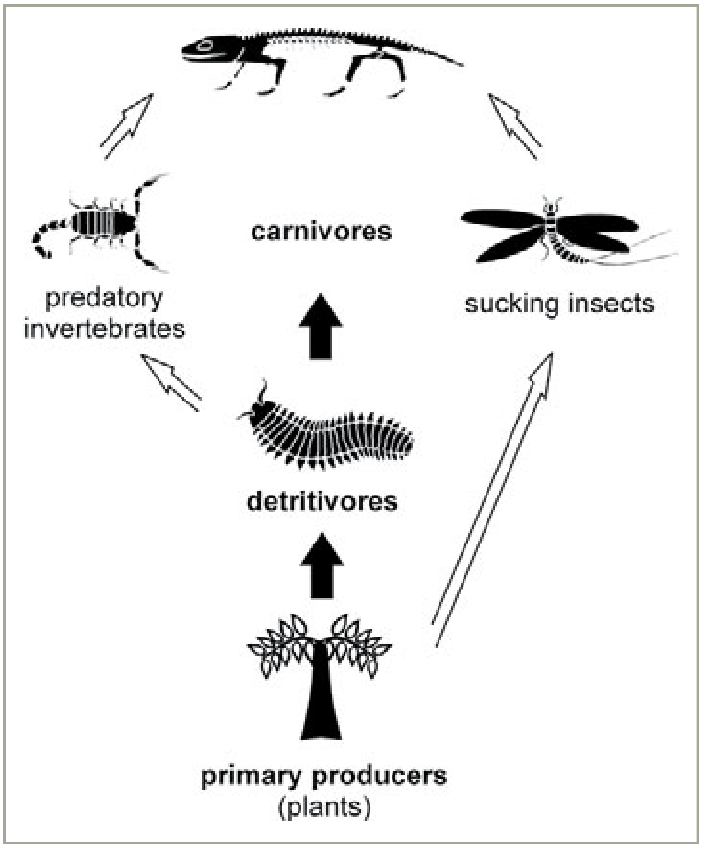


Figure 85 *The food chain of the Coal Age terrestrial ecosystem, fully represented in the fossil record of Joggins.*

Question 2. Does the site provide specimens of a limited number of species or whole biotic assemblages (i.e., how rich is the site in species diversity)?

Yes, the nominated property represents whole biotic assemblages and the trophic system (the food chain) of the iconic "Coal Age" wetland ecosystem.[15] These assemblages include the most diverse terrestrial vertebrate fauna known from any site of the Pennsylvanian Subsystem.[16] Equally well-represented are aquatic vertebrates (fishes) and invertebrates of both the terrestrial and aquatic realms (see Section 2.A, Tables 2.1-2.4 and Section 3.C (ii), Recommendation 1). Nominally, 95 species of plants and 100 species of animals are recorded.

Question 3. How unique is the site in yielding fossil specimens for that particular period of geological time (i.e., would this be the type locality for study or are there similar areas that are alternatives)?

The nominated property is unique in its record of terrestrial life and has long been recognized as the type locality for the terrestrial realm of the "Coal Age" ecosystem.[10,17,18,18A] Joggins is the best locality for the study of fossil life from this time period *in situ* and within its original environmental context.[5,10,19] (See Calder, 2006; Falcon-Lang and Calder, 2004; and Falcon-Lang *et al.*, 2006, Appendix K.) No other site has provided so much knowledge of the evolutionary paths from primitive terrestrial vertebrates to the major groups of terrestrial amniotes.

Figure 86 ***Erect fossil tree photographed during the International Geological Congress field trip of 1913.***

Question 4. Are there comparable sites elsewhere that contribute to the understanding of the total "story" of that point in time/space (i.e., is a single site nomination sufficient or should a serial nomination be considered)?

Extensive comparative analysis[20] of sites from the Pennsylvanian Subsystem has demonstrated that there are no Pennsylvanian sites of comparable exposure, paleoecological integrity (i.e., fossils *in situ*), or completeness as records of the "Coal Age" terrestrial ecosystem, as at Joggins (see Comparative Analysis, Appendix D). As for all fossil sites, however, other localities add specific elements of the global story of life and environments for any given time period.

In order to better reflect the global diversity of ecosystems through earth history, the World Heritage Committee and IUCN in the future may wish to consider recognition of the global distribution of ancient biomes as it has adopted for modern biomes in its Global Strategy[23], and to consider the inherent bias of the fossil record in favour of the aquatic as opposed to the terrestrial realm.[5] Precedent for this approach has been set in the inscription to the World Heritage List of Monte San Giorgio (2003), inscribed for its marine record and subsequent to the Ischigualasto-Talampaya Natural Parks (2000), which represents an outstanding example of the entire Triassic Period, but only from a terrestrial perspective.

Question 5. Is this site the only or main location where major scientific advances were (or are being) made that have made a substantial contribution to the understanding of life on earth?

Joggins is the most important site where substantial scientific advances have been made with respect to the terrestrial "Coal Age" world,[12,21] due largely to the exceptional ecological context it provides for the fossils.[5,9] Joggins played a seminal role in geological and evolutionary principles advanced by Lyell, Darwin, Dawson *et al.* in the mid-nineteenth century, earning it the title of "Coal Age Galapagos."[12] No other locality in the world has provided as much knowledge of the nature of early amniotes, or more informative specimens for linking them to more primitive groups of Palaeozoic tetrapods.[10] (See Carroll on The Evolutionary Significance of Joggins, Section 3.C (v).) The fossil record of Joggins continues to be used as a case study for emerging fields of evolutionary science , such as the "molecular clock."[22,23]

Influential papers in various disciplines are presented in Appendix K, and a comprehensive bibliography of varied science devoted to the Joggins fossil heritage is presented in Section 7E.

Question 6. What are the prospects for ongoing discoveries at the site?

Ongoing discovery at the Joggins Fossil Cliffs is a proven certainty and is a matter of historic record spanning over 150 years of site investigation.[12,21] Unlike many other fossil sites, which are of a

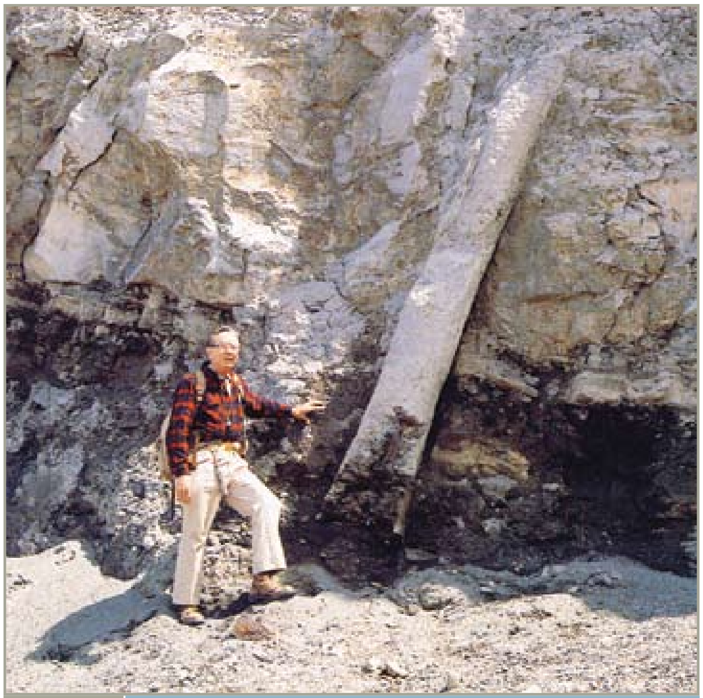


Figure 87 Dr. Aureal Cross with a fossil tree exposed in 1992.

Figure 88 Celebrated author and paleontologist, Stephen Jay Gould (centre) visiting the property in 1986.

restricted area (finite sites) or degraded due to weathering (integrity sites), the Joggins Fossil Cliffs will continue to yield new discoveries frequently and on an ongoing basis. The fossil-bearing beds continue inland from the cliffs and are protected for a distance of 30 kilometres[24] through the *Special Places Protection Act* and at the present rate of erosion (up to 0.25 metres/year) will continue to expose and yield new discoveries for an estimated 120,000 years (Appendix E:1).

Such forecasted renewal is unparalleled in the fossil record of inscribed World Heritage Sites. As a consequence of the ongoing renewal, the site continues to be the subject of major research projects in a wide range of geoscience disciplines (Appendix K).

Question 7. How international is the level of interest in the site?

Since it first appeared in the seminal works of Lyell, Darwin and others in the mid-nineteenth century,[12] the unique fossil heritage at Joggins has continued to be of highest international significance. The rich publication record in international journals and by international authors[121] continues to grow, and major research projects are currently in progress. This high level of interest in Joggins is also shared by the lay public, and visitors to the site are known from at least 44 countries (Section 5.H (i)).

Fossil specimens from the Joggins Fossil Cliffs reside in collections of the world's leading museums and universities. Selected national and international museums housing specimens from the Joggins Fossil Cliffs include the:

American Museum of Natural History, New York, USA
Canadian Museum of Nature, Ottawa, Canada
Field Museum, Chicago, USA
Fundy Geological Museum, Parrsboro, Canada
Geological Survey of Canada, Ottawa, Canada
Harvard Museum of Comparative Zoology, Cambridge, USA
Hunterian Museum, Glasgow, Scotland
Manitoba Museum, Winnipeg, Canada
Museo Paleobotanico de Córdoba, Spain
Natural History Museum, London, England
New Brunswick Museum, St. John, Canada
Nova Scotia Museum of Natural History, Halifax, Canada
Redpath Museum, McGill University, Montréal, Canada
Royal Ontario Museum, Toronto, Canada
Sedgwick Museum of Earth Sciences, Cambridge, England
Yale Peabody Museum, Hartford, USA.

For at least a century, the Joggins Fossil Cliffs have been sought as a destination for field trips by international scientific societies.[12] Selected field trips and excursions to Joggins by learned societies include:

Figure 89 Tetrapod footprint in the collection of the Natural History Museum, London (R2927).

International Geological Congress (1913)
International Botanical Congress (1959)
Canadian Society of Petroleum Geologists (1986)
American Association of Stratigraphic Palynologists (1987)
Geological Association of Canada (1992, 2005)
Society of Vertebrate Paleontologists (1993)
The Society for Organic Petrology (1993)
International Congress of the Carboniferous and Permian (1999)
Canadian Paleontology Conference (2000)
Association of Earth Science Editors (2002)
Euramerican Coal Province Symposium (2002)
International Conference on Arctic Margins (2003)
International Symbiosis Congress (2003)
North American Paleontology Convention (2005).

Figure 90 Delegates to the International Geological Convention of 1913 enjoy lunch on their field trip to Joggins.

Question 8. Are there features of natural value (e.g., scenery, landform, vegetation) associated with the site (i.e., does there exist in the adjacent area modern geological or biological processes that relate to the fossil resource)?

The Joggins Fossil Cliffs comprise a dramatic tidal shore that has many compelling natural features including:

- Impressive sea cliffs reaching heights of more than 30 metres form a compelling seascape over which sea birds and threatened raptors including bald eagles (*Haliaeetus leucocephalus*) and peregrine falcons (*Falco peregrinus*) soar.[3]
- Coastally located on the Bay of Fundy, the cliffs are visited twice daily by the world's highest tides.[25] These surging tides themselves can be considered the most outstanding example in the world of the phenomenon of the earth's ocean tides.
- The cliffs are topped by the record of glacial advance and retreat of the last global Ice Age of the Pleistocene Epoch, which last retreated some 10,500 years ago. Glacial features include the Quaternary raised beach, the wave-cut platform that forms the striking horizontal top to the bedrock cliffs and a classic section of glacial deposits that record repeated advance and retreat of the Quaternary ice cap.[26,27,28,29]
- Recent (Holocene) forests drowned by the global phenomenon of sea level rise offer a modern analogue to the "Coal Age" fossil forests of 315 million years ago.[30] Examples of drowned forests occur at various localities around the Bay of Fundy including Evangeline Beach and Aulac,[29,30] and one of the best and most accessible examples is situated at nearby Amherst Head.

Question 9. What is the state of preservation of specimens yielded from the site?

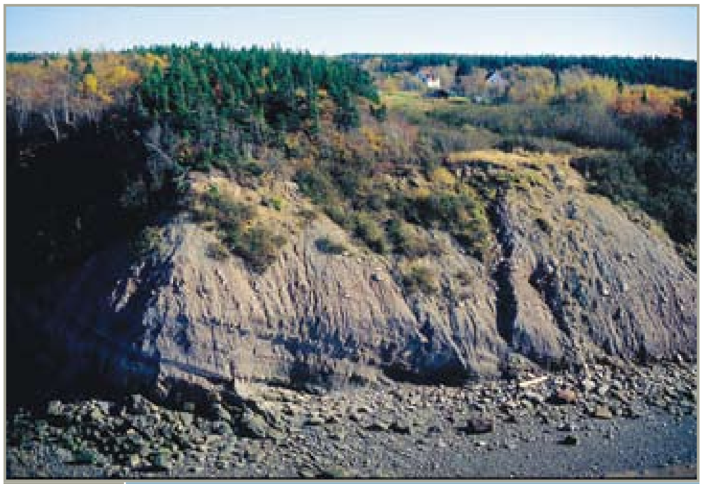


Figure 91 The classic exposure of glacial till, south of MacCarron's River, overlying the Quaternary wave-cut platform.

The uniqueness of the Joggins Fossil Cliffs is derived in large part from the preservation of terrestrial fossils, which are comparatively rare in the fossil record, and their preservation *in situ*, which is even rarer in nature.[31] Fossil preservation of plants varies from casts of entire tree trunks preserved to remarkable heights of seven metres or greater[15,32] to the level of cellular preservation,[33] and similarly in animals from disassembled but complete tetrapod skeletons to skeletons completely articulated in three dimensions.[34]

These ranges in preservation reflect the wide spectrum of environmental conditions that exist in terrestrial ecosystems such as that recorded at the Joggins Fossil Cliffs. Although individually disassembled, the tetrapod skeletons of the hollow tree fauna meet the paleontological classification of Lagerstätten (for extraordinary fossil richness).[35] Even though the articulated skeletons of conservation Lagerstätten are a preservational phenomenon predominantly of

Figure 92a ***The drowned Holocene forest at Lusby's Marsh, Amherst Head, inundated by rising sea level.***

Figure 92b ***Artist depiction of the Coal Age forest (Judi Pennanen, from*** **The Last Billion Years*****).***

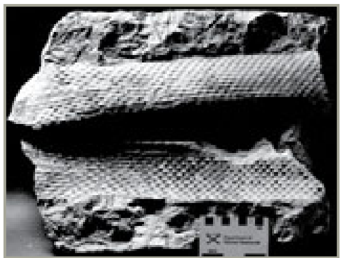


Figure 93a Mould and cast of the lycopsid genus *Sigillaria*.

Figure 93b Cellular preservation of *Mesoxylon* wood within a cordaitalean stem.

Figure 93c Trackways of terrestrial vertebrates.

Figure 93d Articulated skull of *Dendrerpeton acadianum*.

the marine realm,[36] examples at this fine level of preservation do occur in the terrestrial record at Joggins (see Section 3.C).[15,34]

Question 10. Do the fossils yielded provide an understanding of the conservation status of contemporary taxa and/or communities (i.e., how relevant is the site in documenting the consequences to modern biota of gradual change through time)?

The geological record at Joggins reveals the terrestrial ecology of the "Coal Age" world at scales that include landscape, community, and even guild. Landscape evolution from dryland[37] to wetland[15] environments provides instruction into responses to, and consequences of, global change in the modern world. Significantly, the Pennsylvanian Subsystem records the last "Icehouse" period of earth history previous to our own.[38] The outstanding ecological context provided at Joggins has permitted identification of the earliest documented hollow tree guild,[35,39] which persists today in all forested biomes, as an ancient example of ecological persistence and adaptation of co-evolving animal and plant communities.[15,35]

The Joggins Fossil Cliffs were chosen by Charles Darwin in Chapter Nine of *The Origin of Species*[40] to illustrate simultaneously the persistence of fossil forest communities and the inherent incompleteness of the earth's fossil record. The apparent resilience of communities at the scale of hundreds of thousands to millions of years in the pre-human "Icehouse" world provides a stark contrast to rapid changes in global communities recorded at present, pointing to the significant impact of human activity on global ecosystems (see Section 2.B (i), and Calder, in press, Appendix K).[41]

3.C (ii) Fossil–Site Evaluation Criteria Recommended to the IUCN by R.T. Wells (2006)[2]

Recommendation 1: Choose sites that contain well-preserved fossil accumulations of high species diversity which in combination best document the story and environmental change through time.

The fossil record of Joggins represents the most complete representation of terrestrial "Coal Age" biodiversity on earth.[5,10,20] This window of geologic time records evolution in the tropics from dryland to wetland landscapes, and effects of the waxing and waning of the southern hemisphere (Gondwanan) icecap, mediated by global change.[42,43] (See Comparative Analysis, Appendix D and Fossil Record of Biodiversity, Tables 2.1-2.4.)

Recommendation 2: The "events" to be represented in the history of life should, where possible, encompass the iconography of a tree of life not a ladder of progress.

While this recommendation applies to an indicative list as a whole, it can also be applied to the Joggins Fossil Cliffs as an individual site, where the history of life records seminal evolutionary events in diverse lineages within the "Coal Age" ecosystem.[11] For instance, a diversity of accompanying tetrapod lineages recording evolutionary intermediaries between amphibians and reptiles occur simultaneously with the first recorded appearance of the amniotes, the group that includes reptiles, birds and mammals.[8,9] The fossil record of Joggins records not only the divergence of amniotes from more primitive tetrapods, but also the initial and most important division of amniotes into the clades giving rise to modern reptiles, and those in turn which gave rise to mammals (see Evolutionary Significance of Joggins by Dr. R.L. Carroll, Section 3.C (v)).

Recommendation 3: Choose fossil Lagerstätten and make provision for expanding the list or substituting sites/fossils to better tell any chapter of the story.

Lagerstätten is a term that refers to exceptional preservation of fossils: individual fossil specimens that are exceptionally well-preserved (conservation-Lagerstätten); sedimenatry horizons with a rich concentration of fossils (concentration-Lagerstätten); and fossils that possess exceptional ecological integrity (eco-Lagerstätten).[5] Although all three types occur in the sedimentary succession exposed along the 14.7-kilometre nominated property, Joggins has the most outstanding examples in the world of concentration and eco- Lagerstätten of the terrestrial "Coal Age" world.

Conditions that favour Lagerstätten occur primarily in the marine or aquatic realm.[36] As stated under Question 9 (Section 3.A (i)), however, the uniqueness of Joggins derives in large part from the preservation of terrestrial fossils, which are comparatively rare in the fossil record. Although Recommendation 3 thus favours sites with a predominantly marine concentration, the rarity, quality, and breadth of the Joggins collection do yield both concentration Lagerstätten and conservation Lagerstätten, and of the more rare terrestrial fossils.

The range of preservation at Joggins reflects the wide range of environmental conditions that exist in terrestrial ecosystems. Although individually disassembled, the tetrapod skeletons of the hollow tree fauna constitute a concentration Lagerstätten. The articulated skeletons of conservation Lagerstätten are a preservational phenomenon predominantly of the marine realm,[36]

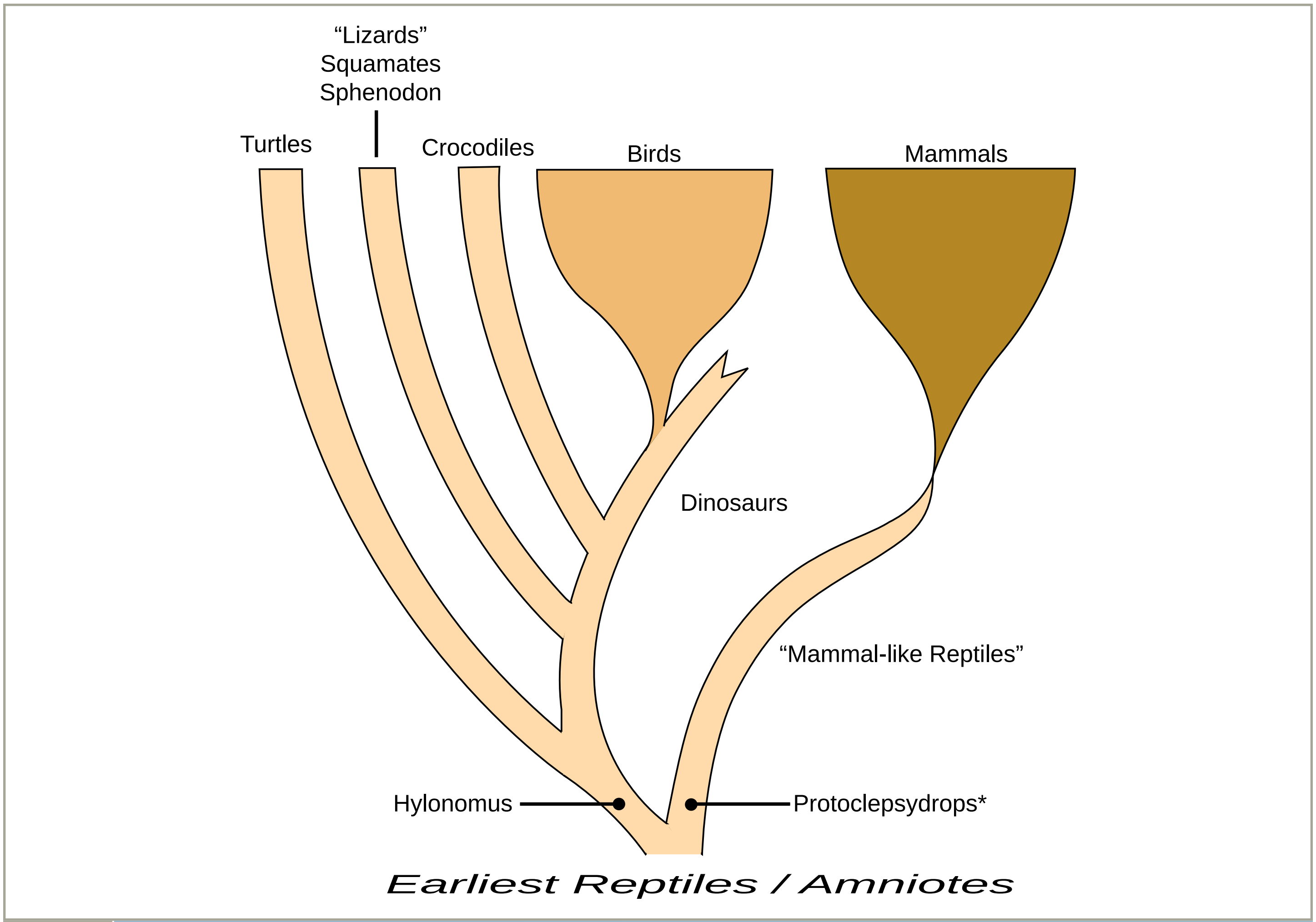


Figure 94 *The amniote tree showing the relationships of reptiles, birds and mammals in relationship to the earliest reptile, Hylonomus (*and equivocally Protoclepsydrops), recorded from the fossil record of Joggins (modified from Carroll, 1988).*

and yet examples at this fine level of preservation do occur in the terrestrial record at Joggins.[15,34] Within a terrestrial context, the hollow tree fauna[37] represent concentration Lagerstätten, recent tetrapod discoveries[34] constitute conservation Lagerstätten, and forests and tree fauna together are examples of eco-Lagerstätten.[5,35]

Sir William Dawson, pioneer of terrestrial paleoecology at Joggins, recognized the value of the ecological context accorded the fossil record when he declared in a letter to Sir Charles Lyell that it was far better to study fossils "as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum."[95]

Joggins has long been recognized as the quintessential locality for the Pennsylvanian "Coal Age" chapter of the history of life[12] and is the most important site for studying the fossil record in its environmental context.[5,18] The outcome of the comparative analysis of Falcon-Lang is for Joggins to replace Mazon Creek on the list of indicative fossil sites. Provision for employing the concept of biomes, as advocated in the Global Strategy[23], and for recognizing both marine and terrestrial realms, could be adopted in future revision to an indicative list, as discussed under Question 4, above (see Comparative Analysis, Appendix D).

Recommendation 4: Separate Precambrian history from Phanerozoic history (the roots from the upper branches of the evolutionary tree respectively), to present Precambrian history in terms of major events, such as the origin of life, multicellularity, etc. and to present Phanerozoic history in terms of communities and/or stages in the evolution of major groups.

As a Phanerozoic site, the Joggins Fossil Cliffs encompass the entire wetland forest ecosystem, representing Pennsylvanian biodiversity at the full spectrum of ecological levels: guild, community and landscape.[15,28] Hollow trees of the wetlands and waterholes of the seasonal drylands represent the earliest known examples of these ecological niches and guilds.[35,44] The communities at Joggins include the earliest representatives of various terrestrial invertebrate lineages (including the first land snails), and vertebrate lineages (including the earliest amniotes).[8,9]

One of the most significant events in the history of life was the origin of reptiles (or more generally amniotes) that achieved the capacity to reproduce on land. Modern amniotes—the reptiles, birds, and mammals—have dominated the terrestrial environment for the past 300 million years, but their ancestry remains enigmatic.

No other locality in the world has provided as much knowledge of the nature of early amniotes, or more informative specimens for linking them to more primitive groups of Paleozoic tetrapods (Section 3.C (v)).[11]

Other significant events in the history of life are recorded in the fossil record of Joggins, including the first appearance of land snails (the genus *Dendropupa*),[45] which persist today, and the last appearance of the huge bivalve clam *Archanodon*, which may prove to be the missing link to the extant unionids.[46]

Figure 95

Specimen of the earliest land snail, *Dendropupa vetusta*.

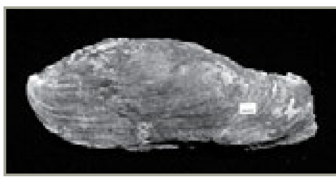


Figure 96

The large unionid clam, *Archanodon westoni*.

Recommendation 5: All published Precambrian fossil sites should be reviewed by an expert panel to select those worthy of evaluation for Heritage listing.

As Joggins is not a 'Precambrian' site, this recommendation does not apply.

Recommendation 6: Phanerozoic sites should be chosen so as to be representative in time and space of both community structure and selected phylogenetic lineages.

Ecological structures from small to large scale (guild, community and landscape) are all preserved in their environmental context.[5,15] All known trophic pathways of the terrestrial Pennsylvanian food chain are represented at the Joggins Fossil Cliffs. The nominated property is considered to be the most important terrestrial tetrapod site of this time,[11,18] and includes the earliest known reptiles (earliest amniotes)[7,8,9] (see Carroll, 1970,1994; and Reisz, 1997, Appendix K).

Recommendation 7: Any fossil Lagerstätten chosen from the Phanerozoic should wherever possible be of high diversity and include significant invertebrate as well as vertebrate assemblages.

The fossil record of Joggins comprises equally diverse representation of vertebrate and invertebrate faunal assemblages from both the terrestrial and aquatic realms, as well as representatives of the key terrestrial plant groups of the "Coal Age" ecosystem.[10] Their preservation *in situ* provides rare ecological context to the fossil record[5,20,36] (see Section 2.A, Tables 2.1-2.4).

Recommendation 8: A condition for granting World Heritage status should make provision for curation, study and display of any site/fossils.

A new interpretation and research Centre is currently under development for the site and will be permanently staffed with facilities for collections management and visiting scientists. This Centre is complemented by curatorial and preparation facilities of the Nova Scotia Museum, Halifax and Fundy Geological Museum, Parrsboro, Nova Scotia (see Sections 5.C and 5.I (i)).

Recommendation 9: Specialists in the major Phanerozoic groups and time periods should be consulted to refine and update the indicative list.

This was a recommendation to the IUCN and World Heritage Committee by Wells[2] that applies to the entire fossil record and so is beyond the scope of a single nomination. Should the IUCN undertake a review in the future of the recommendations regarding the evaluation of fossil sites, however, provision could be made for the global representation of biomes and the inclusion of both marine and terrestrial realms.

Figure 97 **Fundy Geological Museum, Parrsboro, Nova Scotia.**

3.C (iii) Comparative Analysis of Pennsylvanian Sites

A comparative analysis of globally significant fossil sites of the Pennsylvanian was undertaken in a comprehensive, independent study by Dr. H.J. Falcon-Lang, Bristol University, U.K.,[20] appended in full under separate cover (Appendix D). This comparative analysis was undertaken during the process of reviewing the Tentative List for Canada.

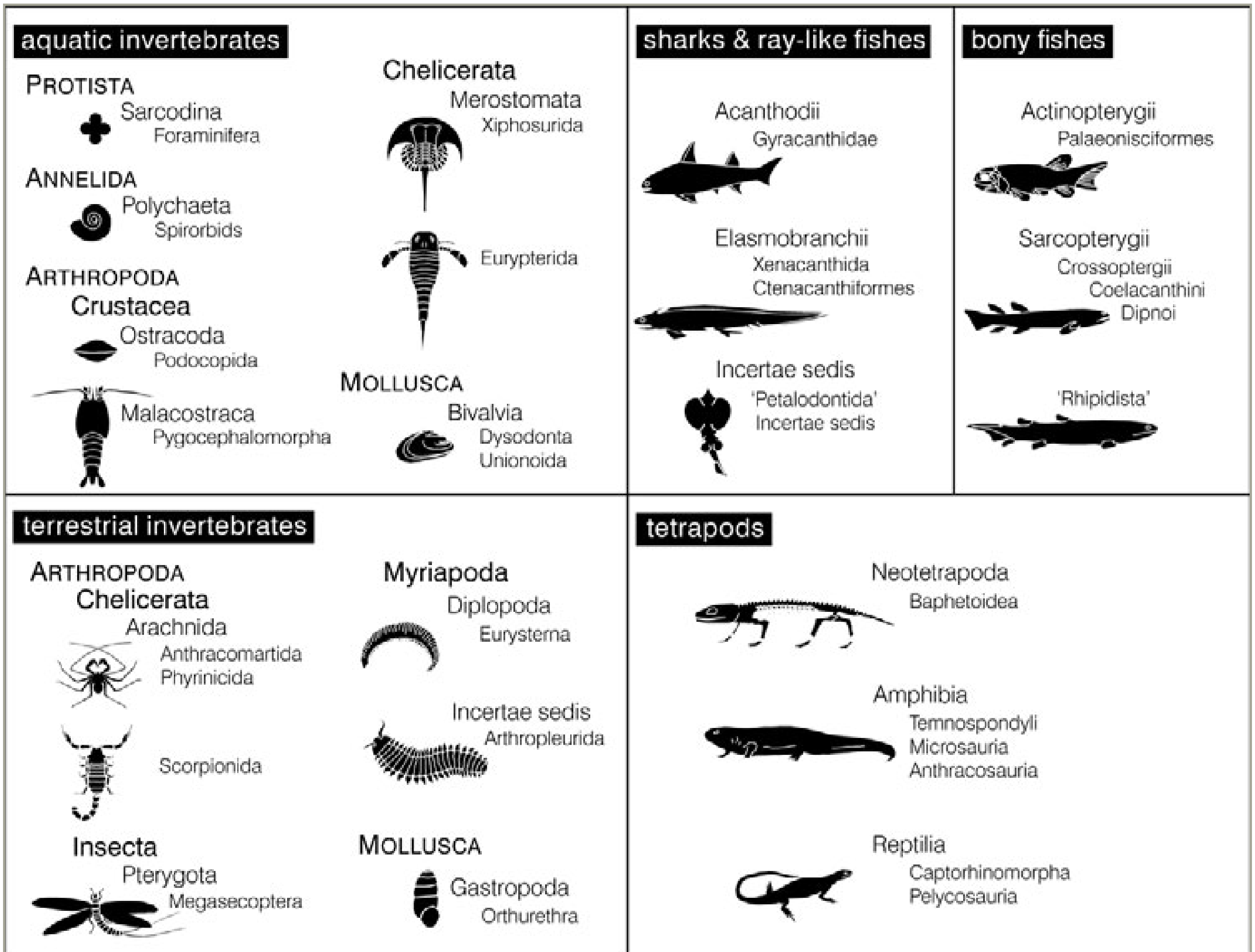


Figure 98 *The fossil record of biodiversity of the tropical "Coal Age" ecosystem at Joggins.*

All sites in the comparative study that were short-listed for comparative evaluation met two prerequisites. These prerequisites were that the site must contain:

(1) body-fossil representatives of each of the three major macrofossil groups, namely vascular plants, invertebrate animals, and vertebrate animals; and
(2) either a major accumulation of tetrapod remains (amphibians and/or reptiles) or a major example of upright coal-age trees (i.e., multiple fossil forests).

Joggins meets both prerequisite factors for short-listing of sites. The fossil record of Joggins comprises near equal representation of the three major macrofossil groups (vascular plants, invertebrates and vertebrates). The nominated property comprises both major accumulations of tetrapod remains (the greatest number of terrestrial amphibian and the earliest reptilian lineages) and a major example of upright "Coal Age" trees (the greatest number of fossil forest horizons, numbering at least sixty). Short-listed sites were evaluated based on three categories and twelve benchmarks (Table 3.1).

Of the nine short-listed sites, Joggins ranks first in terms of seven benchmarks including:

- fossil forest abundance;
- size of the geological window;
- range of major depositional environments (fossil habitats) represented;
- paleobiological representativeness;
- quality of fossil preservation;
- permanence of site; and
- probability of continued discoveries.

These benchmarks were derived from the Questions and Recommendations of the IUCN for evaluation of fossil sites. Overall, Joggins was found to rank first among the short-listed sites, followed by the Sydney coalfield, Nova Scotia, Canada and the Freeport coalfield (including the Linton and Five Points localities), Illinois, United States of America.

It is noteworthy that the Joggins Fossil Cliffs attained first position in spite of the fact that the methodology of Falcon-Lang did not consider the pivotal evolutionary milestone of the earliest reptiles and putative amniotes, which is recorded only at Joggins. Also not included in the comparative analysis were issues of conservation and site integrity, and in each Joggins excels (see State Of Conservation of Similar Properties, Section 3.C (iv) and Table 3.2). The outcome of Joggins as the top ranking site in spite of these exclusions underscores its worthiness as the most outstanding example in the world of the Pennsylvanian "Coal Age."

Table 3.1 **Summary of Results of the Comparative Analysis of Short-Listed Sites of the Pennsylvanian "Coal Age" (after Falcon-Lang, 2002)**

	Comparative Study Benchmark	1st Ranking	2nd Ranking	3rd Ranking
CATEGORY 1. FOSSIL RECORD OF BIODIVERSITY.				
1	Diversity at phylum /class taxonomic level	Mazon Creek	Sydney	Joggins & Freeport
2	Species richness	Mazon Creek	Sydney	Joggins
3	Tetrapod specimen abundance	Freeport	Nýřany	Joggins
4	Fossil forest abundance	Joggins	Sydney	Mary Lee
5	Evolutionary significance at family level	Mazon Creek	Nýřany	Freeport
CATEGORY 2. NATURE, QUALITY AND VARIABILITY OF FOSSIL ARCHIVE.				
6	Size of geological window	Joggins	Sydney & Durham	
7	Range of major depositional environments (fossil habitats) represented	Joggins & Sydney		Freeport, Durham, Nýřany, Yorkshire, Leinster & Mary Lee
8	Paleobiological representativeness	Joggins & Sydney		Freeport
9	Quality of fossil preservation	Joggins, Freeport, Mazon Creek, Durham & Leinster		
CATEGORY 3. PERMANENCE (INTEGRITY) AND SCIENTIFIC IMPACT OF SITE.				
10	Degree of site investigation	Mazon Creek	Joggins	Freeport
11	Permanence of site	Joggins & Sydney		Durham
12	Probability of continued discoveries	Joggins & Sydney		Mazon Creek
OVERALL RANKING		**Joggins**	Sydney	Freeport

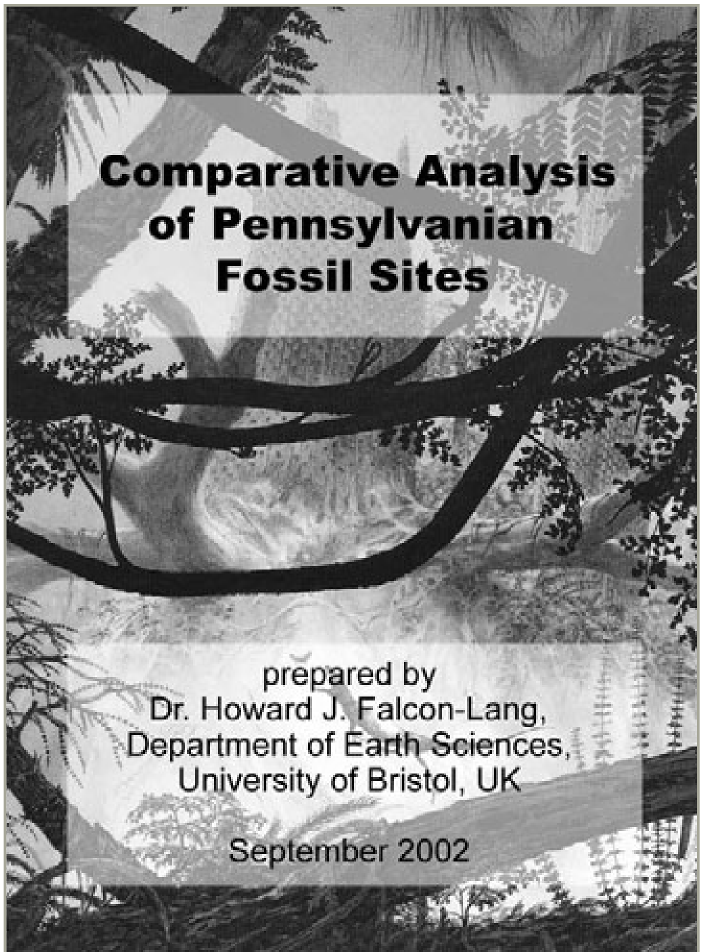


Figure 99 *The comparative study.*

The Wells study prepared for IUCN in 1996 identified Mazon Creek, Illinois, USA, as indicative of the type of site which may be considered as a World Heritage nomination to represent the Carboniferous System. Subsequently, the Falcon-Lang comparative assessment of Pennsylvanian fossil sites concluded that Joggins ranks highest. Mazon Creek, by comparison, did not rank within the top three sites. In fact, it did not meet the prerequisites for inclusion in the assessment, but was included on the basis of the conclusions of the Wells study. The strength of Mazon Creek lies in the exquisite condition of fossils and in the richness of species, both of which are a result of the preservation of the fossils in the marine realm. Its marine setting is problematic, however, in that it provides virtually no ecological context to the terrestrial realm that imparts the iconic elements of the "Coal Age" ecosystem: terrestrial fossils that occur at Mazon Creek have been transported from their original setting and so have lost their ecological integrity. These geological issues aside, a comprehensive assessment of Pennsylvania fossil sites (see Table 3.1) has shown that Mazon Creek lacks integrity both in the environmental context of the terrestrial fossil record, and as a site that is now largely inaccessible. The integrity of Mazon Creek (especially its contextual value) itself is now all but lost due to mine reclamation and nuclear power generation at the site (Table 3.2).

Terrestrial sites of great richness such as Joggins are rare in comparison to the marine realm, from whence 90% of the fossil record derives.[36] This extreme bias of the fossil record in favour of the marine realm is a consideration in the assessment of fossil sites that is not well reflected in attempts at drawing representative lists for World Heritage consideration. The emphasis on choosing fossil Lagerstätten (Recommendation 3 of Wells[2]) is perhaps the most striking example of this; as such a preservational condition is a phenomenon that is virtually exclusive to the marine realm.[36] The difference inherent between the terrestrial and aquatic realms was acknowledged in the decision to inscribe the marine fossil locality of Monte San Giorgio (2003), Switzerland in addition to the superlative terrestrial Triassic site of Ischigualasto-Talampaya, Argentina (2000). Additionally, Falcon-Lang and Calder[4] called for reconsideration of the exclusivity of one site to represent the world at any one period in its history in favour of the biome concept for the terrestrial record of the Phanerozoic Era.

3.C (iv) State of Conservation of Similar Properties

Joggins is the sole site that has a state of conservation equal to or exceeding those inscribed on the list of World Heritage (Table 3.2). With the exception of the Joggins Fossil Cliffs and the Sydney coalfield, all other sites meeting short-list requirements on scientific grounds are now wholly or partly inaccessible, reflecting their connection to underground or open-pit coal mines. Of the nine sites qualifying for the comparative analysis of Falcon-Lang (2002), only Joggins and Sydney are protected under legislation, with controlled collecting, which at Joggins is managed by dedicated staff and on-site facilities.

Table 3.2 State of Conservation of Similar Properties: Nine Sites in Comparative Analysis and Seven Sites on World Heritage List (Carboniferous Sites Status Derived from Falcon-Lang, 2002, and Subsequent Input from Dr. Andrew Milner, UK and Dr. Robert Gastaldo, USA)

Site	Protected designation	Controlled collection	Current status
PENNSYLVANIAN SITES IN COMPARATIVE ANALYSIS			
Northumberland ("Durham": Newsham), UK	No	No	source bed (roof of Low Main Seam, Newsham Colliery) active late 19th century; mine abandoned 1926, spoil tip exhausted by 1970.
Freeport (Linton, Five Points), USA	No	No	former coal mine waste; some collecting at Linton up to 1980's.
Leinster (Jarrow), Eire	No	No	active in 19th century; spoil tip survives. EC-funded visitor/cultural centre possible.
Mary Lee, USA	No	No	open-pit mine sites mainly reclaimed/inaccessible
Mazon Creek, USA	No	No	open-pit mines in-filled; most productive site now used as nuclear reactor cooling pond; collecting at site now limited to remaining coal mine waste
Nýřany, Czech Republic	n/a	n/a	*source bed (Plattelkohle) inaccessible since cessation of coal mining; last collecting from tips in 1970s
Sydney, Canada	In part	Yes	expansive coastal cliffs accessible; active coastal erosion
Yorkshire, UK	No	No	open-pit mine sites, some now inaccessible
Joggins, Canada	Yes	Yes	expansive cliff section accessible; active coastal erosion
WORLD HERITAGE SITES			
Australian Fossil Mammal Sites (Riversleigh/ Naracoorte)	Yes	Yes	cave sites
Burgess Shale WHS (in Canadian Rocky Mountain Parks WHS)	Yes	Yes	stable mountainside exposure; excavation employed by researchers
Dinosaur Provincial Park	Yes	Yes	badlands exposure with moderate erosion; excavation employed by researchers
Dorset & East Devon Coast	Yes	No*	expansive coastal cliffs accessible; active coastal erosion (*most commercial collectors signed code of practice with national park authority)
Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai, and Environs	Yes	Yes	inland sites of moderate erosion
Ischigualasto-Talampaya Natural Parks	Yes	Yes	expansive desert; badlands exposure
Lake Turkana National Parks	Yes	Yes	drylands exposure with moderate erosion: excavation employed by researchers
Grube Messel Pit	Yes	Yes	former oil shale open-pit spared from planned use as a waste facility
Miguasha National Park	Yes	Yes	cliff section accessible; moderate coastal erosion, excavation employed
Monte San Giorgio	Yes	Yes	stable hill-slope requiring excavation by researchers
Wadi Al-Hitan (Whale Valley)	Yes	Yes	desert site, excavation employed

3.C (v)

Evolutionary Significance of the Joggins Fossil Cliffs

The following summary of the evolutionary significance of the nominated property has been provided for this nomination by Dr. Robert L. Carroll (2006), Redpath Museum, McGill University, author of the classic textbook *Vertebrate Paleontology and Evolution*.

One of the most significant events in the history of life was the origin of reptiles (or more generally amniotes) that achieved the capacity to reproduce on land without the necessity for an aquatic larval stage such as characterizes amphibians. Modern amniotes, the reptiles, birds, and mammals, have dominated the terrestrial environment for the past 300 million years, but their ancestry remains enigmatic. Unfortunately, the fossil record of early amniotes is very limited because fully terrestrial animals are rare in Paleozoic deposits. Fish and typically aquatic amphibians were more commonly preserved because they lived in environments where their remains were quickly covered with water borne sediments, and so protected from scavengers and microbial decay. Primitive amniotes, in contrast, were highly terrestrial animals, resembling modern lizards that rarely ventured into the water, and so were much less likely to be preserved in typical aquatic deposits.

The Joggins deposit, along the shore of the Bay of Fundy in Nova Scotia, is unique in the preservation of a succession of forests, dominated by the tree-sized lycopod *Sigillaria*, with their trunks preserved in an upright position. The exceptional nature of these fossil beds was recognized as early as the mid-nineteenth century, when it was studied by Charles Lyell, the father of modern geology, and William Dawson, principal of McGill University and a pioneer in the study of paleontology and other aspects of geology in Canada. They were the first to discover, within these tree stumps, the bones of terrestrial amphibians and those of the oldest known reptiles. Despite more than 150 years of subsequent field work, no more ancient amniotes have been discovered anywhere in the world.

Dawson explained the occurrence of vertebrates within the tree trunks in the following words:

> "A forest or grove of large ribbed trees known as Sigillariae, was either submerged by subsidence, or, growing on low ground, was invaded with the muddy waters of an inundation, or successive inundations, so that the trunks were buried to a depth of several feet. The projecting tops having been removed by sub-aerial decay, the buried stumps became hollow, while their hard outer bark remained intact. They thus become hollow cylinders in a vertical position and open at top. The surface having become dry land, covered with vegetation, was haunted by small quadrupeds and other land animals, which from time to time fell into the open holes, in some cases nine feet deep, and could not extricate themselves."
>
> Dawson, J.W., 1891. On the mode of occurrence of remains of land animals in erect trees at South Joggins, Nova Scotia. Transactions of the Royal Society of Canada, 9, 127-128.

This has been accepted historically as the most probable explanation for the presence of terrestrial vertebrates in the Joggins stumps.

Hundreds of vertebrates have been found in the Joggins tree stumps, belonging to 11 genera, including scores of specimens of the large labyrinthodont, *Dendrerpeton*, less commonly the embolomere *Calligenethlon*, and numerous species of an enigmatic group termed microsaurs. In contrast with most other Carboniferous deposits, all of these animals were primarily terrestrial in having well-developed limbs, and no evidence of lateral line grooves in the skull, which are associated with response to water-borne vibrations. The most important species, biologically, is *Hylonomus lyelli*, known from numerous specimens including nearly every bone in the body. From the configuration of the skull roof, palate, and vertebrae to the nature of the wrist, ankle, and number of toe bones, *Hylonomus* closely resembles not only later Paleozoic amniotes, but even modern lizards.

Another important aspect of *Hylonomus* is its relatively small size, indicating that it hatched from eggs not much larger than those laid on land by some modern salamanders (in the family Plethodontidae), which do not have an aquatic larval stage. *Hylonomus* thus appears as an ideal model for understanding the transition between amphibians and amniotes, as well as being close to the ancestry of all later reptiles, birds, and mammals. Other, less complete specimens suggest the presence of a second amniote genus at Joggins, *Protoclepsydrops*, which may represent the lineage that subsequently gave rise to mammals.

No other locality in the world has provided as much knowledge of the nature of early amniotes, or more informative specimens for linking them to more primitive groups of Paleozoic tetrapods.

While the most critical fossils of *Hylonomus* were found in the nineteenth century, other specimens of this and other highly important species, including embolomeres, temnospondyls, and microsaurs, continue to be collected by professional paleontologists and educated amateurs. A great many scientific papers have been published on fossils from Joggins during the past 30 years and numerous recently collected specimens, some of genera previously unknown at Joggins, are currently under study.

It is clear that many more fossils could be collected at Joggins, but its relatively great distance from any institutions where there are programs for the study of Carboniferous vertebrates, and the physical problems of collecting from the upright trees have limited systematic collection, such as was carried out in Dawson's day. Because of the continuous exposure of the Joggins cliffs to the forces of the highest tides in the world, as well as strong storms from the sea, the buried forests are continually being exposed and then destroyed. A great advantage of having this shoreline declared a UNESCO World Heritage Site would be the more or less constant attention to the exposure and recovery of fossil-bearing trees as they are eroded from the cliffs. This would enable a continuous examination of the contents of nearly all the trees, which would otherwise be quickly broken up and washed into the sea.

Continuing collection and research of the trees at the Joggins site would also provide a dramatic means of public education into the history of the earth, the nature of geological processes, and the evolution of life. The upright forests at Joggins are a great scientific resource that has been far too long under utilized.

Figure 100 ***Diorama of Coal Age Joggins, from the Joggins Fossil Centre, by Doug Henderson.***

3.D INTEGRITY

Joggins is exceptional in that it contains all the key interdependent elements of the terrestrial "Coal Age" preserved in their natural relationships. This combination of key elements located in their natural context (including dependency) together expresses its outstanding universal value and so meets the conditions of integrity (Paragraphs 88 and 93) for properties proposed for inscription under "criterion viii" of the UNESCO Operational Guidelines for the Implementation of the World Heritage Convention (2005). For a paleontological site, this means that the property demonstrates paleoecological integrity, with fossils preserved in their ecological and environmental context.[5,19,20,47]

Well-preserved fossils usually are found preserved in rocks from the aquatic realm, including organisms transported there from the terrestrial realm[34] with loss of ecological integrity. Paleoecological integrity therefore is rare for terrestrial fossil sites,[29] and exceedingly so for the pre-Quaternary record in the absence of frozen or mummified fossils.[34] The uniqueness of the Joggins Fossil Cliffs is exemplified by the many stands of fossil lycopsid trees,[15,44] the ecological framework of the Pennsylvanian coal swamps,[48] standing upright in their positions of growth within the primeval wetlands.[15,31] Within fire-scarred examples of these once hollow trees are found the world's richest collection of terrestrial vertebrates of this antiquity, providing not only the earliest record of the amniote lineage, but also eloquent testimony to the origins of the hollow tree guild of terrestrial ecology that persists today.[35] In recognition of this exceptional ecological integrity, Joggins has been described as an eco-Lagerstätten.[5]

Figure 101 *Trackway of the largest terrestrial invertebrate in earth history, Arthropleura.*

Additionally, Joggins records a spectrum of environments (habitats) ranging from seasonal drylands through wetlands, and intervals of open water.[47] The aquatic record at Joggins may record global responses to climate change, specifically waxing and waning of the south polar ice cap over Gondwana (present day South America, Africa, Australia, Antarctica and India) with its attendant change in global sea level.[42,43]

The 14.7-kilometre long coastal section proposed at Joggins has been selected to ensure the complete representation of the "Coal Measures," and to ensure that older strata are protected in the

Figure 102 *The grand succession.*

event of future discoveries that would then become the earliest examples of life now known from the "Classic Section," which itself spans approximately 3 kilometres. In essence, this expanded geological window accords the property a strong geological buffer. The property includes all elements of the natural coastal exposures of the geological formations, including cliffs and intertidal reefs.

Currently the property does not suffer adverse effects of development. *Land Use Bylaws* (Appendix G:4) have been created with the involvement of the local community to provide the property a landward buffer zone against future adverse effects of development. These zoning bylaws have been enacted with the express purpose of ensuring conservation of the integrity of the property from the perspective of World Heritage. The buffer and the property itself have been designated to keep pace in perpetuity with the natural processes of erosion, even in the face of accelerated climate change.

4 State of Conservation and Factors Affecting the Property

"...where the delicate herbage of a former world is now transmuted in stone." - Abraham Gesner (1836).

Figure 103 The section, looking south from Coal Mine Point towards Ragged Reef.

4.A PRESENT STATE OF CONSERVATION

The robust geological environment that accords this superlative section of coastal cliffs and active shoreline areas much of its outstanding character discourages intrusion by human development. At the same time, the active erosion by the world's highest tides that results in ongoing exposure of new fossils requires active stewardship of the fossil heritage.

The dormant remains of industrial and transportation infrastructure from the area's mining history persist in a few locations within the nominated property, but current conservation legislation and planning bylaws restrict future development of the property by vesting all development decisions with the Joggins Fossil Institute and the Government of Nova Scotia. All such decisions will support the World Heritage Convention. With development severely restricted by topography, legislation and ownership, and a low likelihood of natural disaster (Section 4.B (iii)), the most significant factor that has potential to adversely affect the fossil resource is visitor pressure (e.g., unauthorized fossil collecting). This section describes the present state of conservation for the fossil resource and the property, as well as the environmental and human factors that currently and potentially affect them.

State of Conservation

As detailed in Section 3, several factors contribute to the excellent state of conservation for the Joggins Fossil Cliffs, protecting the property with physical attributes and legal as well as procedural policies that will facilitate recurring present and future fossil discoveries. These factors include:

a) Legal protection from future impacts on the fossil beds both on the nominated property and under adjacent lands (see Section 5.B).
b) Given the 30-kilometre landward extent of the fossil beds, new fossils are predicted to continue to emerge for 120,000 years, based on current and historic rates of erosion.[1] Such a forecasted renewal is unparalleled in the fossil record of inscribed World Heritage Sites.
c) Minimal threat from earthquakes and tsunami (Section 4.B (iii)).
d) Coastal erosion continues to unearth new fossils at Joggins. As discussed below, a possible increase in storm surges resulting from climate change may actually increase the fossil yield.
e) Joggins is unique in that it contains all the key interdependent elements of the terrestrial "Coal Age" preserved in their natural relationships and thus demonstrates paleontological integrity. The ongoing exposure of these fossils, preserved *in situ* in a condition and environment similar to when others of their type were first studied and classified by Sir Charles Lyell and others, permits a continuity of research rarely possible.
f) International, national and provincial museums house fossils from Joggins (Section 3.C (i): Question 7).
g) The new Joggins Fossil Centre, an interpretation and research facility being built at the site in support of World Heritage values, is currently under development to complement the nominated property and will include facilities for collections management and visiting scientists. This centre will be supported through curatorial and preparation facilities of the Nova Scotia Museum, in the provincial capital of Halifax, and of the Fundy Geological Museum in nearby Parrsboro.

h) Provincial legislation overlaps to doubly protect fossils found at the site and preserved inland, beneath the surface. See Section 5.B for detailed descriptions of the *Beaches Act* and the *Special Places Protection Act* (included in Appendix G).
i) *Land use bylaws* (included in Appendix G) have been developed with the involvement of the local community to provide the property a buffer zone against adverse effects of nearby development.
j) Section 3, Table 3.2 provides comparison of the state of conservation with similar properties.
k) Section 5 describes conservation policies, including training in conservation and management techniques.

In addition to the well-preserved, protected and still-emerging fossils, the area's nineteenth century coal mining, transportation and stone quarrying histories remain evident in a few locations. This residual infrastructure occurs within the nominated property, either on the cliff-face or foreshore or on Crown lands atop the cliffs. Past development pressures, including mining, quarrying, construction of transportation infrastructure, in addition to natural coastal processes, and to a lesser degree fossil collecting, have contributed to the present state of conservation of the property.

4.A (i) Mining and Quarrying

Mining of coal, as well as quarrying of sandstone for use as grindstones has taken place at Joggins over the course of several centuries (see Section 2.B (iv) and (v)), yet the mark of these activities on the designated property is slight. The coal beds or seams themselves have not been important sources of fossils at Joggins, whereas the associated shales, sandstones and upright fossil trees have. Current evidence of historic mining operations is restricted to three horizons along the 14.7-kilometre long expanse of coastline, representing less than one percent of the total thickness of sedimentary beds that comprise the property. Pit props from early coal mines exposed by erosion of the cliffs exist at three localities: the Fundy, Forty Brine and Joggins coal seams.

Figure 104 *Groundwater flowing from the Fundy seam, with vestiges of past mining evident.*

Figure 105 *Remnants of wharf at Lower Cove.*

With respect to grindstone quarries, only non-fossiliferous sandstones, primarily of the Boss Point Formation at Lower Cove, were deemed suitable for such use, and so these historic quarries have had virtually no effect on the fossil heritage of the section. Detailed centimetre-scale measurement of the sedimentary strata (Appendix J) within the nominated property showed no sign or effect of quarrying. Remnants of the grindstone quarry operations at Lower Cove comprise:

a) pilings of the wharf (45^{O} 43' 36" N and 64^{O} 26' 22" W);
b) abandoned grindstones on the foreshore; and
c) foundations of the mill house at the edge of the shore (45^{O} 43' 35" N and 64^{O} 26' 19" W).

4.A (ii) Transportation Infrastructure

Transportation infrastructure was constructed on the property to support historic mining and quarrying operations. This infrastructure had little impact on the fossil resources at the property and only remnants exist today.

Remnant pilings of the wharf that served as a loading facility for the Joggins ("Main") coal mine since the mid-nineteenth century exist on the shore below the new Joggins Fossil Centre that is currently under construction (45^{O} 41' 45" N and 64^{O} 27' 4" W). The landward approach to the wharf involves an historic excavation of the cliff-top known locally as "the dugway," which facilitated the transport of coal cars to and from the wharf Groundwater drains from former mine workings, now flooded, at this location.

Concrete abutments of a former trestle bridge and remnant dam exist at MacCarron's River (45^{O} 41' 5" N and 64^{O} 27' 12" W).

The Shulie Road once crossed a substantial bridge near the mouth of MacCarron's River. Between 1957 and 1964, the road was realigned and the bridge was replaced.

In more recent times, wooden access stairs were constructed by the Nova Scotia Department of Natural Resources at the mouth of Bell's Brook to facilitate foot access to the shore. These stairs have been re-built periodically due to the erosive action of the tides and winter ice.

A highway bridge and breakwater on Lower Cove Road over Little River at Lower Cove is maintained by the Nova Scotia Department of Transportation and Public Works. The bridge and road have little impact on the fossil resource as they exist in an area where the cliffs recede to low bluffs dominated by glacial till.

4.A (iii) Fossil Collecting

Over the course of scientific investigation at Joggins, access to the fossil record in the cliffs has been gained chiefly by natural processes of erosion and exposure. Excavation is limited to removal of exposed, and therefore imperilled, specimens under the authority of a Heritage Research Permit granted by the province of Nova Scotia to qualified researchers only. Joggins contrasts therefore with 'static' sites where exposure of new specimens is achieved only through excavation (see Table 3.2).

The most invasive and extensive—and scientifically important—excavation of fossils at Joggins was undertaken by J.W. Dawson in the 1870s, involving the use of explosives to expose the tetrapod-bearing fossil forest of the Lesser Reef of Coal Mine Point. Dawson's excavation resulted in the discovery of over 100 specimens of reptiles and amphibians, constituting the richest assemblage of terrestrial tetrapods from any "Coal Age" site. Today, after more than a century of exposure to the relentless tides of the Bay of Fundy, all vestiges of Dawson's excavation have been reclaimed by erosion, and fresh exposures of the famous fossil forest are in view.

Figure 106 ***Airphoto of the coal loading wharf and breakwater at the Joggins seam.***

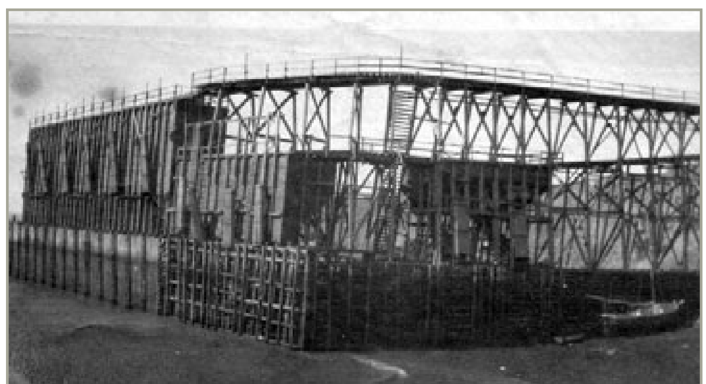


Figure 107 ***The wooden structure of the coal loading wharf at the Joggins seam, completed in 1854.***

Figure 108 ***Remnant pilings of the coal loading wharf at the Joggins seam.***

Figure 109 ***Infrastructure at "McCarrons" (MacCarron's) River, 1957.***

Figure 110 ***"McCarrons" (MacCarron's) River, 2005.***

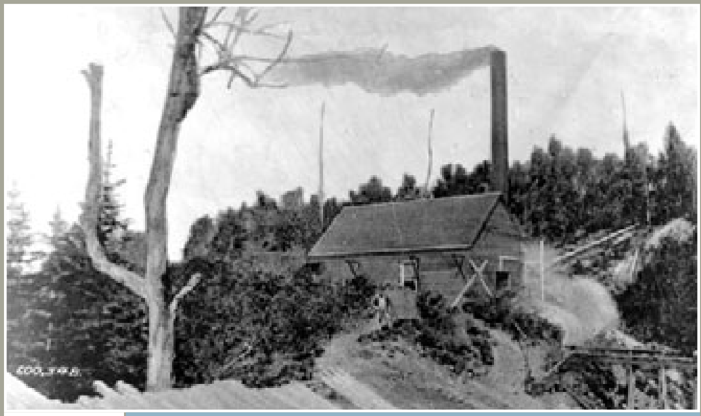


Figure 111 ***Pump station at MacCarron's River, circa 1910.***

Figure 112 ***Highway bridge over Little River at Lower Cove.***

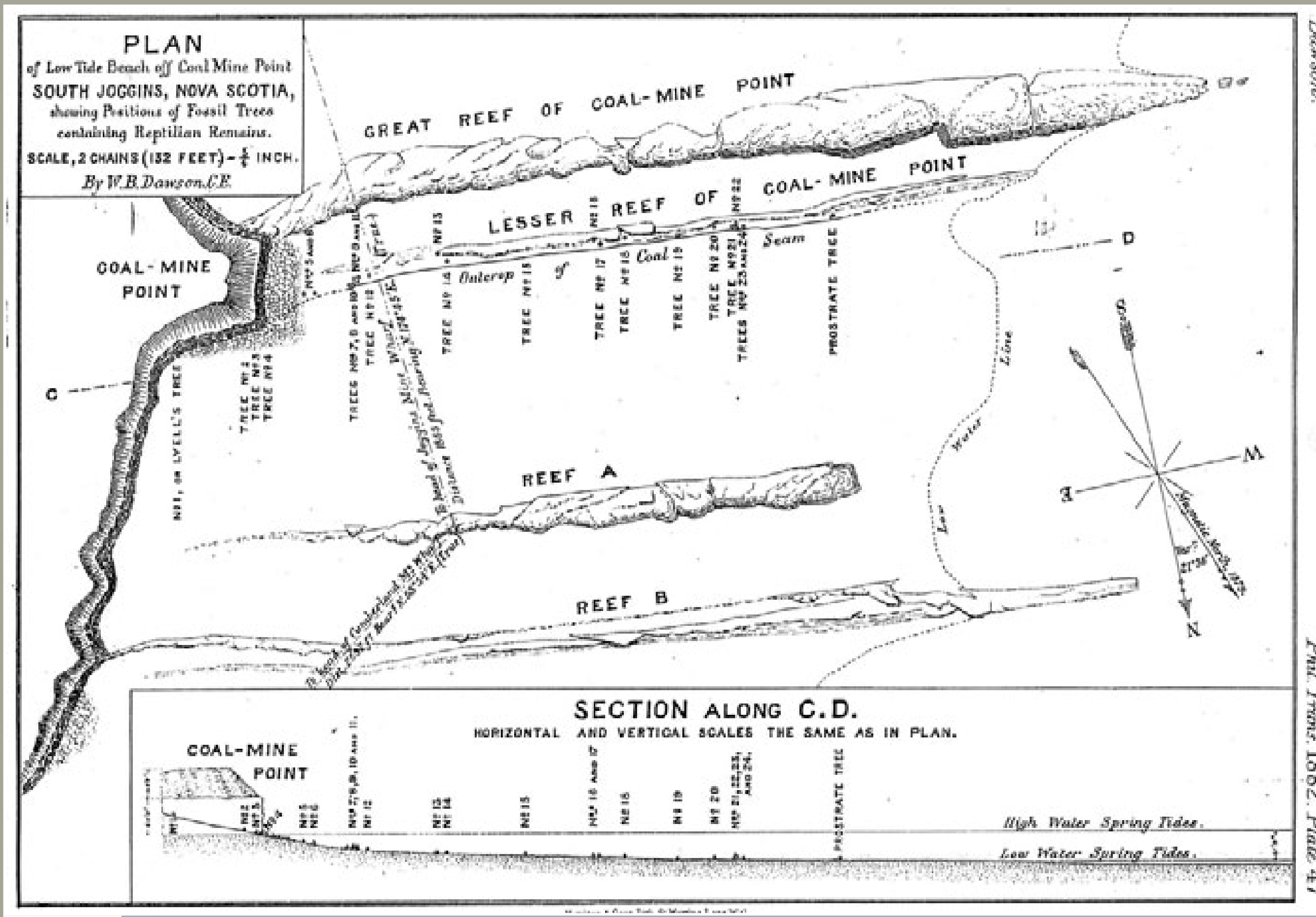


Figure 113a **Nineteenth-century map depicting site of exploration for tetrapods at Coal Mine Point, from Dawson, 1882.**

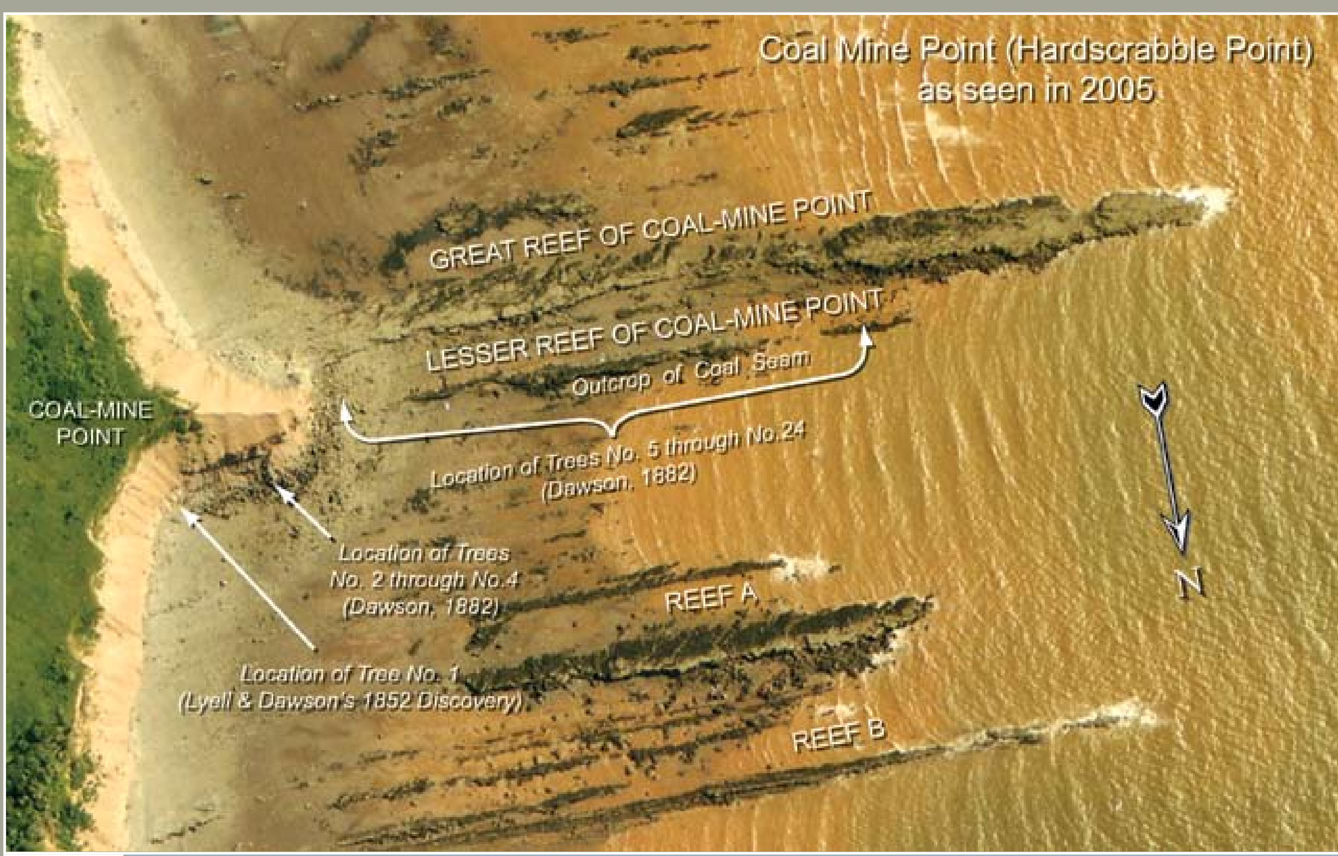


Figure 113b **Coal Mine Point as it appears today.**

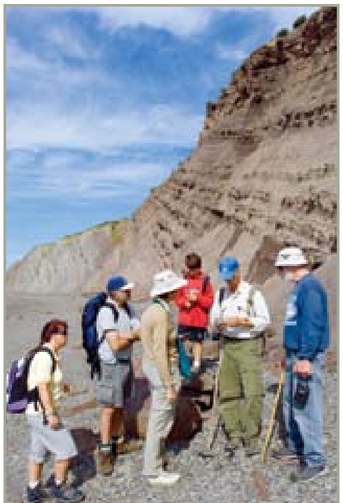


Figure 114 Interpreting the fossil record.

In 1972, the province of Nova Scotia enacted legislation (*Special Places Protection Act*) to protect paleontological and archaeological sites of significance. The *Act* was a direct response to unconstrained attempts by researchers to re-employ explosives in the search for new fossils at Joggins, a strategy that has since been shown to be unnecessary, and which is now deemed to be inappropriate.

Given the stability of the physical factors affecting the property noted below under Section 4.B, the superb state of conservation for the Joggins fossils described above is expected to persist.

4.B FACTORS AFFECTING THE PROPERTY

At present there are no significant threats to the nominated property's natural values in general, and strict protection and regulation of the fossil resource is in place. In contrast to the conservation of living systems, paleontology by its very nature involves intervention at a site, either through collecting or in the absence of erosion, excavation. In the case of the Joggins Fossil Cliffs, an active programme of supervised collecting (through potential excavation of exposed fossils and retrieving loose fossils) is required due to the actively eroding cliffs and high energy coastline. Although fossil collecting has been regulated for many years, the presence of the Joggins Fossil Centre and staff will bring a much higher level of conservation at the site. Extraction of coal for energy production has ceased, and whilst it provided additional specimens from fossil-bearing rocks immediately above the coal beds while the mines were in operation, these same beds continue to be exposed through coastal erosion.

4.B (i) Development Pressures

The nominated property comprises an area of actively eroding coastline that is largely inappropriate for development and is legally protected under multiple conservation designations and their restrictive planning policies (see Section 5.B). The lands represented by the cliff proper have virtually no potential for development. The cliff-face undergoes active erosion and is too dynamic to support infrastructure. Moreover, this active erosion and the nature of the sedimentary rock layers, renders the cliff-face unsuitable for recreational climbing purposes. On adjacent properties, most local residents have built well back from the cliffs in recognition of the threat of erosion. The beach itself is not suited to development because of the extreme tides and active surf.

The long history of mining has left virtually no economic coal resource intact adjacent to the nominated property; the thinness and quality of these coal beds is no longer suitable for mining. Nonetheless, any party who might wish to either explore or develop coal resources anywhere within Nova Scotia is subject to the additional scrutiny of a Special License issued under the *Mineral Resources Act*, and must receive Ministerial approval from the Department of Natural Resources. As an added measure, mineral rights for the property have been placed under closure (withdrawn from exploration) by the Nova Scotia government. Exploration either for petroleum or for coal-bed methane would not affect the coastal property, as such resources can only be viable at depth, and as for any development sited in the Joggins Planning Area, it must meet land use standards set by the Municipality of the County of Cumberland.

Due to the area's low population density and the absence of major industrial developments in the vicinity of Joggins, environmental pressures resulting in loss of habitats, sewage contamination and chemical pollution are minimal when compared to more densely populated coastal regions.[4]

Figure 115 The great succession of strata.

4.B (ii) Environmental Pressures

The dramatic sea cliffs and the geological exposure which constitute the key features of the property exist primarily as a result of natural environmental processes, most notably the erosive action of the Bay of Fundy as well as geomorphic processes that have acted on the land in the recent geologic past. These recurring and natural forces will continue to yield fossils while simultaneously maintaining and reconfiguring coastal landforms.

Figure 116 *Educational programming at the Cliffs.*

Sea Level Rise and Coastal Erosion

Climate change is predicted to have significant global consequences, but limited adverse impact on the character and integrity of the Joggins Fossil Cliffs. A higher frequency of storm events and rising sea levels related at least in part to climate change will affect the nominated property. In both cases it is anticipated that increased rates of erosion will result. Erosion is essential to the exposure of the geological archive and to the certainty of ongoing discovery at the nominated property. During the past century, the water level in the Bay of Fundy has risen approximately 40 centimetres.[4] The towering cliffs along the length of the property provide protection against flooding and reduce sensitivity to sea level rise to low or moderate levels.[5] Low-lying areas at the mouths of MacCarron's River, Bells Brook and Little River have increasing risk of inundation due to sea level rise, but these areas do not figure directly in the fossil and geological archive of the site.

4.B (iii) Natural Disasters and Risk Preparedness

Earthquakes and Tsunamis

Earthquakes and/or tsunamis are not anticipated threats to the nominated property. The eastern coast of Canada is a passive continental margin with one of the lowest number and intensity of seismic events experienced globally. An exceptionally rare earthquake of magnitude 7.2 occurred off the coasts of Nova Scotia and Newfoundland in 1929. Recorded earthquakes in the Bay of Fundy region have not exceeded magnitude three, although an historic earthquake estimated to have been of magnitude five occurred south of the region in the Passamaquoddy Bay area in the nineteenth century. No tsunami has been measurably felt at Joggins in historic times.

Hurricanes and Tidal Surge

Hurricanes and/or tidal surges are not anticipated threats to the nominated property. The record storm event for the upper reaches of the Bay of Fundy was recorded during the Saxby Gale of 1869. Winds associated with an estimated Category 2 hurricane on the Saffir-Simpson scale coincided with an exceptional perigean high tide, resulting in a storm surge of two metres. Low-lying agricultural lands north of the property at the head of Chignecto Bay in the vicinity of Minudie were flooded during the Saxby Gale. The only areas of the property at risk of such an extreme event are the interval of low bluffs adjacent to Little River at Lower Cove and the valley at MacCarron's River. The rocks and fossils in this interval are exposed almost exclusively in the intertidal zone and would be little affected. The extreme tidal range would mitigate the effects of a storm-driven tidal surge (except at high tide).

Risk Preparedness

A specific Emergency Response Plan for the Joggins Fossil Cliffs has been developed in co-operation with the Cumberland Emergency Measures Organization and local officials (Appendix E:2). In the case of storms and tidal surges, meteorological and tidal forecasts will be monitored continuously at the new Joggins Fossil Centre, and Joggins Fossil Institute staff will take proactive action to evacuate any visitors at the site well in advance of approaching severe storms. The members of First Responder teams and the Fire

Department are located approximately one kilometre from the new Joggins Fossil Centre to offer additional support.

Internationally, the National Oceanic and Atmospheric Administration Agency of the United States of America operates the Alaska Tsunami Warning Centre. This centre monitors the Atlantic coast of North America, including the Gulf of Mexico in the south and the Atlantic coast of Canada in the north. Further preparedness measures are provided by Natural Resources Canada, with its Natural Hazards and Emergency Response, which focuses on avoiding tsunami damage by reducing the risks under the *Emergency Preparedness Act*. The Federal Department of Fisheries and Oceans also conducts research on the observation and modeling of tsunamis through the Institute of Ocean Sciences.

The Emergency Management Office of the Government of Nova Scotia is responsible for ensuring that all emergency planning in the province is done in a co-operative and consultative manner with municipal, national and international organizations. As required by the *Emergency Measures Act* of the province of Nova Scotia (1990), the Cumberland Emergency Measures Organization and Emergency Measures Bylaw set out the mandate of the Municipality of the County of Cumberland to plan for and respond to disaster situations.

4.B (iv) Visitor Pressure

Natural erosion of the cliff-face reveals the fossils and eventually removes them with the tide. The greatest potential threat to the fossil heritage, however, is the human impact through unauthorized fossil collecting. Although the rocky, high-energy shoreline is not highly vulnerable, management of the site will assure that the anticipated increased visitation at the site will have limited impact the coastal, inter-tidal ecosystem.

Carrying Capacity of the Nominated Property

For the purpose of managing the Joggins Fossil Cliffs, carrying capacity is defined within the Joggins Fossil Cliffs Management Plan as "an acceptable level of visitor density that the property can sustain without causing destructive effects to the physical environment or decreasing the quality of the visitor experience." Although this definition excludes the assessment and monitoring of impacts on the economic and socio-cultural environment of adjacent communities, the Joggins Fossil Institute will participate in community development and monitoring initiatives as increased visitation has potential to have both positive and negative impacts on the nearby communities.

Carrying capacity can be assessed to best protect the fossil resource; the two important factors in assessing carrying capacity for the management of the nominated property are natural heritage capacity and perceptual capacity. The assessment of these factors requires separate approaches.

Natural Heritage Carrying Capacity

The nominated property is able to sustain and significantly surpass current levels of visitation with little adverse impacts on the fossil resource or the local ecology. As detailed in Section 5.H(i), the absence of an immediate management presence at the property in the past has compromised formal record keeping, and visitor statistics have been difficult to maintain and track. Nonetheless, the generous estimate of past visitation and the conservative estimate of projected traffic find the Joggins Fossil Institute capable of handling nearly double the current level of visitation, with staffing, infrastructure, fossil collecting policies and legislation and visitor traffic management plans ready for both increased and changeable visitation levels.

The largest historic threat to the Joggins Fossil Cliffs prior to the inception of the Joggins Fossil Institute and permanent staffing at the site was the unauthorized, hence illegal, removal of fossils. Illegal removal refers to the casual pilfering of exposed smaller fossils and, far less likely, the unauthorized excavation of fossils from the cliffs and reefs. The most significant fossil resources are located within the cliffs along segments of the nominated property where interpreters will be vigilant and are therefore relatively secure. Although these fossil-rich segments of the property will be monitored by Joggins Fossil Institute staff and visitors will be discouraged from traveling to the remote southern and northern extents of the property, public education through interpretive programs and print media describing the fossil collecting legislation and policies and rationale is the principal conservation tool. Moreover, neighbouring residents continue to act as stewards of the property and will assist managers by reporting suspicious activities and by controlling access. See Section 5.C (v) for descriptions of the fossil collection permit policies, fossil protection legislation and prosecution procedures available for non-compliance.

The new Joggins Fossil Centre and staff of the Joggins Fossil Institute will facilitate visitor control, serving as the focal point of visitor education and experience at the site, controlling access to the beach, and minimizing impact of automobile traffic. Visitors are informed and educated about the fossil collecting legislation and policy in the site literature, on interpretive signs, and through verbal communications.

Heavy foot traffic resulting from increased visitation is not expected to significantly affect the exposed fossils of the cobble beach as the beach stones already experience continuous high wear from the powerful tides. Similarly, it is expected that elevated foot traffic levels will have little to no effect on the beach fauna (including barnacles and periwinkles) in the short term. Sensitive areas will be protected by congestion management and visitor dispersal, education on preserving the beach ecology, and possible path arrangements.

Perceptual Carrying Capacity

While projected visitation to the property is not anticipated to adversely affect the fossil resource or the local ecology, visitor impact will be persistently monitored and evaluated to protect them both and to maximize the quality of visitor experience. The management and marketing policies outlined in Section 5 anticipate increased visitation for recreational, educational and scientific purposes.

Figure 117 Architect's depiction of the Joggins Fossil Centre, scheduled to open in 2007.

The practical and legal management of the Joggins Fossil Institute is designed to adapt positively to increased visitation. A simple increase in staffing commensurate with increased visitation will ensure excellence in visitor experience while simultaneously protecting the fossil resource and local ecology. Should visitation significantly exceed predictions or should fragility within the fossil resource be observed, alternate visitor management is available to the Joggins Fossil Institute. Possible strategies for high visitation management include: prioritizing reservations for groups and individuals, encouraging visits during non-peak seasons (especially for schools and other large groups), timing special activities with visiting scientists, and co-operative marketing with other spring and fall activities in the area, including festivals and seasonal events.

4.B (v) Number of Inhabitants Within Property and the Buffer Zone

The nominated property is a rugged coastal environment (cliff and beach) and is not suitable for human habitation; no people live within its boundaries. The property is located in a rural area of the County of Cumberland that has the lowest population density within the province. Moreover, the area has experienced an ongoing population decline since the closure of the last coal mine in 1980. There are approximately 30 private residences adjacent to the nominated property. Only two of these residences are within the buffer zone prescribed under *The Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Area* and the *Beaches Act* and associated *Regulations.*

Figure 118 Homes overlooking the Bay of Fundy at Joggins.

Area of nominated property	689 hectares
Estimated number of inhabitants within the nominated property	0
Area of buffer zone • Cliff and Shoreline Setbacks - 20 metres landward from break in slope – length of the property (14.7 kilometres) • Protected Beach – 30.48 metres landward of mean high water mark - Lower Cove Beach (8.5 kilometres)	• 29.4 hectares • 25.9 hectares
Estimated number of inhabitants within the buffer zone	5 (in 2 households)
Estimated population total for property and buffer zone	5
Year	2006

5 Protection and Management of the Property

Looking south to Coal Mine Point.

5.A OWNERSHIP

The fossil heritage of Joggins, representing the most outstanding example in the world of the Pennsylvanian "Coal Age" ecosystem, is protected through convergent legislation that includes protective designations, mineral exploration closures, land-use planning and zoning bylaws, as well as property-specific operational policies and management plan. The entire nominated property is protected under the authority of the *Special Places Protection Act* which prohibits the unauthorized excavation and collection of fossils. Virtually all of the "Classic Section" is additionally protected under the authority of the *Beaches Act* and associated *Regulations*.

Figure 119 **Interpreting the geological record.**

Agreements have been made with provincial and local agencies to support in perpetuity future management, promotion and research at the nominated property. The property will be managed through the Joggins Fossil Institute under agreements with the Cumberland Regional Economic Development Association, the Municipality of the County of Cumberland and the Government of Nova Scotia. The Joggins Fossil Cliffs Management Plan has been produced by the Joggins Fossil Institute in concert with government agencies and the community, and is included in Appendix C of this nomination. This management plan sets out agreed objectives, policies and programmes for the nominated property.

Categories of Land Ownership

There are two primary categories of land ownership for the nominated property, government (provincial and municipal) and private (individuals and corporations). Approximately 95% of the property is owned by the Crown (or Government of Nova Scotia). This includes the entire coastline of the nominated property, from the mean high-water mark seaward to the mean low-water mark.

Landward of the mean high-water mark is considered to be owned by those who hold title to the lands adjacent to the shoreline. The title for the majority of the property that is landward of the mean high-water mark is held by private landowners with the exception of three large land parcels that are owned by the province of Nova Scotia and one land parcel that is owned by the Municipality of the County of Cumberland (Appendix I: Map 3).

The new Joggins Fossil Centre is being constructed adjacent to the nominated property on land that is owned by the Municipality of the County of Cumberland.

5.B PROTECTIVE DESIGNATION

This nominated property is currently protected by three *Acts* of the province of Nova Scotia: the *Special Places Protection Act*, the *Beaches Act* and the *Mineral Resources Act* (Appendix G:3). Under the *Special Places Protection Act* the nominated property is legally designated as a "Protected Site." Moreover, a significant portion of the property, including the "Classic Section" (the Joggins Formation proper), is legally designated a "Protected Beach" under the *Beaches Act*. The property is also under a mineral exploration closure, in effect through the *Mineral Resources Act*. A new Municipal land use planning strategy developed expressly to reinforce the integrity of the property complements these provincially-legislated protections.

5.B (i) The *Special Places Protection Act* (1989)

In 1970, the Government of Nova Scotia passed legislation, the *Historical Objects Protection Act*, to protect the province's significant fossil resources. The *Historical Objects Protection Act* was superseded by the *Special Places Protection Act* which now provides for the preservation, regulation and study of archaeological and historical remains as well as paleontological and ecological sites. The *Special Places Protection Act* is administered by the Minister of the Nova Scotia Department of Tourism, Culture and

Heritage. As stated, the purpose of this *Act* that applies to the nomination of this property as a fossil site is:

- to provide for the preservation, protection, regulation, exploration, excavation, acquisition and study of archaeological and historical remains and palaeontological sites which are considered important parts of the natural or human heritage of the Province;
- to promote understanding and appreciation among the people of the Province of the scientific, educational and cultural values represented by the establishment of special places.

The protection under the *Special Places Protection Act* confers special conservation status to "heritage objects" which are defined as "an archaeological, historical or palaeontological object or remain…." Under the *Special Places Protection Act*, carrying out exploration or making excavations on any land (including land covered with water) for the purpose of seeking palaeontological objects requires a Heritage Research Permit.

In 1972, the "Classic Section" of the Joggins Fossil Cliffs property was the first site in Nova Scotia that received "Protected Site" designation in recognition of its outstanding scientific significance. In July 2007, the province of Nova Scotia will have expanded the "Protected Site" boundaries to be consistent with the nominated property boundaries in recognition of the global scientific importance of the larger area.

5.B (ii) *The Beaches Act* and *Regulations* (1989)

The *Beaches Act* is a provincial statute that preserves and protects the beaches of Nova Scotia. Under this *Act*, all beaches in Nova Scotia are dedicated in perpetuity for the benefit, education and enjoyment of present and future generations. The *Beaches Act* and associated *Regulations* are administered through the Minister of the Nova Scotia Department of Natural Resources. As stated, the purpose of this *Act* is:

a) to provide for the protection of beaches and associated dune systems as significant and sensitive environmental and recreational resources;
b) to provide for the regulation and enforcement of the full range of land-use activities on beaches, including aggregate removal, so as to leave them unimpaired for the benefit and enjoyment of future generations;
c) to control recreational and other uses of beaches that may cause undesirable impacts on beach and associated dune systems.

In this *Act*, a "beach" is defined as that area of land on the coastline lying to the seaward of the mean high-water mark and that area of land to landward immediately adjacent thereto to the distance determined by the Governor-in-Council. The *Beaches Regulations*, made under Section 13 of the *Beaches Act*, govern the preservation, control and management of protected beaches. These *Regulations* restrict human activities including, most importantly, the removal of fossils and beach aggregate.

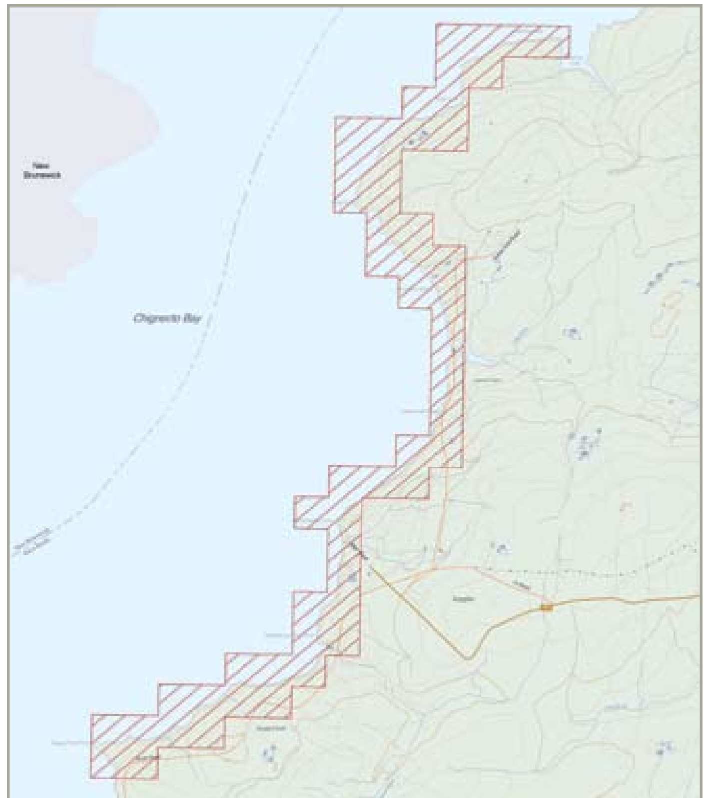


Figure 120 *Lands under closure within the* **Mineral Resources Act.**

The entire length of the nominated property is legally designated as a "Protected Beach" from the mean high-water mark seaward. In addition to this legal designation, in 1975, the province of Nova Scotia provided further protection of the Lower Cove Beach (extending 8.5 kilometres of the 14.7-kilometre length of the property) through a protected area landward of the mean high-water mark.

The Lower Cove Beach runs from the old Government Wharf at Joggins (approximate location 45^{O} 41' 40" N, 64^{O} 27' 5" W) to Downing Head (approximate location 45^{O} 44' 50" N, 64^{O} 22' 26" W), including the area 100 feet (30.48 metres) landward and perpendicular to the mean high-water mark. Under the *Beaches Act*, the designation of areas landward of the mean high-water mark further supports the conservation and integrity of the property as the protection includes areas adjacent to the property and may be considered as a buffer. The official map titled "Plan of Certain Lands Lying Landward from the Mean High-water Mark of Lower Cove Beach, Cumberland County Nova Scotia" with specific boundary definitions is included in Appendix I: Map 5.

5.B (iii) The *Mineral Resources Act* (1990)

Under the authority of the *Mineral Resources Act* of the province of Nova Scotia (Appendix G:3), “closures” are created when land is withdrawn by the Minister of the Department of Natural Resources from general application of the *Act* under Section 22. Therefore, the principles regarding acquisition of a mineral exploration licence do not apply to areas withdrawn (“closed”). This same provision is accorded to areas that are designated “protected” under the *Special Places Protection Act*. The issuance of a mineral exploration licence in such areas would require approval of the Minister and the Governor-in-Council (Cabinet of the provincial government).

In 2006, all lands of the nominated property, the buffer zone, and some adjacent lands were placed under closure by the Registrar of Mineral and Petroleum Rights, Nova Scotia Department of Natural Resources (Appendix I: Map 2).

5.B (iv) *The Municipality of the County of Cumberland: Secondary Municipal Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area*

In accordance with the *Municipal Government Act* of the province of Nova Scotia, the Municipality of the County of Cumberland has developed a *Secondary Municipal Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* (Appendix G:4). The *Municipal Government Act* permits a municipality to establish planning advisory committees to undertake research and public consultation and provide advice to a municipal council with respect to the adoption of planning policies and bylaws. In developing the strategy and bylaw for the Joggins area, The Joggins Area Planning Advisory Committee was formed and included members of the public, elected officials and municipal staff.

Committee meetings were publicized and were open to the general public. Additional public consultation events provided a forum for members of the community to express their ideas and concerns for the future, and to comment on the committee’s proposed planning documents. Once the committee made its final recommendation to County Council, a public hearing was advertised and held as part of a regular Council meeting. The final planning documents were approved by the Province in August 2006.

The *Strategy* addresses planning for future development of the communities of Joggins and Lower Cove and supports the protection of the nominated property through land use policies. The importance of the Joggins Fossil Cliffs is reflected in this *Planning Strategy* and *Land Use Bylaw*. The overriding goal was:

> …to support healthy and sustainable community development by ensuring that future growth and development throughout the Joggins Area will support the goals and priorities of local community members and maximize the benefits and minimize any adverse effects of the development of the Joggins Fossil Cliffs on the community and by ensuring that future land uses and forms of development in the vicinity of the Joggins Fossil Cliffs will protect and enhance their fossil resources and valuable features and be appropriate and compatible with the nominated UNESCO World Heritage Site and Centre.[3]

Figure 121 Community members attend an information session.

The *Planning Strategy* includes two specific policies —“Cliffs and Shoreline Setbacks” and “Prohibited Uses and Structures”—to support the stewardship of the natural heritage values, and protect the features and setting of the Joggins Fossil Cliffs. These two policies provide legal protection for the land adjacent to the landward side of the nominated property. These stringent policies assist in the conservation of the nominated property and will protect the property for future generations.

The policy pertaining to “Cliffs and Shoreline Setbacks” includes development restrictions in areas within 20 metres of the cliffs and shoreline to ensure that there will be no development and that environmental effects from the human activities or land uses will not interfere with the natural erosion processes which regularly expose fossils at the cliffs or adversely affect the setting or views of the Joggins Fossil Cliffs or the aesthetic qualities of the views and natural vistas along the shorelines.

The policy of “Prohibited Uses and Structures” includes *land use bylaws* for areas within 20 metres of the cliffs and shoreline that prohibit grading or alteration in elevation or contour of the land, the excavation and deposition of fill, defacing the cliffs, constructing permanent or temporary structures and outdoor storage of scrap or salvage material.

5.C MEANS OF IMPLEMENTING PROTECTIVE MEASURES

Management and conservation of the nominated property is exercised locally through the Joggins Fossil Institute (JFI). The Joggins Fossil Institute is a registered not-for-profit society under the *Societies Act* of Nova Scotia. The objectives of the Joggins Fossil Institute are to:

a) manage the Joggins Fossil Cliffs property and Joggins Fossil Centre, a place where global heritage values are protected, respected, understood and presented, so that the story of these values and other cultural and natural values can be told to the world, and to future generations;
b) hold and manage, for the benefit and education of humanity, a palaeontological collection representative of the Carboniferous Period alongside its native geographic property;
c) ensure that the property and collection are conserved, safely studied and exhibited and to provide for the advancement of scientific research;
d) acquire by way of grant, gift, purchase, bequest, device or otherwise real and personal property to use and apply such property to the realization of the objects of the Joggins Fossil Institute;
e) buy, own, hold, lease, mortgage, sell and convey such real and personal property as may be necessary or desirable in the carrying out of the objects of the Joggins Fossil Institute; and
f) do all such other things as may be provided by the *Societies Act* (1989).

The Joggins Fossil Institute has the principal role in setting policy and coordinating management for the nominated property. Management of the property is conducted through agreements between provincial and municipal government departments and the Joggins Fossil Institute. The government agencies that are working with the Institute are the:

i) Nova Scotia Department of Tourism, Culture and Heritage (DTCH);
ii) Nova Scotia Department of Natural Resources (DNR);
iii) Municipality of the County of Cumberland (MCC); and
iv) Cumberland Regional Economic Development Association (CREDA).

5.C (i) Nova Scotia Department of Tourism, Culture and Heritage

The Nova Scotia Department of Tourism, Culture and Heritage will work collaboratively with the Joggins Fossil Institute to carry out appropriate functions, including, but not limited to:

a) housing a working scientific collection of fossils and palaeontological material;
b) issuing "collecting permits," as defined by regulation under the *Special Places Protection Act*, to both scientific/excavation and stewardship/avocational collectors;
c) screening and releasing appropriate specimens for public consumption; and
d) making such policies and implementing such practises to properly conserve the nominated property's natural resources and manage the public entering the property.

The Joggins Fossil Cliffs Management Plan, developed by the Joggins Fossil Institute, adheres to parameters defined by the Department of Tourism, Culture and Heritage in relation to protection and conservation of the palaeontological heritage resource at the property and further addresses issues related to ecological sustainability and visitor management through a separate agreement with the Department of Natural Resources. The Joggins Fossil Cliffs Management Plan is approved bi-annually by the Department of Natural Resources and the Department of Tourism, Culture and Heritage.

5.C (ii) Nova Scotia Department of Natural Resources

An agreement with the Department of Natural Resources has been reached in order to permit the Joggins Fossil Institute to proceed with the conservation and management of the nominated property. The Minister of DNR, pursuant to Section 4, Subsections (3) and (4) of the *Beaches Act*, has entered into an agreement whereby the Joggins Fossil Institute will have authority to administer, manage and control the beach at the nominated property. Under this agreement, the Joggins Fossil Institute is authorized to;

- provide safety and interpretive services,
- conduct studies and carry out research, and
- promote educational programs that emphasize the importance of conserving beaches and using the beach for recreational purposes in a manner to maintain their environmental integrity.

5.C (iii) Municipality of the County of Cumberland

The Municipality of the County of Cumberland owns the land and building for the new Joggins Fossil Centre that is under construction adjacent to the nominated property. The Municipality has delegated control of the Centre and associated lands to the Joggins Fossil Institute. The Municipality will also monitor all development in the Joggins Planning Area (which includes the nominated property and adjoining communities) to ensure compliance with the *Secondary Municipal Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area*. Development

Figure 122 *Vertebrate paleontologist Dr. Andrew Milner, visiting from the University of London.*

Control and Building Inspection Officers will reject any non-compliant development proposals and will ensure all developments have complied with the permitting and approval process required by the bylaw. The bylaw can be enforced by prosecution and court orders if necessary.

5.C (iv) Cumberland Regional Economic Development Association

The Cumberland Regional Economic Development Association provided all administrative and staffing support to the Joggins Fossil Cliffs Advisory Board from 1990 - 2006. As the Joggins Fossil Institute is a new entity (established in 2006 from the Joggins Fossil Cliffs Advisory Board), CREDA will continue to act in a supportive capacity until 2010 at which time the agreement between CREDA and the JFI will be re-evaluated. Although the Joggins Fossil Institute is incorporated as a separate legal entity from CREDA, it will initially operate as a sub-committee of CREDA and in addition to its own bylaws, also comply with the policies and bylaws of CREDA. The Cumberland Regional Economic Development Association shall ensure that, as it relates to the Joggins Fossil Cliffs project, liability insurance shall be extended to the JFI and its directors.

5.C (v) Joggins Fossil Institute policies related to the conservation and management of the paleontological heritage at the Joggins Fossil Cliffs

Of particular importance in implementing protective measures is the Joggins Fossil Institute operating policy and procedure related to fossil collecting. The nominated property comprises an extensive geological exposure on an active seacoast that is both well-known and relatively accessible to the public. As an "exposure" site, the Joggins Fossil Cliffs can sustain higher collecting pressures[1] than a "finite" site. Exposure sites, such as an eroding coastline, are sites that have a geological resource that is extensive and frequently renewed. Finite sites are those in which the geological resource is irreplaceable such as a cave sediment or a derelict mine dump. At the Joggins Fossil Cliffs, unauthorized collecting is not permitted under provincial law.

The erosive force of the Bay of Fundy on the coastal cliffs continually exposes and erodes fossils from the cliffs. The exposed fossils inevitably are deposited on the stony cobble beach at the base of the cliffs. The extreme action of the world's highest tides leaves any fossil specimen with only a finite lifespan once it is deposited on the beach. At Joggins, therefore, specimen recovery through supervised collecting is a requirement of responsible site stewardship.

Fossils on the beach and in the cliffs have been an attraction for visitors since the first pioneers of science visited the property in the mid-nineteenth century. In the past, scientists, visitors and local residents have all collected fossils at the property. It is expected that the property will continue to be a popular attraction for visitors who are interested in viewing fossils and learning about the international significance of the cliffs and fossil heritage. Scientific, visitor and local resident activities relative to the beach and cliff must be managed to ensure that the outstanding scientific and educational values of this natural heritage property are conserved and protected in perpetuity.

At Joggins, authorized, legal fossil collecting by responsible permit holders is an integral component in the conservation of this fossil site, which supports the advancement of scientific research. Authorized collecting of fossil specimens that might otherwise be destroyed by the erosive forces of the tide supports science at the site, provided that specimens are properly documented and made available for study. Supervised collecting will help to ensure that the earth's natural heritage and integrity of this globally significant property is sustained for future education, appreciation and inspiration.

The Joggins Fossil Institute Collecting Policy

The management of the fossil resource at Joggins is based on public education of the inherent value of earth's history, backed by a system of strict legal protection through the Government of Nova Scotia. The collecting policy for the nominated property recognizes

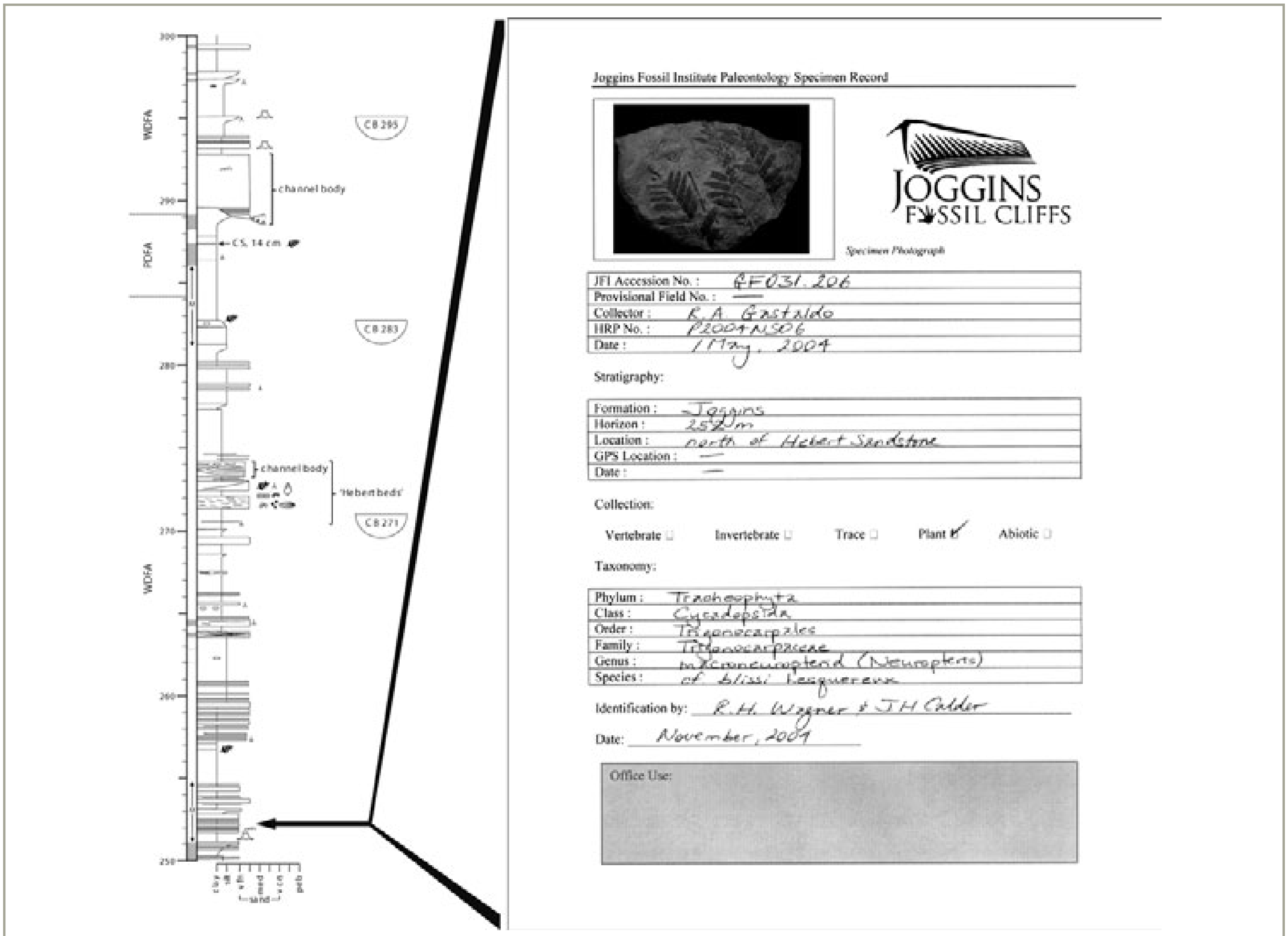


Figure 123 *An example of the method for accession of fossil specimens, keyed to new reference section logs.*

that under the *Beaches Act* and associated *Regulations* (Regulation 7 (c)), a permit is required to remove a fossil from a beach, and under the *Special Places Protection Act*, a permit is required for the exploration or excavation of fossils in Nova Scotia. In keeping with the strict controls as defined by the *Special Places Protection Act* and the *Regulations* of the *Beaches Act*, it is the policy of the Joggins Fossil Institute that a Heritage Research Permit is required for fossil exploration, excavation and collection. Uncontrolled collecting of fossils on the property by persons not in possession of an approved Heritage Research permit is prohibited. Excavation and recovery of fossils from the bedrock at the Joggins Fossil Cliffs property is only to be permitted for scientific, educational, or awareness-building purposes, and a “Professional Survey” or “Excavation” Heritage Research Permit issued under the authority of the *Special Places Protection Act* is required.

The collecting policy and management plan deters visitors from accessing and collecting fossils from freshly fallen rocks (talus) at the base of the cliffs, except under such authority. Specimens within the talus can be related to their original stratigraphic position within the cliff-face, thus providing the ecological context to the fossils that contributes to the outstanding value of Joggins. Limited collecting of loose, tide-worked fossils on the lower reaches of the beach, which have lost their ecological context, on the other hand may be permitted for scientific, educational, or awareness-building purposes and requires a “Stewardship” Heritage Research Permit. If fossil exploration, excavation or collection are to be conducted on privately owned land (some of the areas landward of the mean high-water mark), permission must additionally be attained from the land owner to access that land, but the Province retains ownership of all collected fossils. Regardless of their position of discovery, or by whom, all fossils are screened by Joggins Fossil Institute staff to evaluate their scientific significance. Only fossils of common occurrence or poor condition are released; all others are recorded in the context of the cliff section and accessioned into collections of the Joggins Fossil Institute, Nova Scotia Museum or collegial institutes. Activities of Heritage Research Permit holders are monitored by the JFI Scientist to ensure compliance with this policy, the *Special Places Protection Act* and *Beaches Act* and associated *Regulations*, and are reported annually to the Scientific Advisory Committee, the Joggins Fossil Institute Board of Directors

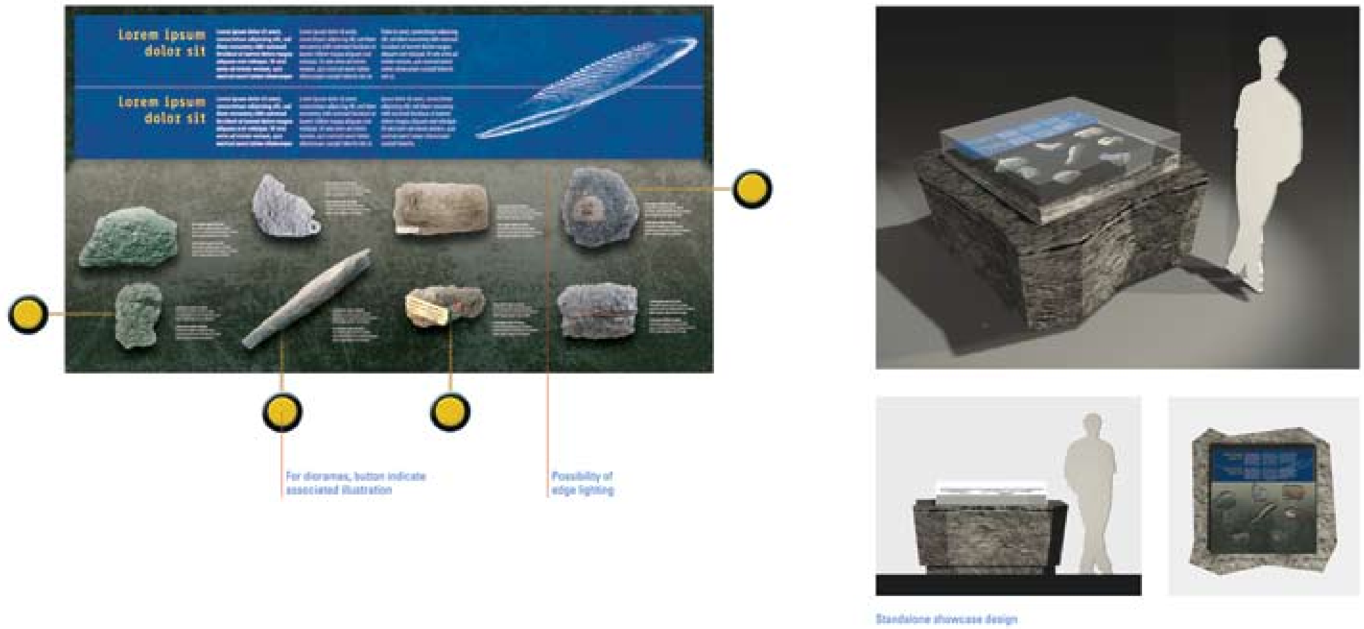


Figure 124 ***Rendition of the exhibition of fossils at the Joggins Fossil Centre.***

and the province of Nova Scotia. The legislation and policies related to fossil collecting at the property meet or exceed highest international standards.

The Joggins Fossil Institute will refer non-compliance issues (e.g., any violations of the *Special Places Protection Act* and *Beaches Act* and associated *Regulations* including illegal collecting, failure to abide by the terms of a permit, etc.) to the Royal Canadian Mounted Police and the Department of Natural Resources, Regional Service Branch, Enforcement Division. The Joggins Fossil Institute will report on fossil collecting to the provincial government as directed, in such time frames, and formats, as have been mutually agreed.

The Institute will develop an educational program consisting, at a minimum, of graphic displays in the new Joggins Fossil Centre, brochures, and web-based materials, regarding the responsibilities of visitors to the property with respect to enjoyment and conservation of the fossil heritage. All visitors to the beach portion of the property will be provided with educational materials reminding them of their responsibilities.

Curation, study and display of fossils

Under the *Special Places Protection Act*, collected specimens remain the property of the province of Nova Scotia. Type specimens (those used as the basis for naming a new species or higher taxon) normally are accessed at the Nova Scotia Museum, in keeping with its Collections Management Policy, but may be provided on permanent loan to the Joggins Fossil Institute for reference, study, and educational purposes.

Excavations of the nominated property are carried out rarely, and exclusively under the aegis of provincial legislation, employing the Heritage Research Permit system administered though the Heritage Division of the Nova Scotia Department of Tourism, Culture and Heritage. Collected specimens will be recorded relative to their stratigraphic horizon in the standard reference section (Appendix J) and geographic location along the section to preserve important information pertaining to their paleoecological context and relative age. Fossil specimens will be curated, catalogued and displayed in Joggins at the Joggins Fossil Centre and in Halifax at the Nova Scotia Museum of Natural History, to international museum standards.

Exhibition of fossils at the Joggins Fossil Centre, immediately adjacent to the nominated property, is important as the Centre will be an active research facility and the main starting point for visitor excursions to the Joggins Fossil Cliffs. This facility is staffed full time and provides facilities for interpretation, collections management and visiting scientists. This Centre will be complemented by curatorial and preparation facilities of the Nova Scotia Museum, Halifax and Fundy Geological Museum, Parrsboro, Nova Scotia.

Figure 125 **Geologist Ken Adams, and university students inspecting a newly fallen tree stump.**

5.D EXISTING PLANS RELATED TO MUNICIPALITY AND REGION IN WHICH THE PROPOSED PROPERTY IS LOCATED

Numerous plans and studies related to the socio-economic development of Cumberland County and the local area have been conducted over a period of approximately 10 years. These studies and plans have either directly been related to the conservation and management of the nominated property or support the development of a broader tourism destination area. Selected plans are briefly described below and full copies are appended (Appendices E and F).

- *Erosion Analysis of the Joggins Area:* A Preliminary Investigation (Appendix E:1). This analysis was prepared by the Municipality of the County of Cumberland and was performed using two sets of aerial photographs covering the area of Downing Cove southward to Ragged Reef Point.
  The photographs were from the years 1964 and 2005, covering a 41-year span. It was observed that most parts of the study area have minimal to moderate erosion rates ranging from undetectable to 25 centimetres per year. General erosion trends and areas of higher erosion are quite evident from the research, but the conclusion is that erosion will likely have little effect on buildings, roads or infrastructure that are situated outside the buffer zone over the next century.
- *Joggins Fossil Cliffs Emergency Response Plan* (Appendix E:2). This plan was prepared by the Joggins Fossil Institute Emergency Response Planning Group to provide Institute personnel and associated agencies with an overview of the guidelines to their expected response and responsibilities to an emergency situation. Furthermore, the plan provides an assessment of emergency preparedness for the Fossil Cliffs. The Joggins Fossil Institute will continue to work with the appropriate agencies to finalize the draft plan, pending completion of the new Joggins Fossil Centre.
- *Communications Plan for Joggins Fossil Cliffs and Cape Chignecto Provincial Park* (Appendix E:3). This plan was prepared to address the goals of enhancing and creating awareness of Joggins as a world-class sustainable tourism, scientific, and educational destination. It also addresses the sustainable framework for the visitor experience over the long-term.The communication plan also explores opportunities to cross-promote Cape Chignecto Provincial Park with Joggins Fossils Cliffs.
- *Joggins Fossil Cliffs: Comprehensive Site Development Plan, 100% Design Development Production Manual,* and *Operating Revenue and Expense Projections Report* (Appendices E:4, 5, & 6). These plans were prepared for the construction and operation of the Joggins Fossil Centre. These plans represent the design development stage for the nominated property including architectural design for the new Joggins Fossil Centre and the

schematic stage of interpretive design for the nominated property. Financial projections for the nominated property over a five year period are also reported.

- *Fundy Shore 209/242 Alliance Tourism Development Study* (Appendix F:1). This study, prepared by EDM Limited (Halifax, Nova Scotia) for the Cumberland Regional Economic Development Association, was commissioned to propose tourism infrastructure and product opportunities that would enhance the visitor experience to the coastline from Maccan to Parrsboro in Cumberland County along the 209/242 highways. This is to be achieved by matching tourists' desires and expectations to the shoreline's amenities. The Joggins Fossil Cliffs nominated property is located on Highway 242.
- *Cumberland Regional Economic Development Association 2006/2007 Business Plan* (Appendix F:2). CREDA has played a leadership role in facilitating the development, management and promotion of the nominated property to help achieve the goals of the Joggins Fossil Institute. Related projects that CREDA has undertaken include repopulation study, community beautification projects, human resource development programs and infrastructure assessments. CREDA has also initiated a project specifically to develop the Nova Scotia "Fundy Shore" as a tourism destination area.
- *Joggins Fossil Cliffs World Heritage Site Designation Initiative: Community Consultation Process & Action Plan* (Appendix F:3). This report was prepared for the Cumberland Regional Economic Development Association by Boon Consulting Enterprises (Joggins, Nova Scotia). The purposes of the project were to assess community interest and motivation relative to the potential inscription of the Joggins Fossil Cliffs as a World Heritage Site; and to generate a community-based action plan to pursue World Heritage designation of the Fossil Cliffs.

5.E PROPERTY MANAGEMENT PLAN

The Joggins Fossil Cliffs Management Plan is appended in a separate document (Appendix C). A summary of the management goals and principles for the nominated property is presented below.

Management Goals for the Nominated Property

The following goals enable the conservation and long-term management of the Joggins Fossil Cliffs.

Goal 1: to provide for the protection, study and safe enjoyment of the Joggins Fossil Cliffs by:

a) ensuring that human activities do not compromise the natural integrity of the Joggins Fossil Cliffs;
b) ensuring that scientific research remains a focal point for property management;
c) ensuring that visitors to the fossil cliffs are aware of and protected, to the extent possible, from hazards associated with cliffs, tides and poor footing;
d) developing interpretation brochures featuring scientific and safety information with respect to the property and its features;
e) developing and implementing an emergency plan.

Goal 2: to promote wide recognition, understanding and appreciation of the scientific, educational and cultural values represented by the Joggins Fossil Cliffs by:

a) implementing a fossil collecting policy that focuses on the inherent scientific value of all fossils;
b) developing and implementing a fossil collecting and cataloguing process that maximizes the scientific potential of each fossil;
c) ensuring that fossil collectors are an acknowledged part of the long-term research goals of the fossil site;
d) ensuring that World Heritage Site status, if granted, will be recognized responsibly in all aspects of publicity in relation to the Joggins Fossil Cliffs in accordance with UNESCO guidelines.

Goal 3: to instil a strong sense of community pride and stewardship in the Joggins Fossil Cliffs by:

a) supporting land use zoning to protect community interests over the long-term;
b) providing for community input and encouraging community participation;
c) supporting entrepreneurial development in the Joggins-River Hebert area;
d) employing a governance model to ensure that developments associated with the Joggins Fossil Cliffs respect the local culture, history, traditions and way of life.

Goal 4: to establish a world-class sustainable tourism destination that contributes to local, regional and provincial economies by:

a) developing and operating a facility and supporting infrastructure for visitor services, interpretation and education;
b) promoting visitation through regional, national and international media.

Goal 5: to ensure community involvement in the interpretation and promotion of the Joggins Fossil Cliffs and provide a range of interpretive opportunities for visitors by:

a) supporting the training and involvement of local and regional students in the interpretation and study of the Joggins Fossil Cliffs;
b) ensuring the local schools are provided sufficient information and opportunities to incorporate the

Joggins Fossil Cliffs into their curriculum;

c) providing knowledgeable beach interpreters during peak visitation periods;
d) providing group tours during peak periods and through special arrangement at other times;
e) incorporating cultural and industrial history components into interpretive and tourism planning for the region;
f) preparing an interpretation plan for the development and dissemination of information on the property and its fossils;
g) developing and posting interpretive material to inform visitors of the nature and extent of tides on the Fundy shore;
h) designing, developing and placing a series of interpretive panels offering key information about features of the property.

Principles for Managing the Nominated Property

This Joggins Fossil Cliffs Management Plan sets out a series of management principles for the property, as well as for the surrounding community.

Principle 1: Management of the property will meet or exceed World Heritage standards regardless of inscription.

The Joggins Fossil Cliffs Management Plan acknowledges that there is an adjudication interval following submission of the nomination. Regardless of inscription or its timing, the management of the property will meet or exceed standards prescribed under the Operational Guidelines for the Implementation of the World Heritage Convention (2005).

Principle 2: The primary focus of Joggins Fossil Cliffs Management Plan is to address issues directly related to management and conservation of the fossil heritage at the Joggins Fossil Cliffs.

The plan addresses those issues that flow from the Joggins Fossil Institute objectives. In relation to possible threats, the Management Plan concentrates on the conservation of values for which the property is designated as a "Protected Site" through provincial legislation and for which it may be inscribed for World Heritage Site status.

Principle 3: The Joggins Fossil Cliffs Management Plan fully recognizes that the nominated property is set within a well-visited coastal area where people continue to live and work.

Unlike other natural sites with more fragile ecosystems, the cliffs and beach enjoy a strong natural defence from human habitation. People have lived immediately adjacent to the cliffs for several generations with little ecological impact or exploitation of the fossil resource. Nonetheless, inscription on the World Heritage List would have an impact on the community, so property management must respect local stakeholders.

Principle 4: Management in relation to World Heritage guidelines will be locally driven and will include the participation and support of government agencies with regulatory responsibilities for the property.

World Heritage designation would augment the property's profile and strengthen its long-term viability; existing legislative protections will continue regardless of inscription. The plan recognizes that regulatory control must include stakeholders including local managers, visitors and local citizens.

Principle 5: Management will be delivered through existing mechanisms, supplemented by new processes and procedures developed to accommodate a designated World Heritage site.

The Joggins Fossil Cliffs Management Plan requires regular review by the Joggins Fossil Institute Board of Directors, as experience and other factors may influence the future direction of site management. Once implemented, the Management Plan review will be on a three-year cycle. Furthermore, components of the Management Plan will be reviewed and approved by the Nova Scotia Department of Tourism Culture and Heritage and Department of Natural Resources.

One of the key ingredients for providing long-term management of the Joggins Fossil Cliffs is the recognition that attention and resources are required to manage the property to World Heritage standards, as well as to deliver an interesting and fulfilling experience for visitors. Implementation of the Management Plan for the property is assured through the agreements with partners, staffing levels, sustained financial commitments through the province of Nova Scotia and through community engagement. For the first time, an on-site management presence will enable implementation of the conservation measures necessary for the sustainable use of the property. Where additional management measures are required in relation to World Heritage Site status, they will be fully integrated with existing initiatives and avoid duplication of effort.

5.F SOURCES AND LEVELS OF FINANCE

The overall range of planning and management skills available for property management is wide, and it is not possible to quantify fully the total budgets involved. The average projected five year, annual staffing and operational budget for the Joggins Fossil Institute (based on agreed assumptions including visitation projections) is approximately $500,000. Details of the projected operational budgets are included in Appendix E:6.

Effective April 1, 2007, the province of Nova Scotia intends to provide annual operating support of $250,000 for operating costs. The Municipality of the County of Cumberland (municipal government) will also contribute to the annual operating revenue for the property by way on an annual grant. Based on financial projections for a five year period, the provincial annual operating contribution, in conjunction with annual contributions of the Municipality of the County of Cumberland, admission and gift shop sales and fundraising will provide adequate resources (projected to be $250,000) to achieve and exceed the Joggins Fossil Institute vision, mission and goals for conservation, management, promotion and research of the Joggins Fossil Cliffs. Opportunities to augment current funding through public and private sources will continue to be pursued.

5.G SOURCES OF EXPERTISE AND TRAINING IN CONSERVATION AND MANAGEMENT TECHNIQUES

The Joggins Fossil Institute, including directors of the Board, managers and staff provide the base level of expertise necessary for the conservation and management of the property. The Joggins Fossil Institute is well-positioned to draw upon other federal, provincial or municipal resources to complement and supplement existing expertise.

The Joggins Fossil Institute human resources performance management system will ensure that managers and staff continually improve performance, resulting in reduced costs, increased innovation, and ultimately providing for overall improvement in the management and sustainability of the property. Annual operational funding has been allocated for ongoing professional development for managers and staff. Joggins Fossil Institute employees will have the opportunity to participate in training programs offered through the provincial, federal and municipal governments. Moreover, professional development opportunities are available through the many private agencies and post -secondary institutions in the region. Joggins Fossil Institute managers and staff will be encouraged to maintain active membership in professional associations at both a national and international level.

Orientation and training will be provided to new employees including mandatory training related to natural and cultural heritage interpretation, customer service, and emergency response. Orientation to the Joggins Fossil Institute policies and procedures is standard practice under International Standards Organization 9001:2001 Registration for which the Cumberland Regional Economic Development Association is accredited.

The newly established (2006) Joggins Fossil Institute's complement of Board Directors supports the mission and goals of the property and has representatives from the local communities, the scientific community, economic development offices and tourism development agencies. In particular, many board members provide technical and scientific support related to conservation and management for the Institute's director, managers and staff. As indicated in Section 5.J, two advisory groups, the Scientific Advisory Committee and Emergency Response Planning Group, will also enhance the capacity for ongoing conservation and management of the nominated property.

In addition to the Joggins Fossil Institute Board, further support for the management and operation of the property is provided

Figure 126 ***Interpreting a new fossil find.***

through a partnership agreement with the Cumberland Regional Economic Development Association. As a regional development association, CREDA has agreed to support the administrative functions of the property, including financial and human resource management. This agreement is in keeping with the leadership role that CREDA has played for the last decade in coordinating the planning and the development of the Joggins Fossil Cliffs property. It is agreed that CREDA will continue to be an advocate of and provide support for the future conservation and management of the property (Appendix H:2).

5.H VISITOR FACILITIES AND STATISTICS

5.H. (i) Visitor Statistics

There has been no local management presence at the nominated property in the past, so visitation estimates have been difficult to quantify accurately. Based on provincial data from nearby attractions attained from the Department of Tourism, Culture and Heritage, visitation to Joggins has been projected for a five year period from 2007 – 2012. The projections are summarized in the table below.

Year	Attendance Projection
2007-08	38,440
2008-09	42,290
2009-10	40,180
2010-11	44,190
2011-12	48,600

The novelty of new attractions (with their attendant media coverage) typically yields higher visitor numbers in the first year and a slight decline in the second. However, should the property be inscribed on the World Heritage List, the Joggins Fossil Cliffs would avoid such a second-year slump, and thus it is anticipated that there will not be an attendance decline in Year Two, but rather a 10% increase from Year One. This increase will be followed by a slight decrease in Year Three when the initial novelty and media attention lessen and many interested residents will have visited for the first time. However, after the third year, attendance is projected to gradually increase to stable levels as the Centre and property begin to develop a higher profile through strategic marketing and as management develops a better understanding of market preferences and patterns and adjust programming and operations accordingly.

Although the attendance projections only address a five-year period, it is anticipated that strategic and sustained promotion of the Joggins Fossil Cliffs will combine with accompanying development of the local tourism infrastructure to yield growth in visitation.

Records of the locally run fossil museum, from the eighteen-year period preceding this nomination and prior to a comprehensive tourism strategy and infrastructure development, supplemented by records of field trips of international societies, attest to visitation to the property from more than 43 countries, representing every inhabited continent:

Australia	Germany	Norway
Austria	Indonesia	Pakistan
Bahamas	Ireland	Poland
Belgium	Israel	Portugal
Bermuda	Italy	Russia
Brazil	Japan	Scotland
Burkina Faso	Kenya	South Africa
Canada	Korea	Spain
Chile	Luxembourg	Sweden
China	Mexico	Switzerland
Czech Republic	Morocco	Thailand
Denmark	Nepal	Ukraine
England	Netherlands	United States
Finland	New Zealand	Wales
France		

5.H (ii) Visitor Facilities

Public and Community Access to the Nominated Property

The nominated property has been used by members of the local community and the public for generations for passive recreational use such as walking, fishing, swimming, parasailing and sight-seeing. These activities have no impact on the fossil resource or global heritage values of the nominated property. Traditional community and public access and use of the property will continue so long as it does not endanger other visitors or affect the management of the property or fossil heritage.

Access to the property is limited to specific areas due to the height of the cliffs, private land ownership and also the height of the tide. Limited access is considered an asset from a visitor management perspective as property managers can easily and consistently track the majority of beach visitors. At present, there is one developed access point to the fossil cliffs at the mouth of Coal Mine Brook (Bell's Brook). Two other informal access points, at Lower Cove and MacCarron's River, are used on occasion by knowledgeable visitors but cannot currently support significant visitor use due to parking and private land ownership constraints.

The new Joggins Fossil Centre development includes a new visitor access to the property that will be constructed at "the dugway" and is within a short walk from the Centre. Moreover, at Lower Cove, the Grindstone Quarry interpretive area will permit access for physically-challenged visitors. All access points will provide interpretive, stewardship and safety information, including tide and safe beach access times. These facilities will be developed with care and according to existing legislation to ensure that they do not affect property conservation objectives negatively.

Figure 127 ***Orientation signage providing introduction to the cliffs.***

Future plans may involve the development of other, more remote, access points. An area of Crown land to the north of Lower Cove at Boss Point (adjacent to the nominated property) has been identified for future development. It would provide access to the northern part of the nominated property, plus provide for additional interpretive and recreational opportunities that are not tide dependent. A hiking trail and rough camping sites are also proposed for the Boss Point site.

Visitor Amenities

The new Joggins Fossil Centre, adjacent to the property, will not only provide interpretive exhibits for visitors but also act as a

Figure 128 *Artist depiction of the entrance to the exhibition gallery, Joggins Fossil Centre.*

departure point for guided tours of the Fossil Cliffs. The Joggins Fossil Institute will facilitate interpretive walks by providing transportation to the Fossil Cliffs via shuttle bus. The Centre will also provide other necessary services including a café, gift shop, lavatories, meeting rooms, parking, general tourism information, and first aid and protection services. Visiting researchers and scientists will also have access to office space, a collection of fossils and laboratory facilities at the Centre.

Public Safety and Risk Management

The physical nature of the nominated property presents several inherent risks including steep cliffs, falling rocks, slippery and uneven terrain for walking, and high tides that could strand beach-goers. The extreme tidal range of the Bay of Fundy and the irregular shape of the shoreline increase the risk of stranding. The following actions have been taken to minimize risks and promote public safety within the nominated property:

- An Emergency Response Plan, that includes search and rescue strategies, has been prepared in consultation with local emergency measures officials (Appendix E:2). This plan identifies foreseeable risks and provides a response plan to address those risks. Implementation of the plan will be carried out by the Joggins Fossil Institute in collaboration with local emergency response agencies. The Royal Canadian Mounted Police is the primary organization charged with responding to on-site emergencies;
- Comprehensive safety signage has been posted and maintained at all official access points. Safety messages will also be provided within the Joggins Fossil Centre and in the interpretive brochures and educational materials prepared for the property;
- The new access to the nominated property has been designed to permit the elevation of an immobilized injured person to the top of the cliffs; and
- Visitors to the property will be encouraged to adhere to property rules that restrict visitation to areas of the property where there are beach attendants (from MacCarron's River north to Little River). Furthermore, visitors desiring access to the restricted areas at the extreme south (MacCarron's River to Ragged Reef Point) and north (Little River to Downing Cove) will be encouraged to register their trip with Joggins Fossil Institute staff prior to departure.

Regional Considerations Regarding Visitor Facilities

The property is located adjacent to the small community of Joggins (population ca. 450). Currently in Joggins there are no hotels, and other amenities are limited for attracting and retaining full-day or overnight visitors. Interviews with tourism operators indicate that this is a barrier to fully developing the tourist market for Joggins. However, it is reasonable to expect that the local tourism infrastructure will develop over time as more visitors are drawn to the Joggins area with the opening of the new Joggins Fossil Centre and with the property's potential for inscription on the World Heritage List.

Although current tourist services are limited in Joggins, the property is very close (within 30 kilometres) to the somewhat larger community of River Hebert (population ca. 845) and the even larger town of Amherst (population ca. 10,000). These communities provide additional services for visitors including: health care (including a new hospital that opened in 2002), restaurants, accommodations, service stations for vehicle repair and fuel, churches, libraries, recreational areas, parks, shopping, museums, and tourist information centres. Amherst is the most frequently used point of entry to Nova Scotia, with 54% visitors entering the province through this gateway.

International visitors can choose from two international airports within a two-hour drive from the nominated property: the Moncton International Airport (approximately 86 kilometres from the property) and the Halifax International Airport (approximately 195 kilometres from the property). The Moncton and Halifax airports together support regular flights from New York, USA and the United Kingdom, and connect to international airports. The proximity to these transportation services and the quality of the roads enhances opportunities for national and international visitation.

5.I POLICIES AND PROGRAMMES RELATED TO THE PRESENTATION AND PROMOTION OF THE PROPERTY

The proper presentation and promotion of the nominated property has a high priority within the existing management policies of the Joggins Fossil Institute, the Nova Scotia Department of Tourism, Culture and Heritage and Department of Natural Resources and in the local community. Specifically, the objectives of the Joggins Fossil Institute and goals in the Joggins Fossil Cliffs Management Plan

Figure 129 *The "Power of the Cliffs."*

reinforce the importance of understanding, presenting, and exhibiting the property as well as the advancement of scientific research and formal educational opportunities (Sections 5.E).

5.I. (i) PRESENTATION OF THE PROPERTY

In keeping with Recommendation 8 (Section 3.C (ii)) of the IUCN, a major interpretation and research facility currently is under development adjacent to the nominated property at a cost of approximately $6 million. The Joggins Fossil Centre will be located in the community of Joggins, overlooking the cliffs and Bay of Fundy south of Bell's Brook and Coal Mine Point. The Centre will welcome visitors, instilling in them a sense of the exceptional value of the property, and serve as an orientation centre and departure point for excursions along the cliffs. The Centre will also house the offices of Joggins Fossil Institute staff. This facility will provide visitors with an exceptional learning experience that is consistent with UNESCO goals. The Centre will feature bilingual (French and English) information and fossil specimens which demonstrate the rich geological history of the nominated property, the history of scientific discovery at Joggins, and the history of coal mining that shaped the local community.

For the presentation of the nominated property, the Joggins Fossil Institute adopted an interpretive master concept focusing on the "Power of the Cliffs" to evoke the power of nature, life, time and knowledge. This master concept inspires the development of property interpretation and the overall visitor experience.

The main interpretive themes and their relative importance reflect the pillars of the proposed statement of outstanding universal value, as enunciated in Section 3.B, and include:

- *The "Coal Age" Ecosystem at Joggins*: This theme reflects the outstanding fossil record and its context at Joggins, and will comprise approximately 50% of the interpretive material. It includes treatment of the biodiversity and ecology of the Carboniferous Period at Joggins, with special reference to the "Hollow Tree Fauna," and modules on how fossils are formed and how to look for fossils in the cliffs and rocks;
- *Big Ideas - Joggins and the History of Science:* This section will constitute 20% of the material, and will deal with the seminal role the Joggins Fossil Cliffs had in the development of key geological and evolutionary ideas and debates. It will feature discussion of the work of nineteenth-century geologists Sir Charles Lyell and Sir William Dawson, as well as the role of Joggins in the first historic debate on evolution; and
- *The Grand Exposure*: The dramatic exposure that, in the words of Sir Charles Lyell, reveals this "marvellous chapter of the big volume" of earth's history.

Additional treatments include:

- *The times*: This theme will comprise 10% of the interpretation and will provide context to Joggins in the history of the earth and life, addressing issues related to geological time and the changing earth. Fossils from sites inscribed on the World Heritage List will be featured on the timeline of earth history; and
- *Complementary themes*:
  - o the Bay of Fundy ecosystem;
  - o community stewardship and heritage values;
  - o cultural history of a "village rooted in coal";
  - o safety;
  - o regional tourism information; and
  - o (pending inscription) an installation on the World Heritage Convention.

A detailed presentation of the interpretive and educational component of the property is found in Appendix E:5.

A suite of interpretive programs will be offered at the site and in the Centre, covering the wide range of visitor age and knowledge. Interpretive exhibits will be located at several locations adjacent to the nominated property to provide self-guided learning opportunities for visitors. Some of the property's major themes will be interpreted at the Grindstone Quarry, Lower Cove, Coal Mine Point, and "the dugway" access adjacent to the Joggins Fossil Centre. Property-wide interpretive themes will include the conceptual geological timeline, cultural history, highest tides in the world, fossil fuels and extinction. On-site signage will be augmented by interpretive brochures that elaborate on the major themes.

Off-site interpretation will be provided through a comprehensive web site, as prescribed in the Operational Guidelines (2005).

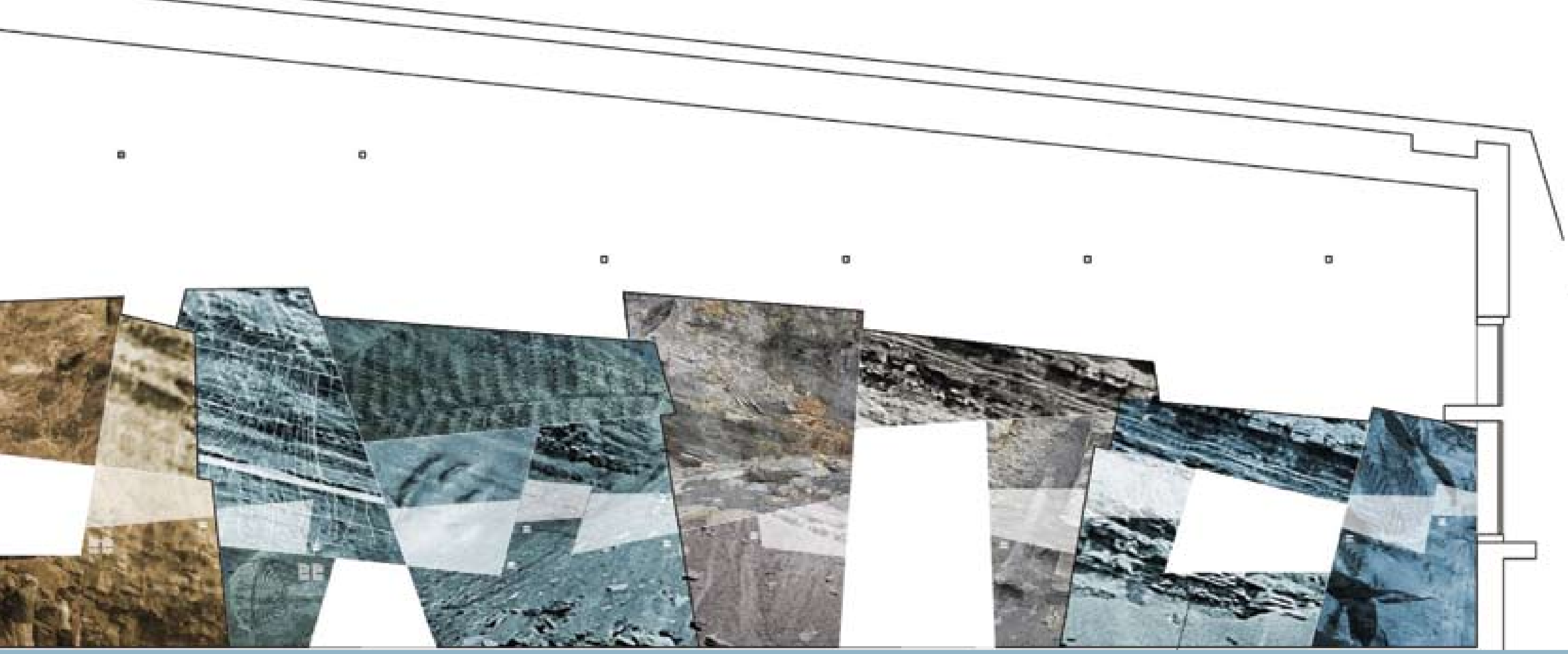


Figure 130 *Rendition of the pillars of the significance of Joggins as they greet the Joggins Fossil Centre visitors.*

The web site will include information on the significance of Joggins: geology, fossils, history of scientific exploration and current research. Outreach education will be pursued through the development of learning modules to incorporate into local and regional public school curricula.

Two management positions of the Joggins Fossil Institute, Manager of Programs and Manager of Visitor Services and Marketing, focus on the education and promotion of the nominated property. The Manager of Programs is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the Centre and property, as well as outreach programs and extension programs. The Manager of Visitor Services and Marketing is responsible for the overall quality of the services offered at the nominated property and for ensuring that high standards of customer care are met.

In addition to the two managerial positions, the Joggins Fossil Institute will employ interpreters on a seasonal basis. These positions are responsible for advancing the educational mission of the Joggins Fossil Institute, monitoring activity of visitors to the site for compliance with the collecting policy, and enhancing the visitor experience by conducting guided tours of the property, by leading workshops and other educational programs.

Past Presentation of the Nominated Property

During the eighteen-year period preceding the nomination, former locally run fossil museums and visitor centres have supported the presentation of the Joggins Fossil Cliffs. In recent years, the Cumberland Regional Economic Development Agency, with support from the Nova Scotia Department of Tourism, Culture and Heritage, and Department of Natural Resources, has erected interpretive and safety signage at access points to the cliffs.

Numerous international associations, societies and conventions have conducted field trips to the Joggins Fossil Cliffs over the past century (a subset of these field trips is presented in Section 3.C (i)).

In particular, the Joggins Fossil Cliffs have attracted post-secondary school groups from Canada, the United States and abroad for investigative field trips. Among universities visiting the cliffs are Dalhousie University, St. Mary's University, McGill University, Mount Allison University, Pennsylvania State University, Colby College, Fairmont State University, University of Chicago, University of Nebraska, Kansas State University, and Berkeley College.

Figure 132 *Interpreting the fossil record.*

A range of Joggins Fossil Cliffs brochures, field guides and web sites exist and provide information related to the protective designation of the property, the geology, ecology and paleontology of the property and also safety considerations.

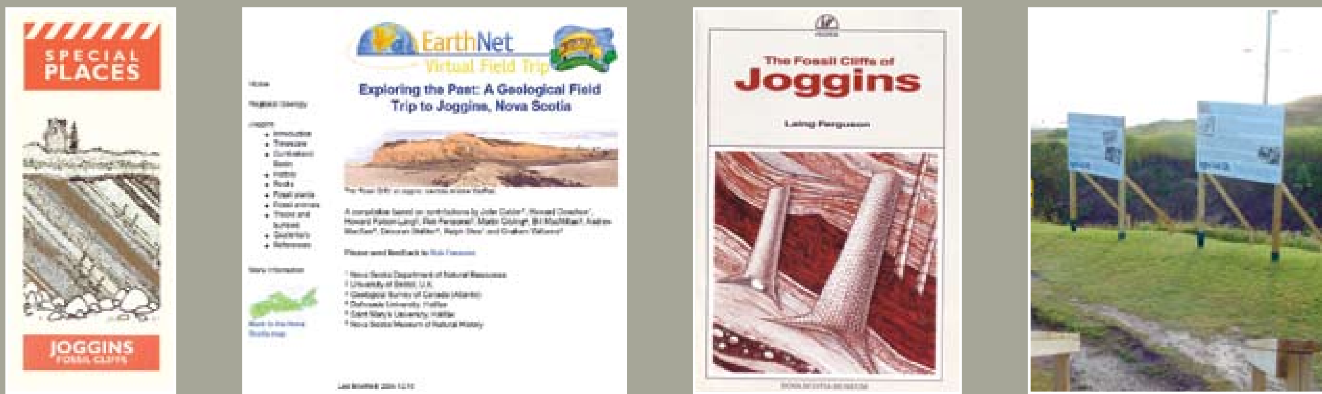


Figure 133 *Examples of visitor information from the recent past.*

Future Opportunities

In the United States, the Geological Society of America (GSA) runs a GeoVenture program that offers geoscience field trip experiences for professionals, amateur geologists, school teachers (K-12), and college students. GeoVentures range from weekend trips (GeoClass), week-long trips (GeoHostels), and fourteen-day or longer experiences (GeoTrips). Discussions with the GSA indicate that Joggins would be considered an excellent destination for a GeoHostel trip. In Canada, there are also a number of organizations involved in the delivery of geosciences education programs to geoscience professionals and teachers, including the Geological Association of Canada and the EdGeo Committee, which coordinates earth science workshops for Canadian teachers. The Canadian Society of Petroleum Geologists also has an outreach program that organizes courses, field trips and other educational initiatives for members. Discussions with each of these organizations indicated interest in collaborating with the Joggins Fossil Institute regarding the development of educational programs.

Cooperation with other, related institutions in the region, including the Fundy Geological Museum, Cape Chignecto Provincial Park and the Nova Scotia Museum of Natural History, will allow cross-interpretation and promotion. Moreover, relationships will be fostered with national and international institutions and organizations and may include the Natural History Museum, London, Smithsonian Institution, Washington D.C., Redpath Museum, Montréal, and other World Heritage fossil sites, including Parc National de Miguasha and Dinosaur Provincial Park & Royal Tyrrell Museum of Paleontology.

5.I (ii) PROMOTION OF THE PROPERTY

The Joggins Fossil Cliffs already receives a moderate level of visitation despite the presence, prior to nomination, of only very basic infrastructure and services, as well as minimal investments in advertising and promotion. If the nominated property is inscribed on the World Heritage List, promotion of the property with the UNESCO endorsement is expected to further increase visitation. Pending inscription as the outstanding representative of the Pennsylvanian Period of earth History, the Joggins Fossil Institute will actively promote the values expressed by the World Heritage Convention.

Figure 134 *The Joggins Fossil Cliffs steering committee members visit the Migusaha National Park World Heritage Site in 2000.*

The Joggins Fossil Institute has contracted the services of a marketing and public relations firm to assist managers and staff with developing and implementing an integrated communication and marketing strategy for The Joggins Fossil Cliffs (Appendix E:3). Immediate marketing objectives include the development of: a brand, a graphics standards manual, a newsletter, brochures, print ads, a website, promotional videos, a “Friends of The Joggins Fossil Cliffs” membership program and fundraising strategy. Multiple strategies will augment existing promotion of nominated property and its outstanding natural heritage values to resident, tourist, school and specialty groups (e.g., professional associations), including:

- prominent positioning of the property and Joggins Fossil Centre in provincial tourism promotion;
- placement of promotional road signage at key points;
- development of print material to be displayed at visitor information centres;
- advertising at regional attractions and hotels and purchased advertising in key tourism publications that

encourage visitors to time their visit to coincide with low tide and plan to spend sufficient time for both a tour of the Centre and a guided tour of the nominated property;
- use of promotional media such as local and provincial print advertising, local radio advertising and TV public service announcements supplemented by paid advertising spots;
- organization of familiarization tours of the property and Centre to increase awareness among the media and tourism industry;
- establishment of partnerships with group sales companies to attract bus tours to the nominated property;
- creation of a dedicated web site that includes the opportunity for on-line gift shop sales, tour booking, posting of tide tables and a schedule of guided tour times;
- creation and distribution of a teacher's guide that highlights the learning opportunities offered at the Centre/property and links to curriculum; and
- creation of a quarterly email newsletter for members and supporters.

These future marketing initiatives will expand the promotional work already undertaken through local signage and cooperative endeavours including:

- collaboration and joint marketing with the Fundy Geological Museum, Central Nova Tourist Association, and Cape Chignecto Park support the development of the Fundy Shore Tourism Destination Area; and
- the Bay of Fundy Tourism Partnership program. This Partnership develops and promotes the Bay of Fundy on Canada's east coast as an internationally-recognized, unique and remarkable nature-based tourism destination. This partnership advocates and delivers programs with the tourism industry in New Brunswick and Nova Scotia that support sustainability and conservation of the Bay of Fundy ecosystem (http://www.bayoffundytourism.com).

5.I.(iii) Use Of The World Heritage Emblem

If inscribed on the World Heritage List, guidelines and principles on the use of the World Heritage emblem that have been prescribed by UNESCO will be adhered to assiduously (Section VIII, The World Heritage Emblem; Operational Guidelines for the Implementation of the World Heritage Convention, 2005). The Joggins Fossil Institute and its municipal, provincial and federal partners recognize these conditions and will follow them for appropriate emblem use.

5.J STAFFING LEVELS

In order to fulfil its essential conservation, management, scientific and education mandate and to maximize the tourism potential and economic benefit of the property to the local community, The Joggins Fossil Institute will employ the following staffing complement.

Director

Reporting directly to the Joggins Fossil Institute Board of Directors, the Director is responsible for overseeing all aspects of the Joggins Fossil Centre and property operations. The Director recommends policies and plans to the Board, implements policies and plans approved by the board and reports on the outcome of these plans and policies. The Director has overall responsibility for human resources management, occupational health and safety and management of the operations of the Centre and property through the staff. The Director is responsible for financial management and seeking out sources of ongoing funding, including both private and public sources. The Director serves as the liaison with all levels of government and the local community, and develops strategies to promote the property locally, nationally and internationally. The Director is also responsible for ensuring compliance with the World Heritage Convention and liaising with Parks Canada.

Scientist

The Scientist is responsible for the security, preservation, documentation and interpretation of the palaeontological heritage at the property. The Scientist carries out and facilitates property-specific research solely and cooperatively with international researchers, makes that research available to the public and liaises with other researchers and institutions in the scientific community. The Scientist provides curatorial input into the development of exhibitions, advises on content of educational programs and is in part, responsible for the training of interpretive and collections staff. The Scientist leads tours and other educational programs for post-secondary and professional groups. To enhance the visibility of the property with the larger scientific community and to further scientific research, the Scientist publishes scientific papers, attends conferences and conducts lectures on a regular basis.

Manager of Programs

The Manager of Programs is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the property, as well as outreach programs and extension programs. The Manager of Programs develops educational materials to accompany exhibitions and provides input into the development of new and/or temporary exhibitions.

Interpreters

Interpreters are responsible for advancing the educational goals of the Joggins Fossil Institute, for monitoring the site, and enhancing the visitor experience by conducting guided tours of the cliffs and centre. Interpreters will lead workshops and facilitate other educational programs for visitors and groups. Interpreters will help to advance the scientific and research mission of the Joggins Fossil Institute by assisting in the preliminary identification, cataloguing and preparation of fossil specimens. Interpreters assigned to

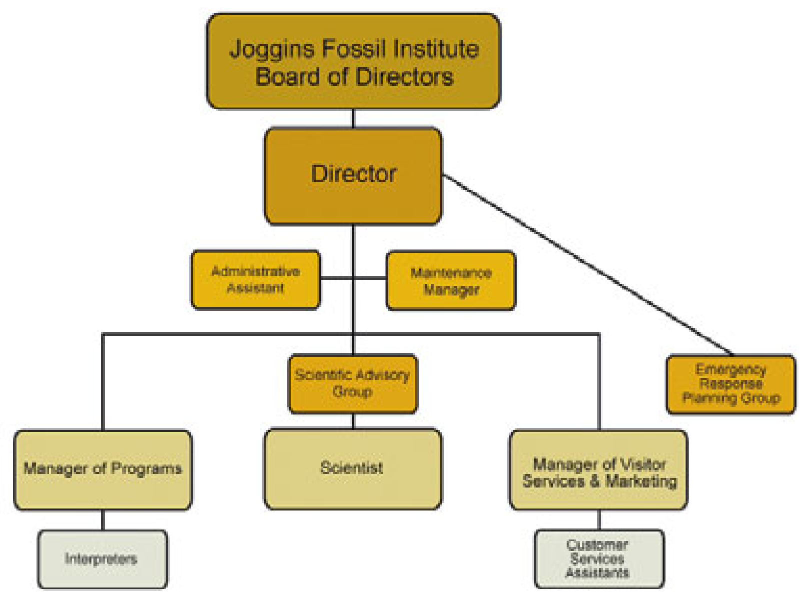


Figure 135 *Organizational chart of the Joggins Fossil Institute.*

coastal patrol will play a role in ensuring safe beach visitation and compliance with the fossil collecting policy.

Manager of Visitor Services and Marketing

The Manager of Visitor Services and Marketing is responsible for the overall quality of the services offered at the Centre and for ensuring that high standards of customer care are met. The Manager of Visitor Services and Marketing recruits and manages customer service staff (admissions and retail), develops and implements the strategic marketing plan for the Joggins Fossil Cliffs and Centre in conjunction with the director and ensures that the Joggins Fossil Institute responds to multiple markets and changing visitors demands. The Manager designs and implements visitor use monitoring systems and social science research related to visitor satisfaction, expectations and trends. The Manager of Visitor Services and Marketing is responsible for overseeing revenue-generation including the gift shop, food-service concession, internet café and rentals.

Customer Service Assistants

Customer Service Assistants are responsible for greeting visitors, answering general enquiries and introducing visitors to the menu of activities and experiences that can be enjoyed at the Centre and property. Customer Service Assistants process admissions, gift shop transactions and fossil exploration permit purchases, and maintain gift shop and information displays.

Administrative Assistant

The Administrative Assistant provides support services for the Centre and property operations. Responsibilities include: bookkeeping; clerical and filing duties; processing payment for workshops and programs; maintaining a database mailing list; program administration including course registration.

Maintenance Manager

The Maintenance Manger is responsible for overseeing all aspects of facility and property maintenance of the physical plant and grounds of the Centre. Through an ongoing system, the Maintenance Manager will determine the need for repairs and preventative maintenance and will carry out necessary maintenance and repairs or will oversee the procurement and delivery of contracted services as necessary.

Shared Staffing Opportunities

There are opportunities for shared staffing between Joggins Fossil Cliffs and nearby Cape Chignecto Provincial Park. The shared staffing positions are envisaged as follows:

- Property and Maintenance Manager:
  50% Joggins - 50% Cape Chignecto
- Manager of Visitor Services and Marketing:
  70% Joggins - 30% Cape Chignecto
- Manager of Programs:
  70% Joggins - 30% Cape Chignecto
- Director:
  80% Joggins - 20% Cape Chignecto
- Scientist:
  90% Joggins – 10% Cape Chignecto

In addition to the 3.9 full-time equivalent management and administrative positions, 6 full-time seasonal Interpreters and 2 Customer Service Assistants are employed to provide resources solely for the Joggins Fossil Cliffs property.

This staffing complement, and commensurate levels of remuneration, ensures that there will be a highly qualified scientific and educational team in place at Joggins, as befits the nominated property's outstanding scientific and educational importance. The structure also puts in place a strong management team, which will be required to oversee the daily operations of the Centre and property, to work closely with the governing board, to work toward ensuring that World Heritage goals are paramount, and toward promoting this property as a world-class destination. In addition to the positions directly associated with the management and operation of the property, managers and staff will have additional support through two advisory groups, a Scientific Advisory Committee and an Emergency Response Planning Group.

Scientific Advisory Committee

The role of the Scientific Advisory Committee is to report on the state of conservation of the nominated property and to support the advancement of scientific research at the Joggins Fossil Cliffs. The Scientific Advisory Committee advises the Joggins Fossil Institute on scientific matters relevant to managing the nominated property. Members of the scientific community nominate representatives for the committee and are appointed by the Joggins Fossil Institute Board of Directors every three years. The committee meets several times a year to identify and evaluate research needs in all areas of science including the social, geological and biological sciences. The committee also examines and advises on development proposals and perceived threats to the nominated property.

Emergency Response Planning Group

The Joggins Fossil Cliffs Emergency Response Planning Group is committed to the planning, preparation, review and reporting of an emergency response for The Joggins Fossil Cliffs. This group acts in an advisory capacity and reports to the Director of the Joggins Fossil Institute. The group membership includes representative from the following organizations:

- Emergency Measures Organization of the County of Cumberland;
- Emergency Health Services of Nova Scotia;
- Joggins Fire Department;
- Royal Canadian Mounted Police;
- Springhill Ground Search and Rescue; and
- Nova Scotia Department of Natural Resources.

Community volunteer groups, including the River Hebert and Joggins Development Association, and the planned membership group, the "Friends of the Joggins Fossil Cliffs," also play a significant role in the promotion and presentation of the property. Furthermore, provincial and federal government employees have an existing role in providing advice on property management, earth science conservation, reporting and monitoring.

6 Monitoring

A field excursion along the "Classic Section."

Figure 136 Coal Mine (Hardscrabble) Point.

6.A KEY INDICATORS FOR MEASURING STATE OF CONSERVATION

The World Heritage Convention requires State Parties to report on the state of conservation of World Heritage properties under their administration on a six-year cycle. If the nominated property is inscribed on the World Heritage List, the Joggins Fossil Institute will prepare a report on the state of conservation of the property and contribute to Canada's report to the World Heritage Committee. A monitoring program has been established to collect data on the state of conservation of the nominated property (for the fossil and ecological heritage) and the quality of the visitor experience (education and promotion of property and its heritage values).

The nominated property comprises the geological exposures of an active and robust coastline that is shaped by profound forces of nature. Conservation measures consider the integrity of the entire geological section, and recognize that special attention must be paid to the fossil record that may be impacted by the forces of nature and by the human penchant for collecting. A detailed log of the sedimentary sequence, recorded bed-by-bed at centimetre-scale by an international team of geoscientists, provides an exceptional record by which to assess conservation of the site and in which to place past and future fossil discoveries (Appendix J).

One of the primary concerns of conservation at the Joggins Fossil Cliffs entails the description, documentation and retrieval of fossils from the actively eroding shoreline. The property is an exposure of fossil-bearing sedimentary rock that is completely exposed in cross-section at the cliff-face and which extends unexposed inland beneath a mantle of unconsolidated glacial deposits for many kilometres.

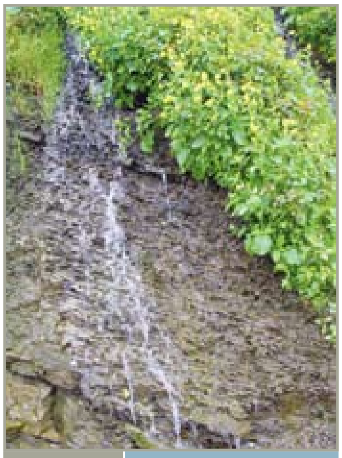


Figure 137 The modern ecology at the Cliffs.

The fossil heritage inland is protected by its subterranean position, as well as by protective legislation of the *Special Places Protection Act*. At the nominated property, coastal erosion creates fresh exposures continually with its attendant potential for ongoing loss of fossils due to erosion by natural processes and collecting pressure. As the main threats to the paleontological heritage at Joggins are excessive or unauthorized collecting of specimens and loss or damage due to the processes of natural erosion, responsible collecting for scientific and educational purposes and monitoring the property is of paramount importance.

6.A (i) Indicators of state of conservation of paleontological heritage

Key indicators of the state of conservation of the paleontological heritage at Joggins have been identified which will serve as a basis for monitoring and the subsequent annual report. The indicators are set out in the table below (Table 6.1).

Table 6.1 Indicators of Conservation of Paleontological Heritage

Attribute	Indicator	Periodicity	Location of Records
Maintain integrity of the classic fossil cliffs	Assessment of sedimentary succession and contained fossil beds related to collecting and natural processes of erosion	Monthly (May – October)	Joggins Fossil Institute
	Review of human impacts in buffer zone	Annual	Joggins Fossil Institute, Municipality of the County of Cumberland, & Nova Scotia DNR
	Stakeholder engagement (community/government etc)	Annual	Joggins Fossil Institute
	Incidences of illegal fossil collecting/excavation	Monthly	Joggins Fossil Institute, Nova Scotia Department of Natural Resources, & RCMP
Continued strong level of scientific interest in the property	Number of peer reviewed papers in scientific journals	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Number of conference/workshop field trips hosted	Annual	Joggins Fossil Institute
	Frequency and duration for hosting visiting scientists	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Report of research conducted by visiting scientist	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Number of research projects	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Number of Scientific Heritage Research Permits issued	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage
	Number of Stewardship Heritage Research Permits issued	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage
Conservation of the fossil record of biodiversity	Report on fossil specimens accessioned to formal museum collections	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage
	Status of type specimens in world collections: newly designated or synonymised	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage

6.A (ii) Indicators of ecosystem health

The Bay of Fundy Ecosystem Partnership (BoFEP: http://www.bofep.org), a "virtual," web-based institute comprising academic institutions, coastal communities, ecotourism groups, environmental and conservation groups, fishery organizations and government agencies, promotes the ecological integrity, vitality, biodiversity and productivity of the Bay of Fundy ecosystem. The Bay of Fundy Ecosystem Partnership also facilitates and enhances communication and co-operation among citizens interested in stewardship of the Bay of Fundy, including its habitats and ecological processes.

Figure 138 *Collaborating in environmental monitoring.*

The Joggins Fossil Institute is a member of the Bay of Fundy Ecosystem Partnership and will collaborate with other member organizations to help identify, study, prevent and treat environmental pressures affecting the Bay of Fundy ecosystem, particularly in the Joggins area. Assessments of wildlife populations and beach conditions (e.g., litter and pollution) will be conducted annually and reported by the Joggins Fossil Institute.

6.A (iii) Indicators of sustainable administrative practices

The low-impact infrastructure necessary to enhance the property and enable pursuit of the Joggins Fossil Institute goals (e.g. fossil protection, safe visitation, promotion of heritage values, interpretation and education) will respect the inclusive, prudent and conservational principles outlined in the Joggins Fossil Cliffs Management Plan (Appendix C). Furthermore, any future development of the property and adjacent lands will be controlled through federal and provincial legislation, and through municipal land use bylaws.

The coal deposits that lent their name to the period of earth history for which Joggins is the outstanding example in the world, fuelled the Industrial Revolution and are today implicated in issues of global change. Accordingly, the Joggins Fossil Institute has made a concerted effort to attain the highest standards of energy conservation and ecological stewardship. Specifically, the Joggins Fossil Institute has strived to ensure that the Joggins Fossil Centre achieves a silver rating in Leadership in Energy and Environmental Design (LEED: accreditation in Green Building Rating System). The independently powered Centre will house and promote fossils from the Carboniferous Period while releasing a minimum of greenhouse gases and capitalizing on the Bay of Fundy's rich wind resources. Moreover, the Joggins Fossil Institute will undergo an annual International Standards Organization 9001:2000 audit through the Cumberland Regional Development Association.

6.B ADMINISTRATIVE ARRANGEMENTS FOR MONITORING PROPERTY

The conservation goals included in the Joggins Fossil Cliffs Management Plan (Section 5.E and Appendix C) can only be demonstrated by monitoring its implementation. The responsibility for coordinating the monitoring of the nominated property will be undertaken by the Joggins Fossil Institute.

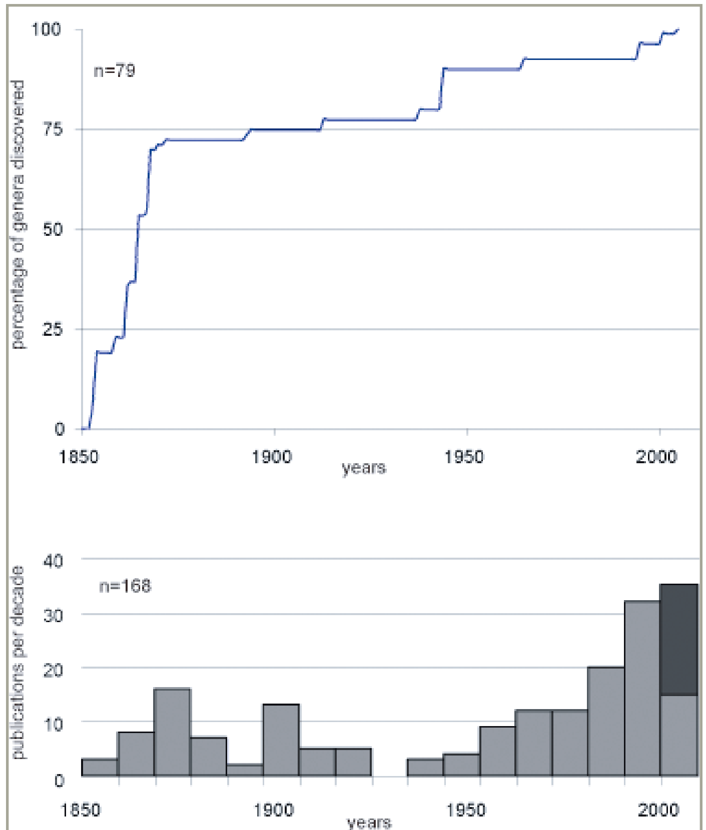


Figure 139 *History of scientific publication on Joggins, from Falcon-Lang, 2006.*

Monitoring data is available through the Director of the Joggins Fossil Institute at:

Joggins Fossil Institute
35 Church Street, P.O. Box 546
Amherst, Nova Scotia
Canada B4H 4A1
902-667-3638

The frequency of monitoring the various indicators and the responsibility for doing so are indicated in Section 6.A. An annual progress report will be prepared and made publicly available on the World Wide Web.

6.C RESULTS OF PREVIOUS REPORTING EXERCISES

No formal reporting has been conducted to date, with the exception of reports of paleontological and geological research conducted under Heritage Research Permits issued by the Nova Scotia Museum, Halifax, and the 178-year publication record of scientific research (Section 7.E).

7

Documentation

The reefs at Boss Point.

Documentation associated with the content of this nomination dossier is appended under separate covers.

7.A PHOTOGRAPHS, SLIDES, IMAGE INVENTORY AND AUTHORIZATION TABLE AND OTHER AUDIOVISUAL MATERIALS

7.A (i) APPENDIX A
Slides (with thumbnails) and Authorization Table

7.A (ii) APPENDIX B
Video overview of property (DVD)

7.B TEXTS RELATING TO PROTECTIVE DESIGNATION, COPIES OF PROPERTY MANAGEMENT PLANS OR DOCUMENTED MANAGEMENT SYSTEMS AND EXTRACTS OF OTHER PLANS RELEVANT TO THE PROPERTY

7.B (i) APPENDIX C
Management Plan

- Joggins Fossil Cliffs Management Plan

7.B (ii) APPENDIX D
Comparative Study

- Comparative Analysis of Pennsylvanian Fossil Sites with reference to the Joggins Fossil Cliffs, Nova Scotia, Canada

7.B (iii) APPENDIX E
Supporting documentation – Specific

E:1 Erosion Analysis of the Joggins Area: A Preliminary Investigation

E:2 Joggins Fossil Cliffs Emergency Response Plan (draft)

E:3 Communications Plan for Joggins Fossils Cliffs and Cape Chignecto Provincial Park

E:4 Joggins Fossil Cliffs: Comprehensive Site Development Plan

E:5 Joggins Fossil Cliffs Centre: 100% Design Development Production Manual

E:6 Joggins Fossil Cliffs: Operating Revenue and Expense Projections Report

7.B (iv) APPENDIX F
Supporting documentation – General

F:1 Fundy Shore 209/242 Alliance Tourism Development Study

F:2 Cumberland Regional Economic Development Association: 2006/2007 Business Plan

F:3 Joggins Fossil Cliffs World Heritage Site Designation Initiative: Community Consultation Process & Action Plan

7.B (v) APPENDIX G
Legislation

G:1 *Special Places Protection Act*

G:2 *Beaches Act* and *Regulations*

G:3 *Mineral Resources Act*

G:4 *The Municipality of the County of Cumberland: Secondary Municipal Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area*

7.B (vi) APPENDIX H
Agreements

H:1 Joggins Fossil Institute/CREDA & Nova Scotia Department of Natural Resources

H:2 Joggins Fossil Institute & The Cumberland Regional Economic Development Association

7.C FORM AND DATE OF MOST RECENT RECORDS OR INVENTORY OF PROPERTY

7.C (i) APPENDIX I

Maps

Map 1: Joggins Fossil Cliffs: Property Nominated for Inscription on the World Heritage List

Map 2: Joggins Fossil Cliffs: Nominated Property and Buffer Area

Map 3: Land Ownership

Map 4: MAP 90-12 Cumberland Basin Geology Map: Amherst, Springhill and Parrsboro Cumberland County

Map 5: Plan of Certain Lands Lying Landward from the Mean High-water Mark of Lower Cove Beach, County of Cumberland, Province of Nova Scotia

7.C (ii) APPENDIX J

Inventory of Property

- Reference Sedementological Logs of the Joggins and Little River Formations

7.C (iii) APPENDIX K

Scientific Research

- A Selection of Key Papers of the Modern Era in International Peer Reviewed Journals

7.D ADDRESS WHERE INVENTORY, RECORDS AND ARCHIVES ARE HELD

Joggins Fossil Institute
35 Church Street, P.O. Box 546
Amherst, Nova Scotia
Canada B4H 4A1

Nova Scotia Department of Tourism, Culture and Heritage
Heritage Division
1747 Summer Street
Halifax, Nova Scotia
Canada B3H 3A6

7.E BIBLIOGRAPHY (OF SCIENTIFIC PAPERS RELATED TO THE JOGGINS FOSSIL CLIFFS AND ITS FOSSIL RECORD)

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The grand succession of sedimentary layers.

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8.B OFFICIAL LOCAL INSTITUTION

The official local institution responsible for the management of the nominated property is the Joggins Fossil Institute.

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8.D OFFICIAL WEB ADDRESS

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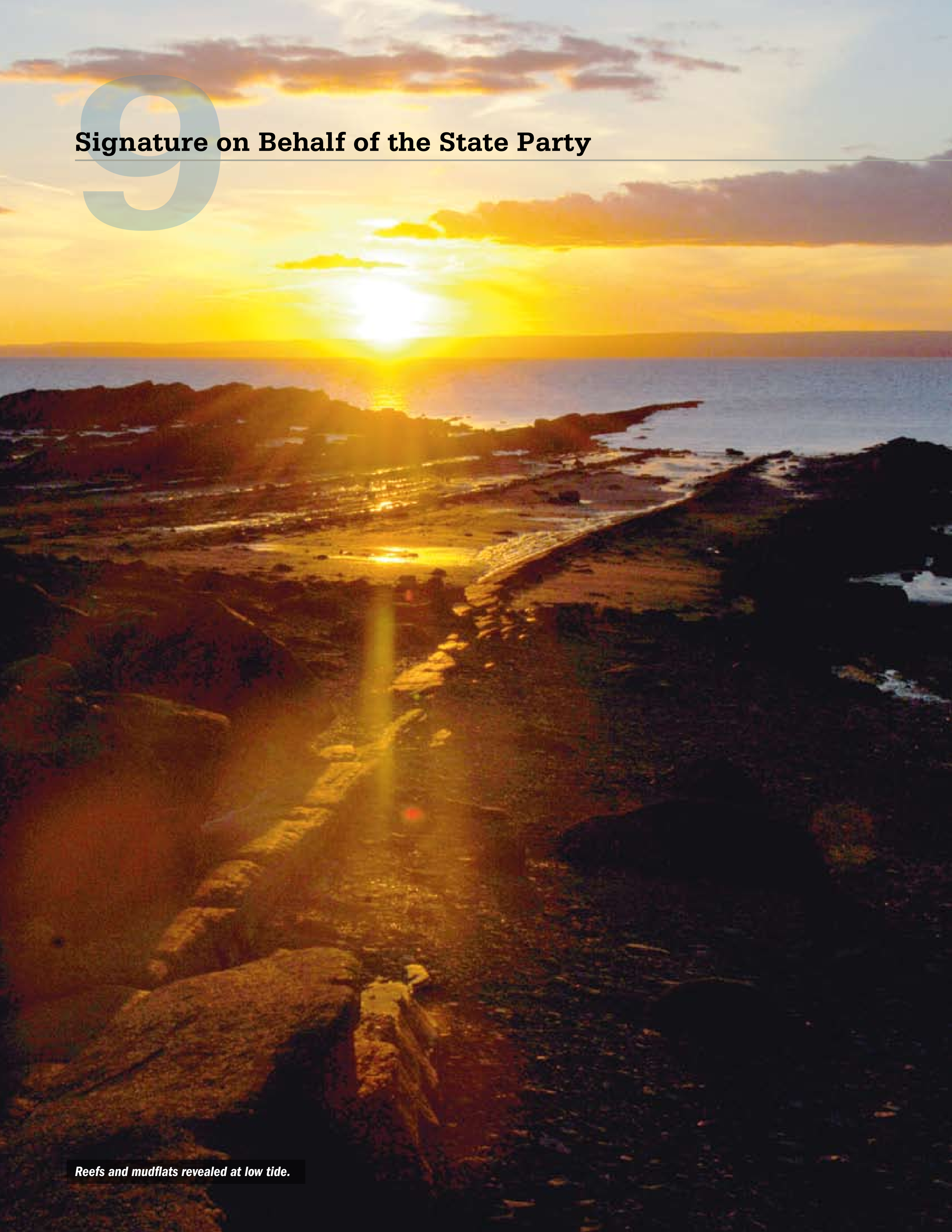
9 Signature on Behalf of the State Party



Reefs and mudflats revealed at low tide.

Signed (on behalf of the State Party)

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Full name	**Dr. Christina Cameron**
Title	**Head of the Canadian Delegation to the World Heritage Convention**
Date	______________________

Citations by Section

SECTION 1

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SECTION 5

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Image Credits

Donald Agnew, CREDA: Figures 2, 3, 4a, 4b, 9b, 14, 25, 28, 29, 30, 32, 36, 84, 94, 99, 105, 106, 108, 109, 110, 112, 113b, 121, 123, 124, 133, 135.
Jenna Boon: Figure 125.
Mark Boon: Figure 80b.
Wayne Burt, NSDNR: Figures (i), 85.
John Calder, NSDNR: Section 2, 4 frontispieces, Figures 7, 8, 9a, 13, 15, 16, 17, 18, 21, 22, 23, 26, 27, 31, 33, 44, 58, 74, 65, 66, 68, 69, 74, 90, 78, 79, 80a, 80c, 87, 93c, 95, 101, 102, 104, 118, 122, 132, 134, 137.
Cumberland County Museum: Figure 70.
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Howard Falcon-Lang: Figures 93b, 139.
Laing Ferguson: Figure 81.
Deanne Fitzpatrick: Figure 80b.
Geological Survey of Canada: Figures 42, 43, 64, 86, 90.
Robert Grantham: Figure 88.
Stephen Greb: Figure 82, 116.
Wally Hayes, NSDTCH: Sections 1, 5, 6, 8, 9 frontispieces, Figures 5, 6, 11, 12, 19, 20, 35, 56, 103, 114, 115, 119, 126, 136.
Douglas Henderson: Section 3 frontispiece, Figure 100.
Dara Legere: Figures 71, 72, 73, 83, 84, 85, 107, 111.
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Reg Morrison, NSDNR: Figures 46, 93a; Thumbnails, Tables 2.1-2.4.
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John Sherlock: Sections 7 frontispiece.
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DiMichele and DeMaris: Figure 34 (modified).
Lyell and/or Dawson: Figures 45, 60, 61, 63, 77, 113a.
Natural History Museum of London: Figure 89.
Fundy Geological Museum: Figure 97.
Nova Scotia Department of Natural Resources: Figure 120.
Bay of Fundy Ecosystem Partnership: Figure 138.
Uncredited: Figures 37, 40, 41, 48, 49, 50, 51, 52, 53, 54, 55, 62.

ar Minudie, Nova Scotia.

with upright trees. Sandstone and shale. Sou

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Fig. 21.

Funding Partners

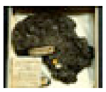
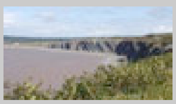
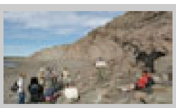
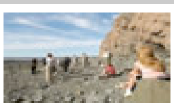
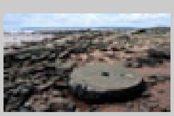
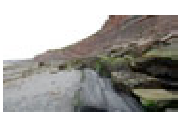
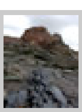
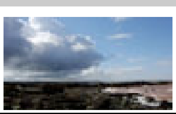
This project was made possible through the generous funding support of the province of Nova Scotia, Atlantic Canada Opportunities Agency and The Municipality of the County of Cumberland.

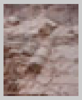
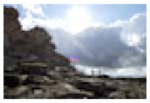
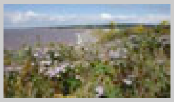
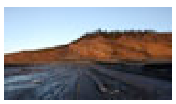
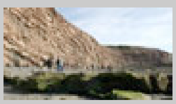
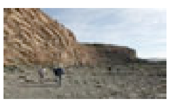
NOVA SCOTIA

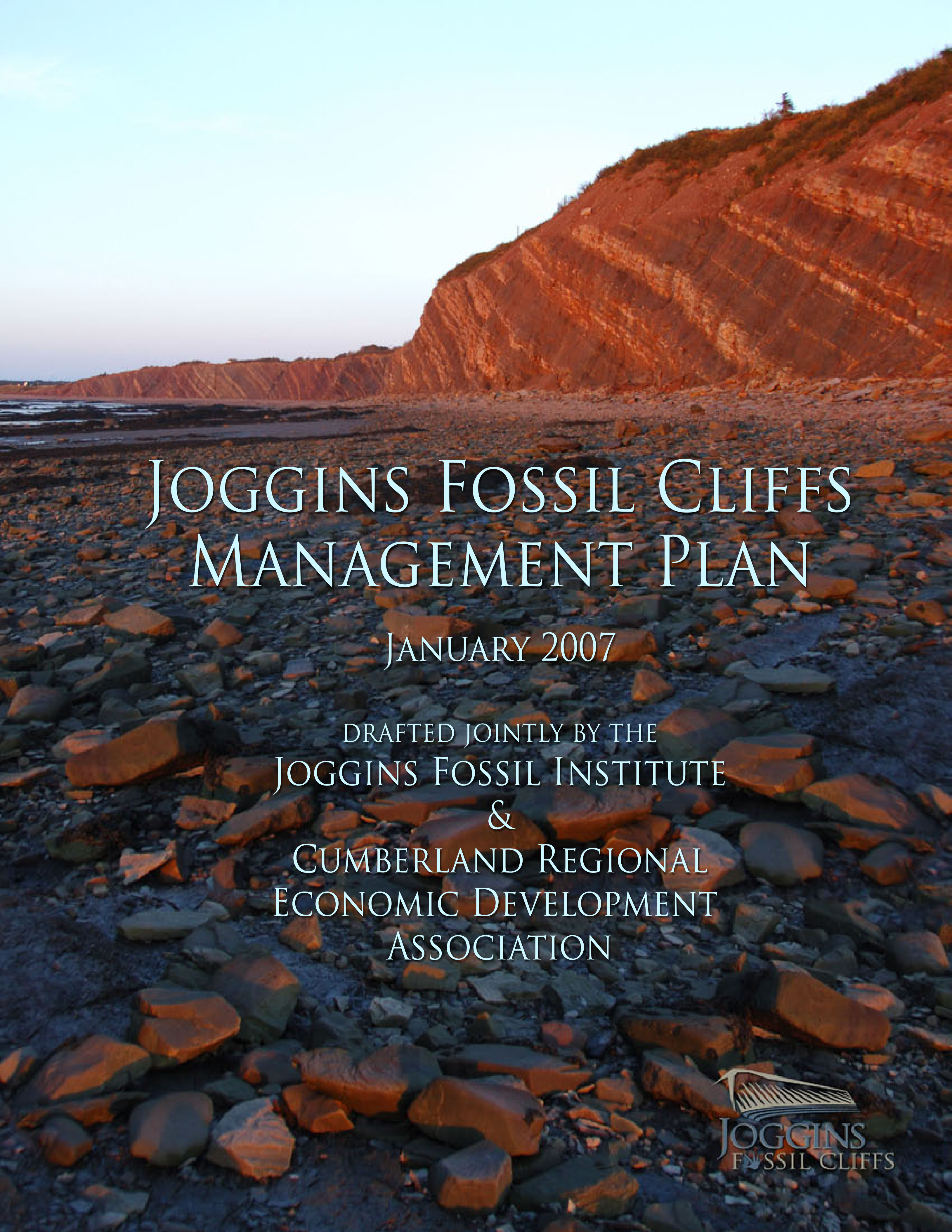
Atlantic Canada Opportunities Agency

Agence de promotion économique du Canada atlantique

CUMBERLAND COUNTY MUNICIPALITY CORPORATION

16		Visiting scientist Dr. Andrew Milner	1999	John Calder		Yes
17		*Adiantites*	1993	Reg Morrison	N.S. Dept. of Natural Resources, (902) 424-2778	Yes
18		*Macroneuropterid*	2005	John Calder		Yes
19		Skull of *Dendrerpeton acadianum*	2003	Heinz Wiele		Yes
20		Amniote tree and earliest reptiles from Joggins	Nov./2006	Donald Agnew	CREDA - JFI	Yes
21		Type specimen of *Hylonomus lyelli,* the oldest known reptile	Jun-94	John Calder		Yes
22		Cliffs from Hardscrabble Road	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
23		The Big Volume	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
24		Interpreting the Rocks	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
25		Interpreting the Rocks I	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
26		Interpreting the Rocks II	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
27		Interpreting the Rocks III	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
28		Nineteenth century grindstone at Lower Cove	1998	John Calder		Yes
29		"Clam coal" and cliffs	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
30		Coal bed at Coal Mine Point	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
31		Towards Ragged Reef	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes

32		Standing tree in cliff	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
33		Coal Mine Point silhouette	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
34		Vista at Lower Cove	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
35		The cliff face at sunset	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
36		The cliffs, reefs and intertidal flats	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
37		The cliffs, reefs and flats	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
38		Visitors at the cliffs	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
39		Field trip making their way	Aug./2005	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes
40		Cliffs at sunset, towards Lower Cove	Oct./2006	Walley Hayes	N.S. Dept. of Tourism, Culture and Heritage	Yes



Joggins Fossil Cliffs Management Plan

January 2007

drafted jointly by the

Joggins Fossil Institute

&

Cumberland Regional Economic Development Association

Joggins Fossil Cliffs

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1.0 INTRODUCTION AND PURPOSE

This plan specifies how the natural heritage values of the Joggins Fossil Cliffs will be protected for present and future generations. In doing so it fulfills the requirements of paragraph 108 of the *Operational Guidelines for the Implementation of the World Heritage Convention* (2005), and supports the nomination and subsequent operation of the Joggins Fossil Cliffs as a World Heritage Site. It constitutes the commitment of the partners (the Joggins Fossil Institute, the province of Nova Scotia -Departments of Tourism Culture and Heritage and Natural Resources-, the Municipality of the County of Cumberland and the Cumberland Regional Economic Development Association) to the conservation, protection and promotion of the property. This Plan identifies the outstanding universal value of the nominated property, the legislative and policy framework for the management of the property, and the management system in place to protect, present and monitor the site. This plan builds on the province of Nova Scotia's commitment to conservation, protection and promotion of natural heritage through the *Special Places Protection Act* and responsible coastal resource management through the *Beaches Act* and associated *Regulations*.

The management approach of the Joggins Fossil Institute places great importance on the scientific value of the fossil resources and bedrock exposures of the Joggins Fossil Cliffs. As a strategic document, the Joggins Fossil Cliffs Management Plan specifies the commitments and actions that will be implemented in order to protect, conserve and promote the nominated property over the long term.

2.0 STATEMENT OF OUTSTANDING UNIVERSAL VALUE

The coastal cliffs at Joggins reveal the most complete fossil record in the world of terrestrial life in the Pennsylvanian "Coal Age" of earth history. Nowhere is this record of the evolution of life on land and biodiversity in the tropical "Coal Age"—encompassing plant, invertebrate and vertebrate life—rendered more evocatively. The magnificently exposed succession of sedimentary layers preserves the fossils *in situ*, providing environmental context that is unrivalled in the world. The fossil record includes the two defining, iconic elements of the "Coal Age": fossil forests of the "coal swamps" and the first reptiles, which as the earliest amniotes are the oldest known representatives of reptiles, birds and mammals. The origin of amniotes, the first vertebrates to achieve the capacity to reproduce on land, was one of the most significant events in the history of life on earth, an evolutionary milestone first recorded with certainty at Joggins. No other locality in the world has provided as much knowledge of the nature of early amniotes or more informative specimens for linking them to more primitive groups of Palaeozoic tetrapods, and to the world in which they lived. Through the power of the Bay of Fundy tides, which are unsurpassed in the world, ongoing discovery is ensured at this site of outstanding universal value.

This dramatic setting is home to what Sir Charles Lyell, founder of modern geology, described as "the finest exposure in the world" of the rocks and fossil record of the Pennsylvanian "Coal Age" of earth history. The fossil record of Joggins figured in the first debate on evolution, and remains pivotal to understanding the terrestrial origins of vertebrate life, including our own species. This uniquely representative chapter of the earth's history has been the subject of the research and writings of some of the world's most influential scientists since the mid-nineteenth century. Joggins has figured in such seminal works as *Principles of Geology* by Lyell and *The Origin of Species* by Charles Darwin, and has come to be known as a "Coal Age Galapagos."

3.0 CRITERION FOR INSCRIPTION ON THE WORLD HERITAGE LIST

The coastal cliffs of Joggins are nominated for inscription to the World Heritage List under "criterion viii" of the Operational Guidelines for World Heritage (2005), which states that sites:

> "be outstanding examples representing major stages of Earth's history, including record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features."

The nominated property is the most outstanding example of the tropical terrestrial ecosystems of the Pennsylvanian period in earth history. The fossil record, preserved *in situ* at Joggins, provides environmental context unrivalled in the world. The presence of the first reptiles marks a major evolutionary event in earth's history, recording a significant advance in the adaptation of invertebrates to life on land. Other events in the history of life are recorded in the fossil record of Joggins, including the first appearance of land snails (the genus *Dendropupa*), which persist today, and the last appearance of the huge bivalve clam Archanodon, which may prove to be the missing link to the extant unionids. Nowhere is this record of biodiversity and evolutionary innovation of life on land – encompassing plant, invertebrate and vertebrate life – rendered more evocatively, as exemplified by fossils of the world's earliest known reptile *Hylonomus lyelli*, entombed within once hollow trees.

The fossils of Joggins are set apart from those of other Carboniferous sites because they are preserved *in situ*, rather than having been transported and subsequently deposited. Consequently the ecological context of the Joggins fossil organisms is also preserved allowing for a much fuller understanding of the palaeoecology of the "Coal Age." An example of the value of this ecological context is demonstrated by recent research at Joggins that has revealed a history of climate change during the "Coal Age" that produced periodic dryland ecosystems that contrast with the more typical tropical wetland environments.

The fossils at Joggins display a high quality of preservation, and the site has been important historically in the evolution of the science of palaeontology. Ongoing discovery and research at this dramatic natural site, continually eroded by the world's highest tides, ensure that this history will continue.

In addition to its role in fulfilling the above criterion as an outstanding example of earth history, Joggins is one of only a few natural sites in the world that also meets virtually all international criteria for fossil sites.

4.0 MANAGEMENT FRAMEWORK FOR THE NOMINATED PROPERTY

4.1 Description and Status of the Nominated Property

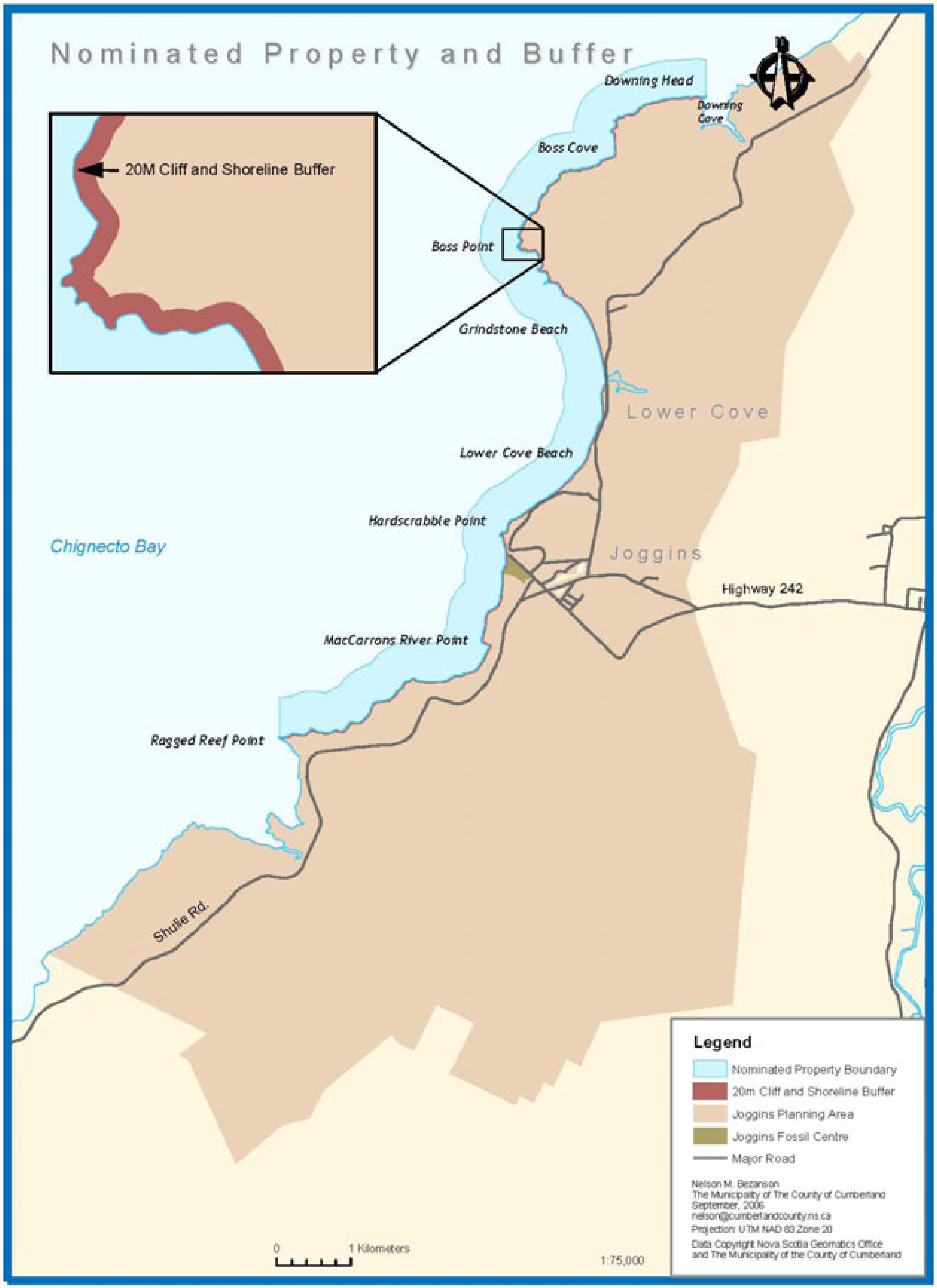
The nominated property consists of a 14.7 kilometre section of sea cliffs on the eastern shore of Chignecto Bay, a northern arm of the Bay of Fundy in northern mainland Nova Scotia. The site extends north and south of the village of Joggins, from Downing Head, the eastern headland at the mouth of Downey Cove (45° 45' 07'' North Latitude 64° 25' 05" West Longitude), south to Ragged Reef Point (45° 40' 24'' North Latitude, 64° 23' 09" West Longitude) (Figure 1). The landward boundary is defined as the top of the cliff face or bank. The seaward boundary is 500 metres from the landward boundary.

The nominated property includes the entire coastal exposure of the coal-bearing Joggins formation (the "Classic Section"), and the overlying Springhill Mines formation. The site also includes a portion of the overlying Ragged Reef formation in the south, and the underlying Little River and Boss Point formations of the Cumberland Group, and Claremont and Shepody formations of the Mabou Group in the north. These strata serve as geological buffer zones on either side of the "Classic Section". The geological buffer is greater for the older, underlying rocks in the north, as discoveries in these strata have the potential to become the oldest known examples of certain fossil taxa (Figure 2).

The geological contact at the base of the Boss Point Formation represents the base of the Pennsylvanian Period in the section, and the Boss Point-Claremont contact coincides with the globally significant Mississippian-Pennsylvanian ("Miss-Penn") unconformity (45 ° 42' 35" North Latitude 64° 26' 09" West Longitude).

The "Classic Section" at Joggins has been protected since 1972 through provincial legislation. In 2007, the boundaries of the nominated property will designated as a "protected site" through the *Special Places Protection Act* in recognition of the global scientific importance of the larger area. The property boundary includes geological formations that are considered to contain the features of current interest to the scientific community. The boundary also provides sufficient opportunities to develop infrastructure in support of public education and visitor use of the site. These boundaries have been described in such a way as to allow for variable erosion over the length of the site.

A significant portion (the Lower Cove Beach - including the "Classic Section") of the site has also been declared a "Protected Beach" pursuant to Nova Scotia's *Beaches Act*. Under this *Act*, the beaches of Nova Scotia are dedicated in perpetuity for the benefit, education and enjoyment of present and future generations of Nova Scotians (Figure 3). This legislation provides for the strong protection and regulation of the full range of land use activities on designated beaches.


Nominated Property and Buffer
20M Cliff and Shoreline Buffer
Downing Head
Downing Cove
Boss Cove
Boss Point
Grindstone Beach
Lower Cove
Lower Cove Beach
Hardscrabble Point
Chignecto Bay
Joggins
Highway 242
MacCarrons River Point
Ragged Reef Point
Shulie Rd.
Legend
Nominated Property Boundary
20m Cliff and Shoreline Buffer
Joggins Planning Area
Joggins Fossil Centre
Major Road
Nelson M. Bezanson
The Municipality of The County of Cumberland
September, 2006
nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
Data Copyright Nova Scotia Geomatics Office
and The Municipality of the County of Cumberland
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1 Kilometers
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Figure 1

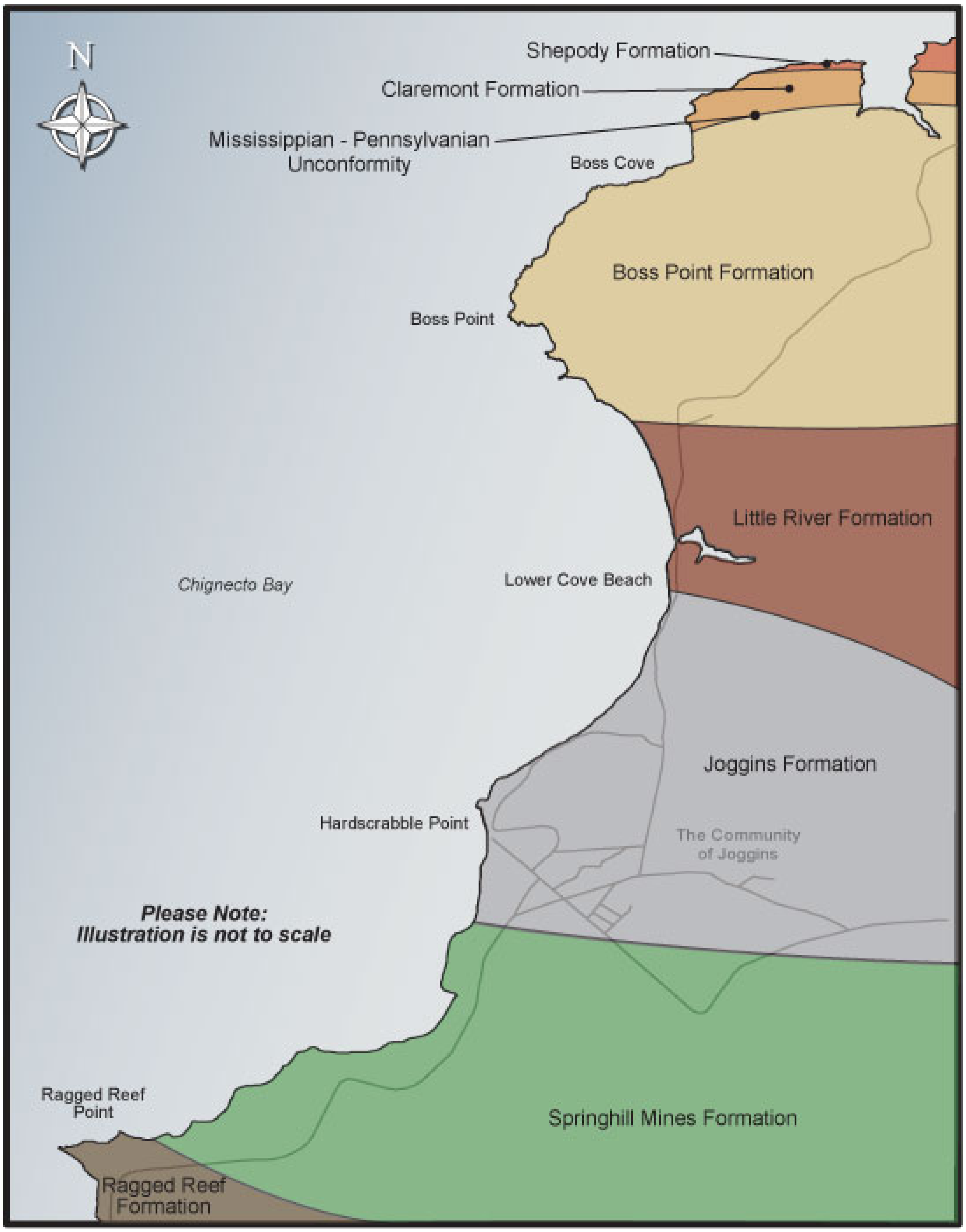
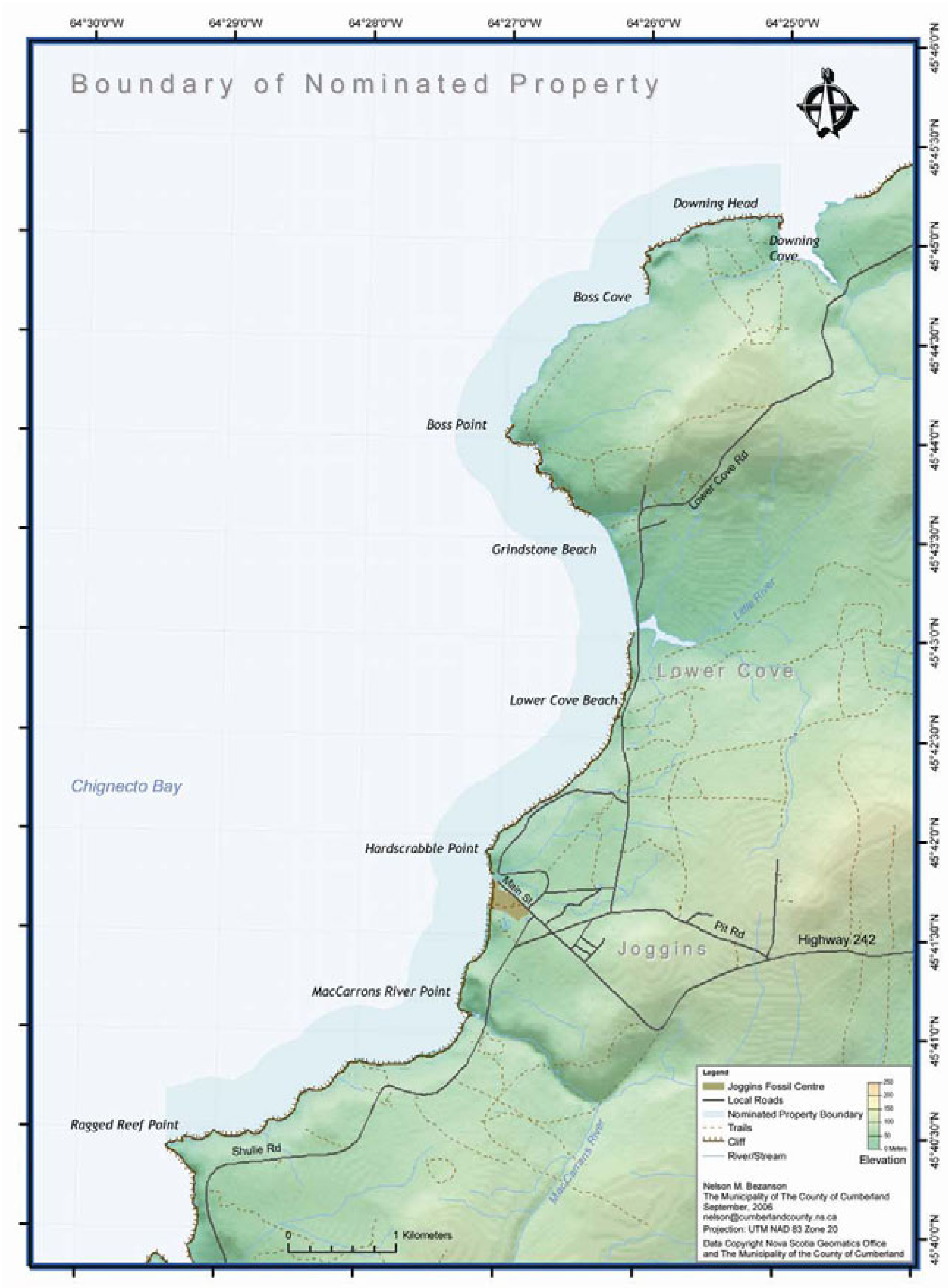

N
Shepody Formation
Claremont Formation
Mississippian - Pennsylvanian
Unconformity
Boss Cove
Boss Point Formation
Boss Point
Little River Formation
Chignecto Bay
Lower Cove Beach
Joggins Formation
Hardscrabble Point
The Community
of Joggins
Please Note:
Illustration is not to scale
Ragged Reef
Point
Springhill Mines Formation
Ragged Reef
Formation

Figure 2


64°30'0"W
64°29'0"W
64°28'0"W
64°27'0"W
64°26'0"W
64°25'0"W
45°46'0"N
45°45'30"N
45°45'0"N
45°44'30"N
45°44'0"N
45°43'30"N
45°43'0"N
45°42'30"N
45°42'0"N
45°41'30"N
45°41'0"N
45°40'30"N
45°40'0"N
Boundary of Nominated Property
Downing Head
Downing Cove
Boss Cove
Boss Point
Lower Cove Rd
Grindstone Beach
Little River
Lower Cove
Lower Cove Beach
Chignecto Bay
Hardscrabble Point
Main St
Pit Rd
Highway 242
Joggins
MacCarrons River Point
MacCarrons River
Ragged Reef Point
Shulie Rd
0
1 Kilometers
Legend
Joggins Fossil Centre
Local Roads
Nominated Property Boundary
Trails
Cliff
River/Stream
Elevation
0 Meters
Nelson M. Bezanson
The Municipality of The County of Cumberland
September, 2006
nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
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and The Municipality of the County of Cumberland

Figure 3

4.2 The Effect of Coastal Erosion on the Site and its Boundaries

As with any coastal site, the effects of erosion have a considerable impact on the cliffs. As this natural impact cannot be reasonably mitigated, boundaries have been described to maintain their integrity over time. The Joggins Fossil Cliffs are affected twice daily by the tides of the Bay of Fundy, which are the largest in the world. Not only do these tides have an impact on coastal erosion, they also reveal a large sub-tidal area twice daily during ebb (low) tide. This foreshore area includes a series of resistant bedrock "reefs" that offer a third dimension to the view of the strata revealed in cross-section in the cliffs. These reefs are also rich in fossils and offer special opportunities for visitors and researchers (Figure 4).

Figure 4

It is in recognition of the dynamic nature of coastal erosion, that the boundary has been described according to the physical features of the cliff and bank rather than absolute surveyed boundaries. As the cliffs erode the site boundary is congruent with the new exposure. The boundary is defined by topographic features visible in the landscape and therefore ensures that they are clearly identifiable on the ground and ultimately useful for site management.

A preliminary analysis of coastal erosion based on interpretation of historic air photos at Joggins was conducted in 2006. This analysis revealed that most of the area is subject to minimal to moderate rates of erosion, ranging from nil to 25 cm/year. The erosion trends suggest that there will be little effect on buildings, infrastructure or roads over the next century. The exceptions are the road near Lower Cove Beach, and Hardscrabble Road north of Hardscrabble Point (Figure 5).

Figure 5

4.3 Adjacent Land Use and Buffer Zone

Paragraph 104 of the *Operational Guidelines for the Implementation of the World Heritage Convention* makes provision for the identification of a buffer zone to protect World Heritage Sites from threats beyond their boundaries. In the case of the Joggins Fossil Cliffs, the integrity of the fossil heritage is naturally protected by the cliff, whose sheer face prevents development, and which is continually renewed by erosion. Nonetheless, four legislative controls including:

a) the *Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* (2006), through the *Municipal Government Act* (1998),
b) the *Beaches Act* and associated *Regulations* (1989),
c) the *Mineral Resources Act* (1990), and
d) the *Special Places Protection Act* (1989),

support the conservation of lands adjacent to the property and establishes a buffer to the nominated property. These legislative controls ensure the integrity of the nominated property for future generations (Figure 6, 7 and 8).

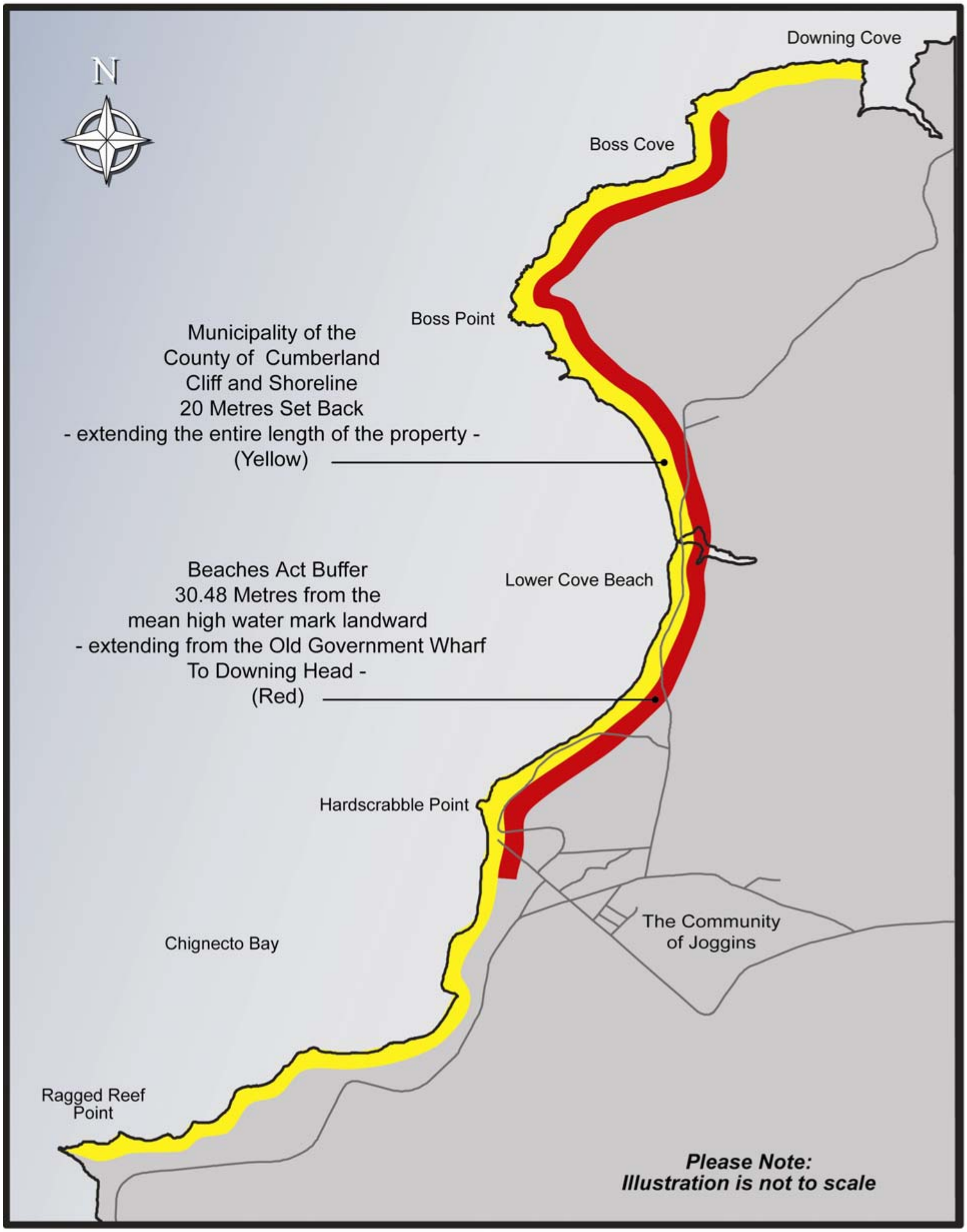

N
Downing Cove
Boss Cove
Boss Point
Municipality of the
County of Cumberland
Cliff and Shoreline
20 Metres Set Back
- extending the entire length of the property -
(Yellow)
Beaches Act Buffer
30.48 Metres from the
mean high water mark landward
- extending from the Old Government Wharf
To Downing Head -
(Red)
Lower Cove Beach
Hardscrabble Point
The Community
of Joggins
Chignecto Bay
Ragged Reef
Point
Please Note:
Illustration is not to scale

Figure 6

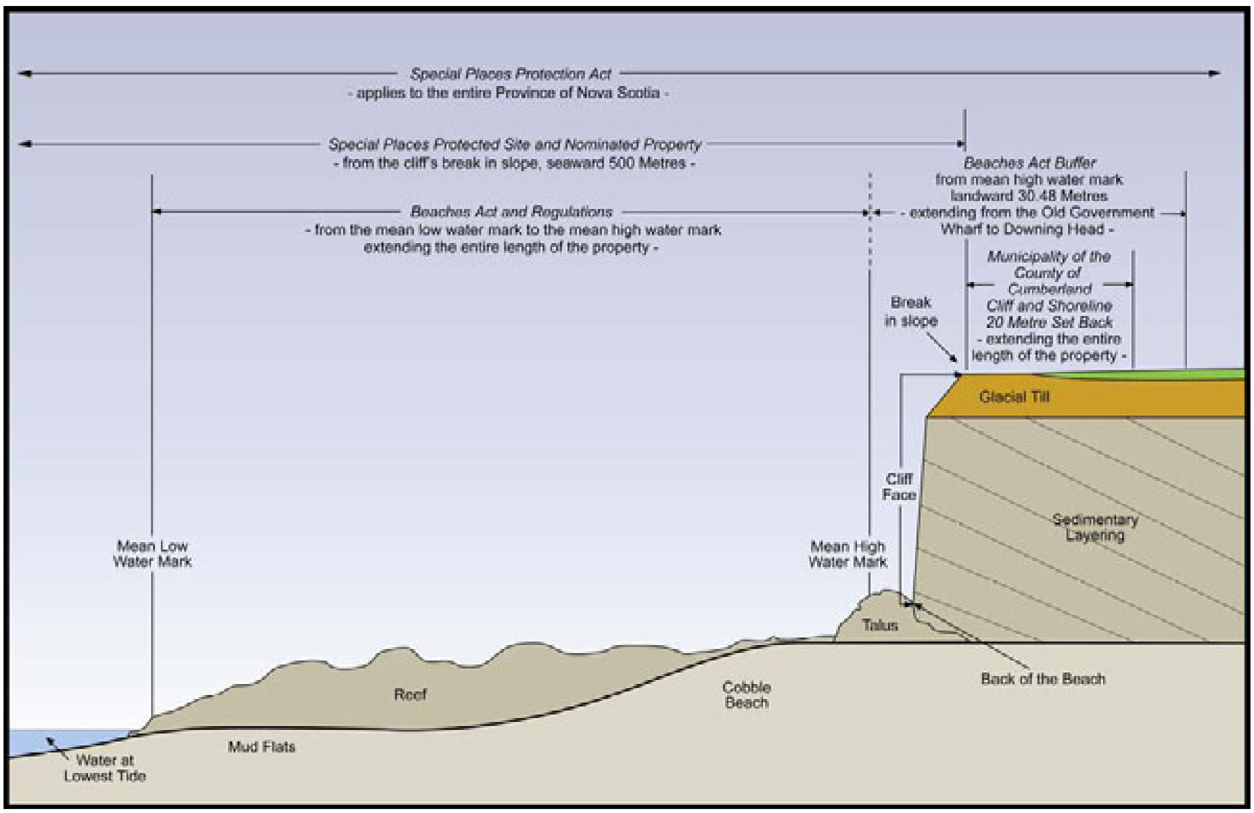

Special Places Protection Act
- applies to the entire Province of Nova Scotia -
Special Places Protected Site and Nominated Property
- from the cliff's break in slope, seaward 500 Metres -
Beaches Act Buffer
from mean high water mark
landward 30.48 Metres
- extending from the Old Government
Wharf to Downing Head -
Beaches Act and Regulations
- from the mean low water mark to the mean high water mark
extending the entire length of the property -
Municipality of the
County of
Cumberland
Cliff and Shoreline
20 Metre Set Back
- extending the entire
length of the property -
Break
in slope
Glacial Till
Cliff
Face
Sedimentary
Layering
Mean Low
Water Mark
Mean High
Water Mark
Talus
Back of the Beach
Reef
Cobble
Beach
Mud Flats
Water at
Lowest Tide

Figure 7

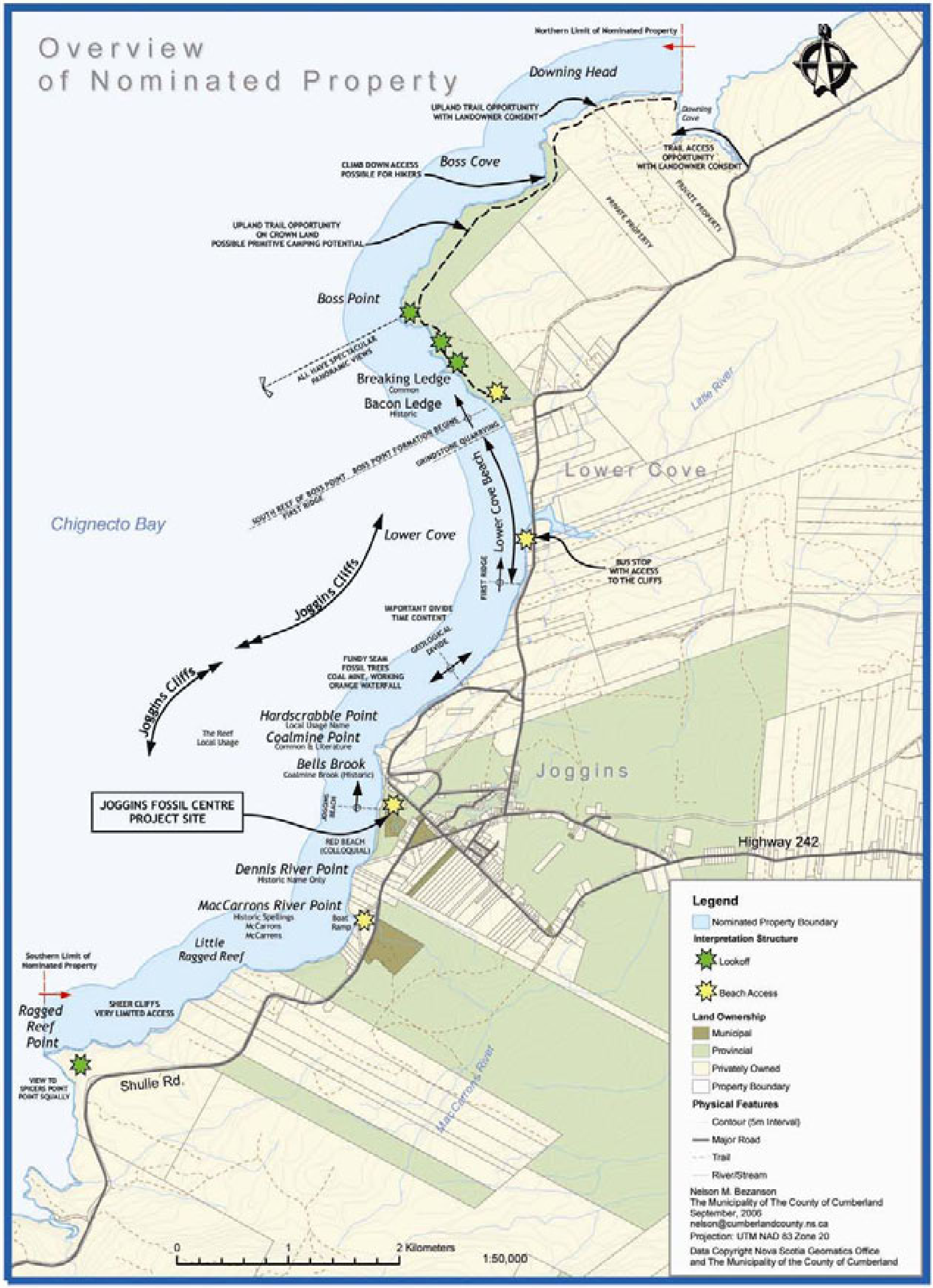

Overview
of Nominated Property
Northern Limit of Nominated Property
Downing Head
UPLAND TRAIL OPPORTUNITY
WITH LANDOWNER CONSENT
Downing Cove
TRAIL ACCESS
OPPORTUNITY
WITH LANDOWNER CONSENT
CLIMB DOWN ACCESS
POSSIBLE FOR HIKERS
Boss Cove
UPLAND TRAIL OPPORTUNITY
ON CROWN LAND
POSSIBLE PRIMITIVE CAMPING POTENTIAL
PRIVATE PROPERTY
PRIVATE PROPERTY
Boss Point
ALL HAVE SPECTACULAR
PANORAMIC VIEWS
Breaking Ledge
Common
Bacon Ledge
Historic
Little River
GRINDSTONE QUARRYING
Lower Cove
Lower Cove Beach
Chignecto Bay
Lower Cove
BUS STOP
WITH ACCESS
TO THE CLIFFS
FIRST RIDGE
Joggins Cliffs
IMPORTANT DIVIDE
TIME CONTENT
GEOLOGICAL
DIVIDE
FUNDY SEAM
FOSSIL TREES
COAL MINE, WORKING
ORANGE WATERFALL
Joggins Cliffs
Hardscrabble Point
Local Usage Name
The Reef
Local Usage
Coalmine Point
Common & Literature
Bells Brook
Coalmine Brook (Historic)
Joggins
JOGGINS FOSSIL CENTRE
PROJECT SITE
RED BEACH
(COLLOQUIAL)
Highway 242
Dennis River Point
Historic Name Only
MacCarrons River Point
Boat
Ramp
Little
Ragged Reef
Southern Limit of
Nominated Property
SHEER CLIFFS
VERY LIMITED ACCESS
Ragged
Reef
Point
VIEW TO
SPICERS POINT
POINT SQUALLY
Shulie Rd.
MacCarrons River
0
1
2 Kilometers
1:50,000
Legend
Nominated Property Boundary
Interpretation Structure
Lookoff
Beach Access
Land Ownership
Municipal
Provincial
Privately Owned
Property Boundary
Physical Features
Contour (5m Interval)
Major Road
Trail
River/Stream
Nelson M. Bezanson
The Municipality of The County of Cumberland
September, 2006
nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
Data Copyright Nova Scotia Geomatics Office
and The Municipality of the County of Cumberland

Figure 8

The *Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* contains planning policies and land use regulations that provide stringent protection to the lands adjacent to the nominated property, as contemplated by the Operational Guidelines. Within the *Planning Strategy* and *Land Use Bylaw* there are two specific policies developed to protect lands immediately adjacent to the nominated property. These two policies include strict protection within 20 metres of the landward property boundary and encompass an area of 29.4 hectares (14,700 metres X 20 metres = 29.4 hectares). The two specific policies —"Cliffs and Shoreline Setbacks" and "Prohibited Uses and Structures"—support the stewardship of the natural heritage values, and protect the features and setting of the Joggins Fossil Cliffs. These two policies provide legal protection for the land adjacent to the landward side of the nominated property. These stringent policies assist in the conservation of the nominated property and will protect the property for future generations.

The policy pertaining to "Cliffs and Shoreline Setbacks" includes development restrictions in areas within 20 metres of the cliffs and shoreline to ensure that there will be no development and that environmental effects from the human activities or land uses will not interfere with the natural erosion processes which regularly expose fossils at the cliffs or adversely affect the setting or views of the Joggins Fossil Cliffs or the aesthetic qualities of the views and natural vistas along the shorelines.

The policy of "Prohibited Uses and Structures" includes land use bylaws for areas within 20 metres of the cliffs and shoreline that prohibit grading or alteration in elevation or contour of the land, the excavation and deposition of fill, defacing the cliffs, constructing permanent or temporary structures and outdoor storage of scrap or salvage material.

The definition of the boundary of this 20-metre buffer is contingent on the definition of the landward property boundary (the cliff), and as the cliffs erode the protection within the buffer migrates landward as well. Currently, at present rates of erosion, this 20-metre area equates to approximately 100 years of protection. Furthermore, the protection afforded to the property by these municipal policies extends in perpetuity as the cliffs and associated buffer move landward through erosion.

For the most scientifically important part of the nominated property, the beach and cliffs are protected 100 feet (30.48 metres) landward from the mean high-water mark. Within this buffer zone land use activities are restricted through the application of the *Beaches Act* and associated *Regulations*. The added protective measures governed under the *Beaches Act* and associated *Regulations* specifically apply to the "Classic Section" of the nominated property where the most important fossil discoveries and research have taken place and where visitation is highest.

In addition to the buffer zone, complementary planning and regulatory controls are in place, further contributing to conservation of the nominated property. The entire length of the property and adjacent lands are "closed" for mineral exploration through the application of the *Mineral Resources Act*. "Closures" under the *Mineral*

Resources Act are created when land is withdrawn by the Minister of the provincial Department of Natural Resources from general application of the *Act* under Section 22. Therefore, the principles regarding acquisition of a mineral exploration licence do not apply to withdrawn ("closed") areas. *The Municipality of the County of Cumberland Secondary Planning Strategy* and *Land Use Bylaw for the Joggins Planning Area* come into effect from as far away as seven kilometres. For the entire Planning Area, land use zoning has been established and policies pertaining to protection of views, outdoor lighting, health and safety, and traffic management are in place. Additionally, the *Special Places Protection Act* provides for the protection and conservation of heritage objects (fossils) for the entire province of Nova Scotia (Figures 9 and 10).

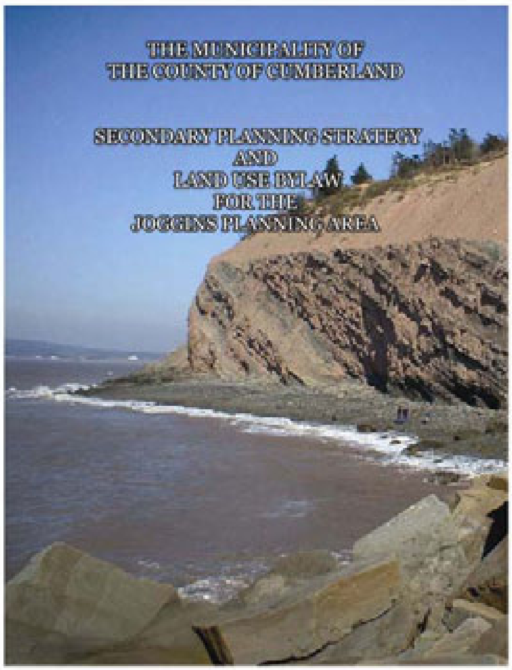


Figure 9

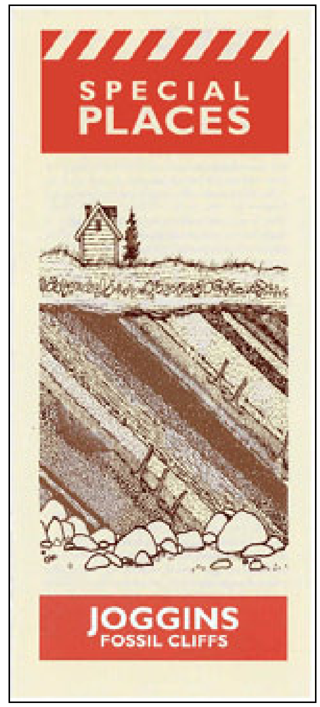


Figure 10

5.0 MANAGEMENT GOALS AND PRINCIPLES FOR THE NOMINATED PROPERTY

5.1 Management Goals

The management and operation of the nominated property will be guided by the following goals:

Goal 1: to provide for the protection, study and safe enjoyment of the Joggins Fossil Cliffs by:

a) ensuring that human activities do not compromise the natural integrity of the Joggins Fossil Cliffs;
b) ensuring that scientific research remains a focal point for property management;
c) ensuring that visitors to the fossil cliffs are aware of, and protected to the extent possible, from hazards associated with cliffs, tides and other natural

characteristics of the site;

d) developing site brochures and signage featuring scientific, stewardship and public safety information; and,
e) developing and implementing an Emergency Response Plan.

Goal 2: to promote wide recognition, understanding and appreciation of the scientific, educational and cultural values represented by the Joggins Fossil Cliffs by:

a) implementing a fossil collecting policy that focuses on the inherent scientific value of all fossils;
b) developing and implementing a fossil collecting and cataloguing process that maximizes the scientific potential of each fossil;
c) ensuring that fossil collectors are an acknowledged part of the long-term research goals of the fossil site;
d) ensuring that World Heritage Site status, if granted, will be recognized responsibly in all aspects of publicity in relation to the Joggins Fossil Cliffs in accordance with UNESCO guidelines.

Goal 3: To instil a strong sense of community pride and stewardship in the Joggins Fossil Cliffs by:

a) supporting land use zoning to protect community interests over the long-term;
b) providing for community input and encouraging community participation;
c) supporting entrepreneurial development in the Joggins-River Hebert area;
d) employing a governance model to ensure that developments associated with the Joggins Fossil Cliffs respect the local culture, history, traditions and way of life.

Goal 4: to establish a world-class sustainable tourism destination that contributes to local, regional and provincial economies by:

a) developing and operating a facility and supporting infrastructure for visitor services, interpretation and education;
b) promoting visitation through regional, national and international media.

Goal 5: To ensure community involvement in the interpretation and promotion of the Joggins Fossil Cliffs and provide a range of interpretive opportunities for visitors by:

a) supporting the training and involvement of local and regional students in the interpretation and study of the Joggins Fossil Cliffs;
b) ensuring the local schools are provided sufficient information and opportunities to incorporate the Joggins Fossil Cliffs into their curriculum;
c) providing knowledgeable beach interpreters during peak visitation periods;
d) providing group tours during peak periods and through special arrangement at other times;
e) incorporating cultural and industrial history components into interpretive and tourism planning for the region;
f) preparing an interpretation plan for the development and dissemination of information on the property and its fossils;
g) developing and posting interpretive material to inform visitors of the nature and extent of tides on the Fundy shore;
h) designing, developing and placing a series of interpretive panels offering key

information about features of the property

5.2 Management Principles

The following principles will be applied to the management and operation of the nominated property. They will also be used, where appropriate, to support compatible planning and development in the surrounding community.

Principle 1: Management of the property will meet or exceed World Heritage standards regardless of inscription. The Joggins Fossil Cliffs Management Plan acknowledges that there is an adjudication interval following submission of the nomination. Regardless of inscription or its timing, the management of the property will meet the *Operational Guidelines for the Implementation of the World Heritage Convention* (2005).

Principle 2: The primary focus of Joggins Fossil Cliffs Management Plan is to address issues directly related to management and conservation of the fossil heritage at the Joggins Fossil Cliffs. The plan addresses those issues that flow from the Joggins Fossil Institute objectives. In relation to possible threats, the Management Plan concentrates on the conservation of values for which the property is designated as a "Protected Site" through provincial legislation and for which it may be inscribed for World Heritage Site status.

Principle 3: The Joggins Fossil Cliffs Management Plan fully recognizes that the nominated property is set within a well-visited coastal area where people continue to live and work. Unlike other natural sites with more fragile ecosystems, the cliffs and beach enjoy a strong natural defence from human habitation. People have lived immediately adjacent to the cliffs for several generations with little ecological impact or exploitation of the fossil resource. Nonetheless, inscription on the World Heritage List would have an impact on the community, so property management must respect local stakeholders.

Principle 4: Management in relation to World Heritage guidelines will be locally driven and will include the participation and support of government agencies with regulatory responsibilities for the property. World Heritage designation would augment the property's profile and strengthen its long-term viability; existing legislative protections will continue regardless of inscription. The plan recognizes that regulatory control must include stakeholders including local managers, visitors and local citizens.

Principle 5: Management will be delivered through existing mechanisms, supplemented by new processes and procedures developed to accommodate a designated World Heritage site. The Joggins Fossil Cliffs Management Plan requires regular review by the Joggins Fossil Institute Board of Directors, as experience and other factors may influence the future direction of site management. Once implemented, the Management Plan review will be on a three-year cycle. Furthermore, components of the Management Plan will be reviewed and approved by the Nova Scotia Department of Tourism Culture and Heritage and Department of Natural Resources.

6.0 MANAGEMENT POLICIES, STRATEGIES AND ACTIONS FOR THE NOMINATED PROPERTY

6.1 Conservation and Protection

The priority of this management plan is to ensure the conservation and protection of the nominated property's features of outstanding universal value. These include the geological section of sedimentary rocks, the adjacent beach, and the fossils – both in the bedrock and loose fossils on the beach.

This nominated property is currently protected by three *Acts* of the province of Nova Scotia: the *Special Places Protection Act*, the *Beaches Act* and the *Mineral Resources Act*. Under the *Special Places Protection Act* the nominated property is legally designated as a "Protected Site." Moreover, a significant portion of the property, including the "Classic Section" (the Joggins Formation proper), is legally designated a "Protected Beach" under the *Beaches Act*. The property is also under a mineral exploration closure, in effect through the *Mineral Resources Act*. A new Municipal land use planning strategy developed expressly to reinforce the integrity of the property complements these provincially legislated protections.

The *Special Places Protection Act* (1989)

In 1970, the Government of Nova Scotia passed legislation, the *Historical Objects Protection Act*, to protect the province's significant fossil resources. The *Historical Objects Protection Act* was superseded by the *Special Places Protection Act* which now provides for the preservation, regulation and study of archaeological and historical remains as well as paleontological and ecological sites. The *Special Places Protection Act* is administered by the Minister of the Nova Scotia Department of Tourism, Culture and Heritage. As stated, the purpose of this Act that applies to the nomination of this property as a fossil site is:

- to provide for the preservation, protection, regulation, exploration, excavation, acquisition and study of archaeological and historical remains and palaeontological sites which are considered important parts of the natural or human heritage of the Province;
- to promote understanding and appreciation among the people of the Province of the scientific, educational and cultural values represented by the establishment of special places.

The protection under the *Special Places Protection Act* confers special conservation status to "heritage objects" which are defined as "an archaeological, historical or palaeontological object or remain…." Under the *Special Places Protection Act*, carrying out exploration or making excavations on any land (including land covered with water) for the purpose of seeking palaeontological objects requires a Heritage Research Permit. In 1972, the "Classic Section" of the Joggins Fossil Cliffs property was the first site in Nova Scotia that received "Protected Site" designation in recognition of its outstanding scientific significance. In July 2007, the province of Nova Scotia will have expanded the "Protected Site" boundaries to be consistent with the nominated property boundaries in recognition of the global scientific importance of the larger area.

The *Beaches Act* and *Regulations* (1989)

The *Beaches Act* is a provincial statute that preserves and protects the beaches of Nova Scotia. Under this Act, all beaches in Nova Scotia are dedicated in perpetuity for the benefit, education and enjoyment of present and future generations. The *Beaches Act* and associated *Regulations* are administered through the Minister of the Nova Scotia Department of Natural Resources. As stated, the purpose of this *Act* is:

a) to provide for the protection of beaches and associated dune systems as significant and sensitive environmental and recreational resources;
b) to provide for the regulation and enforcement of the full range of land-use activities on beaches, including aggregate removal, so as to leave them unimpaired for the benefit and enjoyment of future generations;
c) to control recreational and other uses of beaches that may cause undesirable impacts on beach and associated dune systems.

In this *Act*, a "beach" is defined as that area of land on the coastline lying to the seaward of the mean high-water mark and that area of land to landward immediately adjacent thereto to the distance determined by the Governor-in-Council. The *Beaches Regulations*, made under Section 13 of the *Beaches Act*, govern the preservation, control and management of protected beaches. These *Regulations* restrict human activities including, most importantly, the removal of fossils and beach aggregate.

The entire length of the nominated property is legally designated as a "Protected Beach" from the mean high-water mark seaward. In addition to this legal designation, in 1975, the province of Nova Scotia provided further protection of the Lower Cove Beach (extending 8.5 kilometres of the 14.7-kilometre length of the property) through a protected area landward of the mean high-water mark.

The Lower Cove Beach runs from the old Government Wharf at Joggins (approximate location 45^{O} 41′ 40″ N, 64^{O} 27′ 5″ W) to Downing Head (approximate location 45^{O} 44′ 50″ N, 64^{O} 22′ 26″ W), including the area 100 feet (30.48 metres) landward and perpendicular to the mean high-water mark. Under the *Beaches Act*, the designation of areas landward of the mean high-water mark further supports the conservation and integrity of the property as the protection includes areas adjacent to the property and may be considered as a buffer.

The *Municipality of the County of Cumberland: Secondary Municipal Planning Strategy and Land Use Bylaw for the Joggins Planning Area* (2006)

In accordance with the *Municipal Government Act* of the province of Nova Scotia, the Municipality of the County of Cumberland has developed a *Secondary Municipal Planning Strategy* and a *Land Use Bylaw for the Joggins Planning Area*. The *Municipal Government Act* permits a municipality to establish planning advisory committees to undertake research and public consultation and provide advice to a municipal council with respect to the adoption of planning policies and bylaws. In developing the strategy and bylaw for the Joggins area, The Joggins Area Planning

Advisory Committee was formed and included members of the public, elected officials and Municipal staff. Committee meetings were publicized and were open to the general public. Additional public consultation events provided a forum for members of the community to express their ideas and concerns for the future, and to comment on the committee's proposed planning documents. Once the committee made its final recommendation to County Council, a public hearing was advertised and held as part of a regular Council meeting. The final planning documents were approved by the Province in August 2006.

The Strategy addresses planning for future development of the communities of Joggins and Lower Cove and supports the protection of the nominated property through land use policies. The importance of the Joggins Fossil Cliffs is reflected in this Planning Strategy and Land Use Bylaw. The overriding goal was:

> …to support healthy and sustainable community development by ensuring that future growth and development throughout the Joggins Area will support the goals and priorities of local community members and maximize the benefits and minimize any adverse effects of the development of the Joggins Fossil Cliffs on the community and by ensuring that future land uses and forms of development in the vicinity of the Joggins Fossil Cliffs will protect and enhance their fossil resources and valuable features and be appropriate and compatible with the nominated UNESCO World Heritage Site and Centre.

The *Mineral Resources Act* (1990)

Under the authority of the *Mineral Resources Act* of the province of Nova Scotia, "closures" are created when land is withdrawn by the Minister of the Department of Natural Resources from general application of the Act under Section 22. Therefore, the principles regarding acquisition of a mineral exploration licence do not apply to areas withdrawn ("closed"). This same provision is accorded to areas that are designated "protected" under the *Special Places Protection Act*. The issuance of a mineral exploration licence in such areas would require approval of the Minister and the Governor-in-Council (Cabinet of the provincial government).

In 2006, all lands of the nominated property, the buffer zone, and some adjacent lands were placed under closure by the Registrar of Mineral and Petroleum Rights, Nova Scotia Department of Natural Resources.

6.1.1 Means of Implementing Protective Measures

Management and conservation of the nominated property is exercised locally through the Joggins Fossil Institute (JFI). The Joggins Fossil Institute is a registered not-for-profit society under the Societies Act of Nova Scotia. The objectives of the Joggins Fossil Institute are to:

a) manage the Joggins Fossil Cliffs property and Joggins Fossil Centre, a place where global heritage values are protected, respected, understood and presented, so that the story of these values and other cultural and natural values can be told to the world, and to future generations;

b) hold and manage, for the benefit and education of humanity, a palaeontological collection representative of the Carboniferous Period alongside its native geographic property;
c) ensure that the property and collection are conserved, safely studied and exhibited and to provide for the advancement of scientific research;
d) acquire by way of grant, gift, purchase, bequest, device or otherwise real and personal property to use and apply such property to the realization of the objects of the Joggins Fossil Institute;
e) buy, own, hold, lease, mortgage, sell and convey such real and personal property as may be necessary or desirable in the carrying out of the objects of the Joggins Fossil Institute; and
f) do all such other things as may be provided by the *Societies Act* (1989).

The Joggins Fossil Institute has the principal role in setting policy and coordinating management for the nominated property. Management of the property is conducted through agreements between provincial and municipal government departments and the Joggins Fossil Institute. The government agencies that are working with the Institute are the:

i) Nova Scotia Department of Tourism, Culture and Heritage (DTCH);
ii) Nova Scotia Department of Natural Resources (DNR);
iii) Municipality of the County of Cumberland (MCC); and
iv) Cumberland Regional Economic Development Association (CREDA).

Nova Scotia Department of Tourism, Culture and Heritage

The Nova Scotia Department of Tourism, Culture and Heritage will work collaboratively with the Joggins Fossil Institute to carry out appropriate functions, including, but not limited to:

a) housing a working scientific collection of fossils and palaeontological material;
b) issuing "collecting permits," as defined by regulation under the *Special Places Protection Act*, to both scientific/excavation and stewardship/avocational collectors;
c) screening and releasing appropriate specimens for public consumption; and
d) making such policies and implementing such practises to properly conserve the nominated property's natural resources and manage the public entering the property.

Nova Scotia Department of Natural Resources

An agreement with the Department of Natural Resources has been reached in order to permit the Joggins Fossil Institute to proceed with the conservation and management of the nominated property.

The Minister of DNR, pursuant to Section 4, Subsections (3) and (4) of the

Beaches Act, has entered into an agreement whereby the Joggins Fossil Institute will have authority to administer, manage and control the beach at the nominated property. Under this agreement, the Joggins Fossil Institute is authorized to:

- provide safety and interpretive services,
- conduct studies and carry out research, and
- promote educational programs that emphasize the importance of conserving beaches and using the beach for recreational purposes in a manner to maintain their environmental integrity.

Municipality of the County of Cumberland

The Municipality of the County of Cumberland owns the land and building for the new Joggins Fossil Centre that is under construction adjacent to the nominated property. The Municipality has delegated control of the Centre and associated lands to the Joggins Fossil Institute. The Municipality will also monitor all development in the Joggins Planning Area (which includes the nominated property and adjoining communities) to ensure compliance with the *Secondary Municipal Planning Strategy* and the *Land Use Bylaw for the Joggins Planning Area*.

Development Control and Building Inspection Officers will reject any noncompliant development proposals and will ensure all developments have complied with the permitting and approval process required by the bylaw. The bylaw can be enforced by prosecution and court orders if necessary.

Cumberland Regional Economic Development Association

The Cumberland Regional Economic Development Association provided all administrative and staffing support to the Joggins Fossil Cliffs Advisory Board from 1990 - 2006. As the Joggins Fossil Institute is a new entity (established in 2006 from the Joggins Fossil Cliffs Advisory Board), CREDA will continue to act in a supportive capacity until 2010 at which time the agreement between CREDA and the JFI will be re-evaluated. Although the Joggins Fossil Institute is incorporated as a separate legal entity from CREDA, it will initially operate as a sub-committee of CREDA and in addition to its own bylaws, also comply with the policies and bylaws of CREDA. The Cumberland Regional Economic Development Association shall ensure that, as it relates to the Joggins Fossil Cliffs project, liability insurance shall be extended to the JFI and its directors.

6.1.2 Joggins Fossil Institute policies related to the conservation and management of the paleontological heritage at the Joggins Fossil Cliffs

The following policies and strategies are intended to achieve this purpose.

Fossil Collecting

The fossil heritage at Joggins requires active management to ensure that important specimens are not lost and that fossils are accessible at any given time for study by scientists and for viewing by visitors. Ongoing steady erosion of the cliffs will continue to reveal new fossil specimens, and some of these will have significant interest to science. Visitors to the site should have an opportunity to view these fossils, gain an understanding of their significance, and contribute to the long term study of the site.

The fossil collecting policy for the nominated property is governed by the provisions of the *Special Places Protection Act* and the *Beaches Act* and associated *Regulations*). This legislation regulates all fossil collecting in the province, reflecting the richness and scientific value of the resource. Collecting is authorised by permit only, and bedrock excavation is restricted to scientists who are conducting approved research.

Fossil collecting has been an important part of the visitor experience at Joggins. Many significant specimens have been discovered by fossil enthusiasts as well as scientists. The existing local and independently operated fossil centre displays an excellent collection gathered over the years by local residents. Cooperation between collectors and scientists has been beneficial to both parties, and this points the way to future management of fossil collecting at the site.

Ongoing scientific research has been undertaken through the Heritage Research Permit system as administered through the *Special Places Protection Act* of the provincial government. Only qualified scientists with a defined research plan are eligible to receive permits that allow excavation from bedrock. Specimens and reports are submitted to the Joggins Fossil Institute and Provincial repository as part of the permit requirements. This reporting practice will continue for the foreseeable future.

The planned development of the Joggins Fossil Cliffs Centre, scheduled for completion in the summer of 2007, will provide an on-site management presence that will assist in coordinating, monitoring and enforcing the fossil collecting policy. The pressure of an anticipated increase in visitation to the site and support for the research agenda means that an effective and manageable policy must be put in place to ensure the protection of World Heritage Values.

The fossil collecting policy for the site has been established. This policy respects the limits of the *Special Places Protection Act* and the *Beaches Act* and associated *Regulations* while continuing to encourage public participation in the larger research goals of the nominated property.

The policy sets out the following limits on fossil collecting at the site:

1. Only persons with approved Heritage Research Permits may remove fossils from the bedrock, and then only with permission of the landowner. Excavation and removal is permitted for explicit scientific, educational or awareness building purposes. These permits are issued under the authority

of the Minister of Tourism, Culture & Heritage through the Joggins Fossil Institute, to qualified, accredited experts only.

2. Heritage Stewardship Permits will be issued to qualified individuals working in association with accredited experts. These permits will permit the removal of loose fossils from the beach for explicit scientific, educational or awareness building purposes.

3. All fossils belong to the Province of Nova Scotia with the exception of those which have been screened and released by the Nova Scotia Museum or Joggins Fossil Institute.

4. Information regarding fossils collected from the bedrock or the beach will be documented according to provincial and site guidelines.

5. Visitors to the site may not break open rocks while looking for fossils, whether by hammer, chisel or any other means, except for those granted such permission through the specific provisions of a Heritage Research Permit or Stewardship Permit.

6. Information on this collecting policy will be freely available to visitors to the Joggins Fossil Cliffs.

6.1.3 Curation, study and display of fossils

Under the *Special Places Protection Act*, collected specimens remain the property of the province of Nova Scotia. Type specimens (those used as the basis for naming a new species or higher taxon) normally are accessed at the Nova Scotia Museum, in keeping with its Collections Management Policy, but may be provided on permanent loan to the Joggins Fossil Institute for reference, study, and educational purposes.

Excavations of the nominated property are carried out rarely, and exclusively under the aegis of provincial legislation, employing the Heritage Research Permit system administered though the Heritage Division of the Nova Scotia Department of Tourism, Culture and Heritage. Collected specimens will be recorded relative to their stratigraphic horizon in the standard reference section and geographic location along the section to preserve important information pertaining to their paleoecological context and relative age. Fossil specimens will be curated, catalogued and displayed in Joggins at the Joggins Fossil Centre and in Halifax at the Nova Scotia Museum of Natural History, to international museum standards.

Exhibition of fossils at the Joggins Fossil Centre, immediately adjacent to the nominated property, is important as the Centre will be an active research facility and the main starting point for visitor excursions to the Joggins Fossil Cliffs. This facility is staffed full time and provides facilities for interpretation, collections management and visiting scientists. This Centre will be complemented by curatorial and preparation facilities of the Nova Scotia Museum, Halifax and Fundy Geological Museum, Parrsboro, Nova Scotia.

6.2 Development within the Nominated Site

The cliff face at Joggins is subject to continuing erosion. Consequently, there is little development, and limited development potential, of the property. The shoreline itself is not suited to development because of the extreme tides and active surf. Much of the land adjacent to the top of the cliffs is too unstable to support normal infrastructure development. Most nearby residents have built their homes and other structures well back from the cliff edge in recognition of the dangers posed by natural erosion.

There are a few instances of built property within or near the nominated property either on the cliff face or foreshore or on Crown lands atop the cliff. Most of these developments are remnants of 19th century coal mining or stone quarrying. They include:

i) remnant pilings from the wharf on the shore that served as a loading facility for the Joggins (Main) coal mine since the mid-19th century. The landward approach to the wharf follows an excavated area of the cliff top known as the 'dugway' which facilitated transport of coal cars to and from the wharf (Figure 11).

ii) pit props from abandoned coal mines have been exposed by erosion on the cliffs at three localities; the Fundy, Forty and Joggins Seams (Figure 12).

iii) remnants of an old quarry at Lower Cove, known as the "Grindstone Quarry" comprise pilings of a wharf, abandoned grindstones on the foreshore, foundations of the mill-house at the edge of the shore and small quarries landward of the shore (Figure 13).

iv) at MacCarron's River, remnant bridge footings or concrete abutments at the site of a former bridge and concrete boat ramp is present at the foot of the road leading to the beach (figure 14).

v) The road at Lower Cove near Little River is protected by a breakwater comprised of boulders. The breakwater includes a ramp to provide access to the shore (Figure 15).

vii) A stairway has been constructed at the mouth of Coal Mine Brook (Bell's Brook) to facilitate access to the shore. The lower component has been re-built several times due to damage caused by high tides and winter ice (Figure 16).

A new access point is proposed to be located in the vicinity of the existing dug-way. This structure will facilitate secure, regulated access to the beach along the cliffs.

Once the Joggins Fossil Centre has been completed, further development is unlikely to take place. Any development that may be proposed will be in keeping with, and in support of, the principles outlined in this management plan.

Figure 11

Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

Quarrying and Gravel Extraction

A Grindstone Quarry had operated historically in the Boss Point Formation between Lower Cove and Boss Point. The Grindstone quarry has been abandoned for many decades, and there is has not been any interest recently in re-activating them.

There is some potential for these strata to be quarried for ornamental or building stone. The province's environmental assessment process (*Environment Act*) would preclude any operation that was connected to the sea coast. An inland quarry could access the same strata without interfering with the site operations or jeopardising the site's World Heritage values. The beach at Joggins, due to the high energy of the shoreline, has coarse and poorly sorted aggregate of little interest to commercial ventures.

Potential Contamination from Oil or Chemical Spills

The Joggins coast is distant from most potential sources of large-scale oil and chemical pollution. It is located near the head of the Bay of Fundy, well-removed from the sea lanes to ports at Saint John (New Brunswick), Digby, Parrsboro and Hantsport (Nova Scotia). This suggests that it is unlikely that any sort of spill will threaten the shore. This threat is further mitigated by its position near the mouth of Chignecto Bay and the Petitcodiac River, as flow from these bodies would work against any pollution carried by the tide.

Port Activity

This part of the rugged Fundy coast does not have many large commercial harbours or ports. The power of the tides makes it difficult and expensive to maintain wharf facilities. The government wharf and breakwater that serviced the Joggins Coal mines has all but disappeared since the mines closed in the early 1960's. No trace remains of the shipping facilities at the long-abandoned Lower Cove grindstone quarry.

The only nearby wharf is just south of the nominated site at Two Rivers. This is a small wharf that is used to support local fisheries. Currently there are just two small fishing boats that dock at the Two Rivers Wharf.

Off-Highway Vehicles

The beach at Joggins is rarely used by off highway vehicles. On occasion, fishermen use their vehicles to access the water's edge to retrieve fishing gear. Use of recreational vehicles could have an impact upon the fossil resource by allowing quick entry and removal of fossils by unlicensed collectors. Vehicles may also annoy and endanger site visitors.

Off highway vehicles may be useful for management purposes, especially during emergencies or when large specimens are being collected from the beach under permit. The only reasonable access points are at Lower Cove and MacCarron's

River.

The *Beaches Act* and associated *Regulations* (and recent amendments to the province's *Off Highway Vehicles Act)* prohibit the use of off highway vehicles on beaches. Through an agreement with the Nova Scotia Department of Natural Resources, the Joggins Fossil Institute staff is permitted to use of off-highway vehicles for management purposes (collecting large fossils and for emergency response).

6.3 Science and Research

The role of Joggins in the early development of the sciences of geology and palaeontology has been a significant one. The work of Sir Charles Lyell, Sir William Logan and Sir William Dawson has been of major influence in Canada and around the world.

As a site that constantly generates fresh exposures, opportunities for new discoveries are abundant. Scientific research on the site has been ongoing since the early 19th century. Designation of the Protected Site, development of visitor infrastructure and potential inscription as a World Heritage Site can only increase the pace of research.

Establishing an on-site management and research presence will facilitate new field research by providing a work space for students and visiting researchers. The presence of a geoscientist on staff and on site will allow implementation of a collecting policy that encourages new research and discovery by professional scientists and associated "stewards".

The science and research agenda will focus on the following priorities:

- encouraging the funding of new research;
- continuing the development of a database of Joggins fossils held in world-wide collections;
- developing a research strategy to guide long-term research at the site;
- establishing authority to issue and manage the collection permit system on-site to ensure that it provides efficient support for the on-going research priorities of the site;
- ensuring that all holders of collection permits record basic information (location, date, collector, preliminary identification, etc.) for each fossil at the time of collection (Figure 17);
- maintaining and disseminating a bibliography and research register of scientific work that has been done on the site.

Future research possibilities and priorities are best identified by researchers working in concert with site managers. Site staff will participate in additional meetings, symposia, etc. where feasible in order to promote and support an active and vibrant research effort.

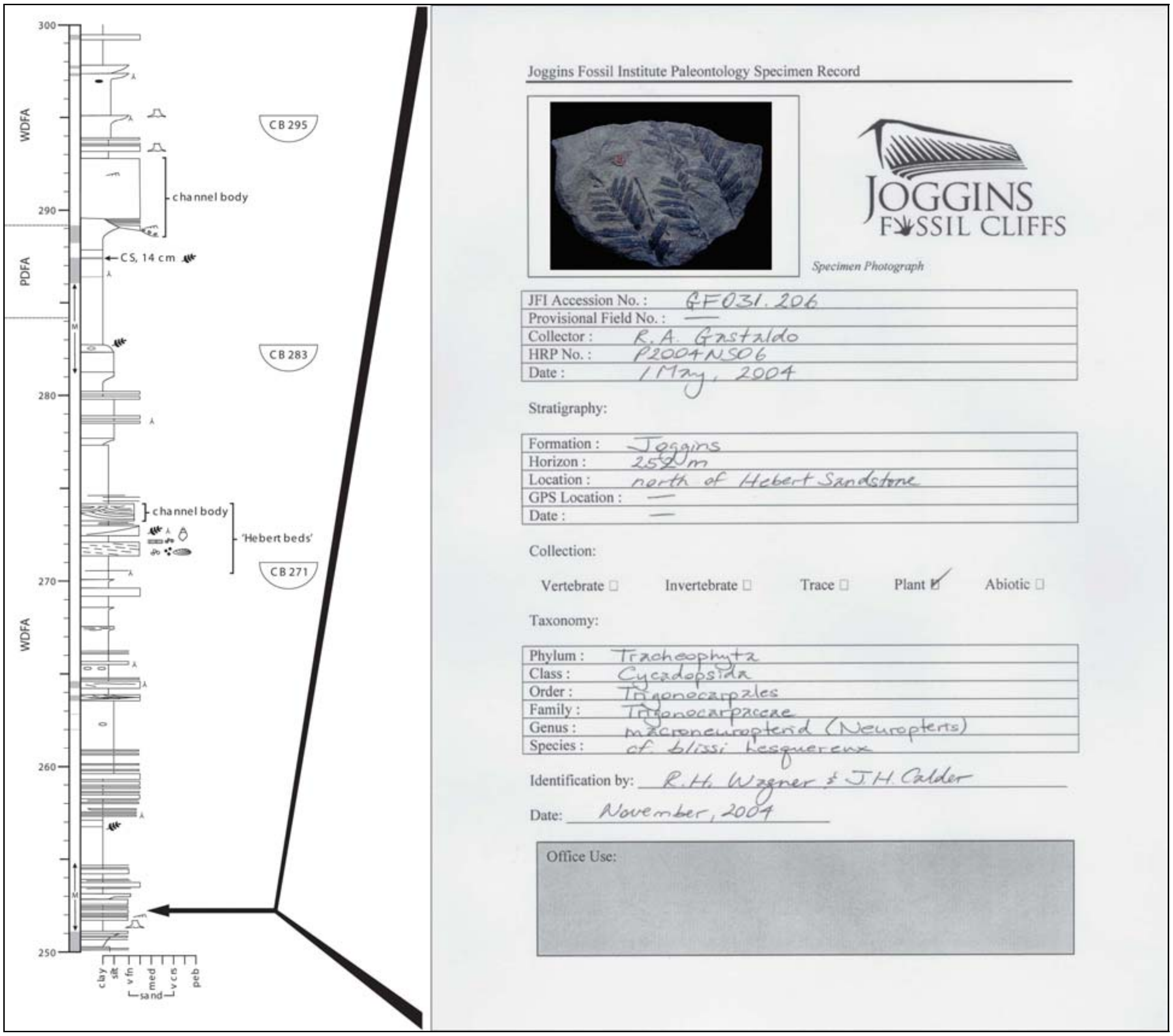


Figure 18

6.4 Presentation and Interpretation of the Nominated Property

6.4.1 Main Interpretive Themes

The interpretive Master Concept for the Joggins Fossil Cliffs focuses on the "Power of the Cliffs" as representative of the power of nature, life, time and knowledge. This Master Concept serves as the inspiration for the development of site interpretation and the overall visitor experience.

The main themes and their relative importance include:

- <u>The "Coal Age" Ecosystem at Joggins</u>: This theme will comprise approximately 50% of the interpretive material. It includes coverage of the biodiversity and ecology of the Carboniferous Period at Joggins, special reference to the "Hollow Tree Fauna", and modules on how fossils are formed and how to look for fossils in the cliffs and rocks (Figure 19).
- <u>Science and Big Ideas</u>: This section will include 20% of the material, and will

deal with the seminal role the Joggins site had in the development of key geological and evolutionary ideas and debates. It will feature discussion of the work of 19th century geologists Sir Charles Lyell, and Sir William Dawson, as well as the role of Joggins in the great debate over evolution and creationism (Figure 20).

- The Times: This will include 10% of the interpretation and will address issues related to geological time and the changing world (Figure 21).

Figure 19

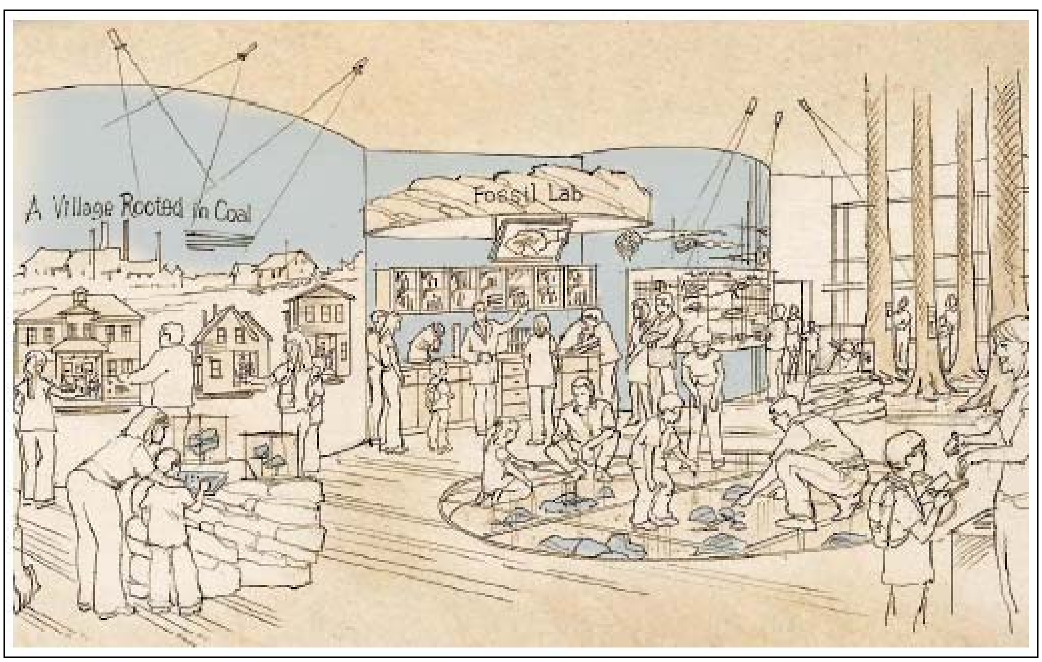


Figure 20

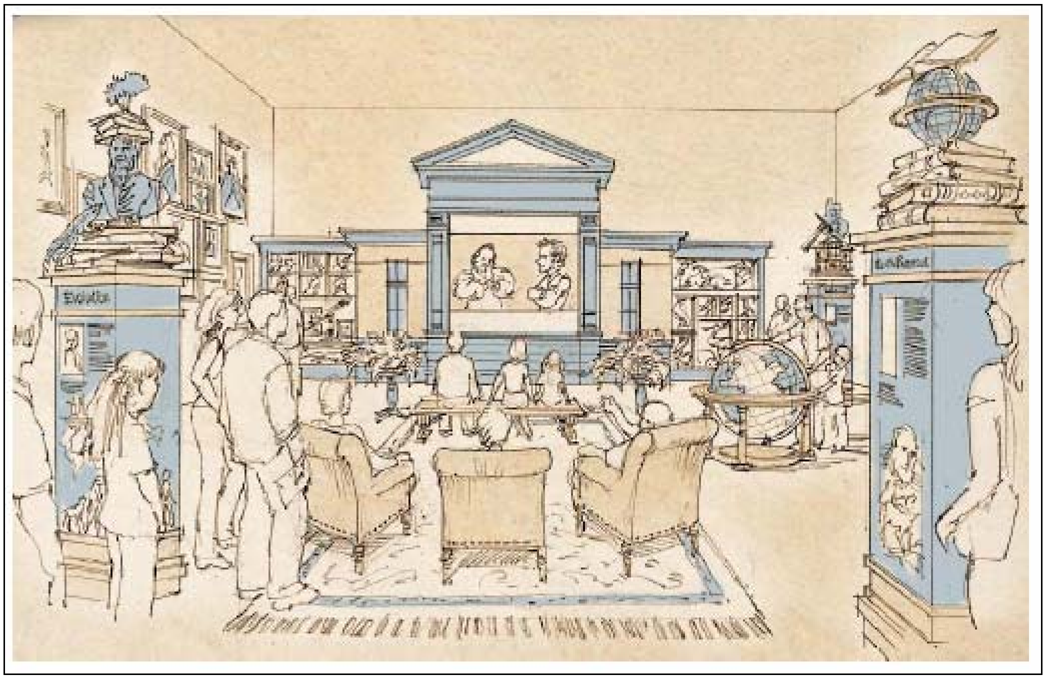


Figure 21

The remainder of the interpretation will focus on the themes including; the Bay of Fundy Natural Ecosystem, Site Stewardship and Safety, heritage values, cultural history, and associated tourism information.

6.4.2 Visitor Centre

A visitor centre is currently under development within the nominated site. This facility will provide visitors with an exceptional learning experience that is consistent with UNESCO goals. The centre will feature information and fossil specimens that demonstrate the rich geological history of the site, the history of scientific discovery at Joggins, and the history of coal mining that shaped the local community (Figures 22 and 23).

Figure 22

Figure 23

The new Joggins Fossil Centre will be located in the community of Joggins, overlooking the cliffs and Bay of Fundy just south of Coal Mine Point. The centre will welcome visitors and provide an orientation to the site, and serve as the departure point for tours of the cliffs. The centre will also house the offices of the site staff.

6.4.3 On-Site Interpretation

Guided tours of the fossil cliffs will be conducted by trained staff to enrich the visitor experience. Interpretive guides will be trained about the nature of the cliffs, the fossils they contain, and their significance to our understanding of earth history. The guides will also fill a monitoring and compliance role by ensuring that collecting procedures are followed. They will also be trained to address safety issues with visitors.

Interpretive exhibits will be located at several locations adjacent to the nominated site to provide self-guided learning opportunities for visitors. Some of the site's major themes will be interpreted at the Grindstone Quarry, Lower Cove, Coalmine Point, and the Dugway access adjacent to the interpretive centre. On-site signage will be augmented by interpretive brochures that elaborate on the major themes.

6.4.4 Off-Site Interpretation and Outreach

Off-site interpretation will be provided through a comprehensive web site. The web site will include information on the geology, fossils, exploration history and current research relevant to the Joggins section.

Outreach education will be pursued through developing modules to incorporate into local and regional public school curricula.

Cooperation with other, related institutions in the region, such as the, Fundy Geological Museum and the Nova Scotia Museum of Natural History, will allow cross-interpretation and promotion. Relationships will be fostered with international institutions and other World Heritage fossil sites.

6.5 Visitor Facilities and Access

6.5.1 Community Access to the Nominated Property

The beach at Joggins has been used by members of the community for generations for passive recreational use such as walking, fishing, swimming, parasailing and sight- seeing. These activities have no impact on the fossil resource or World Heritage values of the site. Traditional community access and use of the site will continue so long as it does not endanger other visitors or affect the management of the site or fossil resources.

6.5.2 Public Access to the Nominated Property

At present, there is one developed access point to the fossil cliffs at the mouth of Coal Mine Brook (Bell's Brook). Two other informal access points, at Lower Cove and MacCarron's River, are used on occasion by knowledgeable visitors but cannot currently support significant visitor use due to parking constraints.

The new Joggins Fossil Centre development includes a new visitor access that will be constructed in the vicinity of the Dugway. Moreover, at Lower Cove, the Grindstone Quarry property will permit access to the property for visitors with physical limitations. This area will also provide interpretive and safety information. Theses facilities will be developed with care and according to existing legislation to ensure that they do not affect site conservation objectives negatively.

Future plans may involve the development of other access points. An area of Crown lands to the north of Lower Cove at Boss Point has been identified. It would provide access to the northern part of the designated site, plus provide for additional interpretive and recreational opportunities that are not tide dependent. A proposed hiking trail and rough camping sites are also proposed for the northern portion of the nominated property. This trail would run along the coastal headlands between Lower Cove and Downing Cove, including Boss Point.

6.5.3 Public Safety and Risk Management

The physical nature of the nominated property presents several inherent risks including steep cliffs, falling rocks, slippery and uneven terrain for walking, and high tides that could strand beach goers. The extreme tidal range of the Bay of Fundy and the irregular shape of the shoreline increase the risk of stranding.

Additional environmental risks include hurricanes, extreme storm surges and tsunamis. Hurricanes and storm surges can be reasonably predicted and the beach evacuated well in advance of any event. Tsunamis are less predictable, but the risk is low given the relative tectonic stability of the Bay of Fundy region.

The following actions have been taken to minimize risks and promote public safety within the nominated property:

- An *Emergency Response Plan* has been prepared in consultation with local emergency measures officials. This plan identifies all foreseeable risks and provides a response plan to address those risks. Implementation of the plan will be carried out by the Joggins Fossil Institute in collaboration with the local community. The Royal Canadian Mounted Police (RCMP) is the primary organization charged with responding to on-site emergencies (Figure 24).

- Comprehensive safety signage has been posted and maintained at all official access points. Safety messages will also be provided within the visitor centre and in the interpretive brochures and educational materials prepared for the site.

- The new Dugway access to the beach has been designed to permit the elevation of an immobilized injured person to the top of the cliffs.

- Visitors to the property will be encouraged to adhere to site rules that restrict visitation to areas of the property where there are beach attendants. Furthermore, visitors desiring to access the extreme south (MacCarron's River to Ragged Reef Point) and north (Grindstone Quarry to Downing Cove) will be encouraged to register their trip with JFI staff prior to departure.

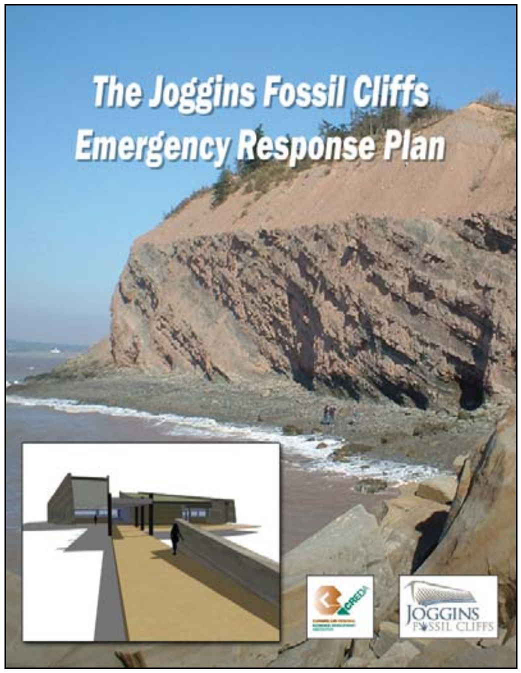


Figure 24

6.6 Marketing and Promotion

Targeted marketing and promotion efforts will be critical to attracting the right audiences to the nominated property. If the site is inscribed on the World Heritage list, then promotional materials will highlight the outstanding universal values of the site and UNESCO World Heritage messages. It will be particularly important to ensure that local communities and the regional tourism industry are aware of the importance and implications of the UNESCO designation.

A regional tourism promotion and development endeavour (the Bay of Fundy Tourism Partnership) between Nova Scotia and New Brunswick is already focusing significant effort on the tourism products along the Bay of Fundy. If this nomination is successful, the Bay of Fundy Tourism Partnership will utilize the UNESCO designation as part of its regional tourism strategy.

6.7 Sustainable Tourism

6.7.1 Visitation Projections

Current visitation to this relatively remote region of Nova Scotia is quite low. Although no formal census has been conducted it is estimated that for the last five years, visitation is in the range of 15 - 20,000 visitors per year.

The development of the site, the new Joggins Fossil Centre and potential inscription on the World Heritage list is expected to bring about a substantial growth in visitation to the site. Attendance projections estimate approximately 38,000 visitors for the first year of operation of the interpretation centre. This figure is projected to rise to more than 48,000 in the fifth year, with strong potential for further growth in the future. Most of the visitors would arrive during the peak tourist season of July-August, but shoulder season visitation is increasing, particularly among the demographic who visit sites of this type and stature.

The new facility and associated site infrastructure has been designed to accommodate this increase. Further, the physical nature of the site, including rocky shorelines and high tidal action means that the site can easily accommodate the increase in visitation without negative impacts. The fossil collecting policy and procedures outlined in this plan will ensure that increased visitation does not adversely affect the outstanding universal values of the site.

6.7.2 Carrying Capacity of the Site

The site is in an area that traditionally has drawn relatively few tourists and has little infrastructure to support visitation, either on-site or in the surrounding communities. Development of the site and associated facilities can be expected to bring about a substantial growth in tourist numbers and these will have to be carefully managed. Natural erosion of the cliff-face reveals the fossils and eventually removes them with the tide. The greatest potential threat to the fossil heritage, however, is the human impact through unauthorized fossil collecting. Although the rocky, high-energy shoreline is not highly vulnerable, management of the site will assure that the anticipated increased visitation at the site will have limited impact the coastal, inter-tidal ecosystem.

Carrying capacity at the Joggins Fossil Cliffs is defined as “an acceptable level of visitor density that the property can sustain without causing destructive effects to the physical environment or decreasing the quality of the visitor experience.” Although this definition excludes the assessment and monitoring of impacts on the economic and socio-cultural environment of adjacent communities, the Joggins Fossil Institute will participate in community development and monitoring initiatives as increased visitation has potential to have both positive and negative impacts on the nearby communities. Carrying capacity can be assessed to best protect the fossil resource; the two important factors in assessing carrying capacity for the management of the nominated property are natural heritage capacity and perceptual capacity. The assessment of these factors requires separate approaches.

Natural Heritage Carrying Capacity

The nominated property is able to sustain and significantly surpass current levels of visitation with little adverse impacts on the fossil resource or the local ecology. The absence of an immediate management presence at the property in the past has compromised formal record keeping, and visitor statistics have been difficult to maintain and track. Nonetheless, the generous estimate of past visitation and the conservative estimate of projected traffic find the Joggins Fossil Institute capable of handling nearly double the current level of visitation, with staffing, infrastructure, fossil collecting policies and legislation and visitor traffic management plans ready for both increased and changeable visitation levels.

The largest historic threat to the Joggins Fossil Cliffs prior to the inception of the Joggins Fossil Institute and permanent staffing at the site was the unauthorized, hence illegal, removal of fossils. Illegal removal refers to the casual pilfering of exposed smaller fossils and, far less likely, the unauthorized excavation of fossils from the cliffs and reefs. The most significant fossil resources are located within the cliffs along segments of the nominated property where interpreters will be vigilant and are therefore relatively secure. Although these fossil-rich segments of the property will be monitored by Joggins Fossil Institute staff and visitors will be discouraged from traveling to the remote southern and northern extents of the property, public education through interpretive programs and print media describing the fossil collecting legislation and policies and rationale is the principal conservation tool. Moreover, neighbouring residents continue to act as stewards of the property and will assist managers by reporting suspicious activities and by controlling access. The new Joggins Fossil Centre and staff of the Joggins Fossil Institute will facilitate visitor control, serving as the focal point of visitor education and experience at the site, controlling access to the beach, and minimizing impact of automobile traffic. Visitors are informed and educated about the fossil collecting legislation and policy in the site literature, on interpretive signs, and through verbal communications.

Heavy foot traffic resulting from increased visitation is not expected to significantly affect the exposed fossils of the cobble beach as the beach stones already experience continuous high wear from the powerful tides. Similarly, it is expected that elevated foot traffic levels will have little to no effect on the beach fauna (including barnacles and periwinkles) in the short term. Sensitive areas will be protected by congestion management and visitor dispersal, education on preserving the beach ecology, and possible path arrangements.

Perceptual Carrying Capacity

While projected visitation to the property is not anticipated to adversely affect the fossil resource or the local ecology, visitor impact will be persistently monitored and evaluated to protect them both and to maximize the quality of visitor experience. The management and marketing policies outlined in a separate communication and marketing plan anticipate increased visitation for recreational, educational and scientific purposes.

The practical and legal management of the Joggins Fossil Institute is designed to adapt positively to increased visitation. A simple increase in staffing commensurate with increased visitation will ensure excellence in visitor experience while simultaneously protecting the fossil resource and local ecology. Should visitation significantly exceed predictions or should fragility within the fossil resource be observed, alternate visitor management is available to the Joggins Fossil Institute. Possible strategies for high visitation management include: prioritizing reservations for groups and individuals, encouraging visits during non-peak seasons (especially for schools and other large groups), timing special activities with visiting scientists, and co-operative marketing with other spring and fall activities in the area, including festivals and seasonal events.

6.7.3 Sustainability Initiatives

The development and management of the Joggins Fossil Cliffs nominated property will adhere to the UNESCO Principles for Tourism in Natural World Heritage Sites (1993). Key initiatives include:

1. Tourism development considers and respect ecological and socio-cultural values of the Site and is consistent with the World Heritage concept;
2. A management plan, considering the regional context and addressing the tourism component is established and regularly updated;
3. Environmental assessments, inclusive of cumulative impacts, are carried out on recreational and commercial facilities and activities before approvals are granted;
4. Monitoring programs based on appropriate and updated indicators are in place and their outcomes are taken into account into the planning and decision taking process;
5. Local populations, in and around the site, are involved in order that they take pride in their heritage and gain benefits from tourism;
6. Co-operation with the different stakeholders involved in tourism development is sought and co-ordination of the promotion of the Site is ensured;
7. All site staff are aware of the World heritage values and are well trained in visitor management;
8. Relevant information and education programmes are in place to ensure that visitors and local people understand and have respect for the Site and its values;
9. A substantial proportion of the income generated through entrance fees is directly allocated to the Site for its improvement and management;
10. The Site participates in the World Heritage concept through all appropriate means.

An *Environmental Sustainability and Resource Utilization Policy* has been adopted for the site. This policy will guide all activities and decisions of the Joggins Fossil Institute. The new Joggins Fossil Centre has been designed using the principles of "Leadership in Energy and Environmental Design" (LEED) Green Building Rating System. Renewable wind power and geothermal energy is being explored as alternative energy sources for the site.

7.0 MONITORING AND REVIEW

A monitoring program will be established to collect data on the state of conservation of the nominated property and the quality of the visitor experience. Key indicators have been identified which will serve as a basis for the monitoring program.

7.1 Indicators of state of conservation of paleontological heritage

Key indicators of the state of conservation of the paleontological heritage at Joggins have been identified which will serve as a basis for monitoring and the subsequent annual report. The indicators are set out in the table below.

Table 1. Indicators of conservation of paleontological heritage

Attribute	Indicator	Periodicity	Location of Records
Maintain integrity of the classic fossil cliffs	Assessment of sedimentary succession and contained fossil beds related to collecting and natural processes of erosion.	Monthly (May – October)	Joggins Fossil Institute
	Review of human impacts in buffer zone	Annual	Joggins Fossil Institute, Municipality of the County of Cumberland, & Nova Scotia DNR
	Stakeholder engagement (community/government etc)	Annual	Joggins Fossil Institute
	Incidences of illegal fossil collecting/excavation	Monthly	Joggins Fossil Institute, Nova Scotia Department of Natural Resources, & RCMP
Continued strong level of scientific interest in the property	Number of peer reviewed papers in scientific journals	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Number of conference/workshop field trips hosted	Annual	Joggins Fossil Institute
	Frequency and duration for hosting visiting scientists	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Report of research conducted by visiting scientist	Annual	Joggins Fossil Institute, Scientific Advisory Committee
	Number of research projects	Annual	Joggins Fossil Institute with Scientific Advisory Committee
	Number of Scientific Heritage Research Permits Issued	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage
	Number of Stewardship Heritage Research Permits Issued	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage

Attribute	Indicator	Periodicity	Location of Records
Conservation of the fossil record of biodiversity	Report on fossil specimens accessioned to formal museum collections	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage
	Status of type specimens in world collections	Annual	Joggins Fossil Institute & Nova Scotia Department of Tourism, Culture and Heritage

7.2 Indicators of ecosystem health

The Bay of Fundy Ecosystem Partnership (BoFEP: http://www.bofep.org/), a "virtual', web-based institute comprising academic institutions, coastal communities, ecotourism groups, environmental and conservation groups, fishery organizations and government agencies, promotes the ecological integrity, vitality, biodiversity and productivity of the Bay of Fundy ecosystem. The Bay of Fundy Ecosystem Partnership (Figure 25) also facilitates and enhances communication and co-operation among citizens interested in stewardship of the Bay of Fundy, including its habitats and ecological processes.

Figure 25

The Joggins Fossil Institute is a member of the Bay of Fundy Ecosystem Partnership and will collaborate with other member organizations to help identify, study, prevent and treat environmental pressures affecting the Bay of Fundy ecosystem, particularly in the Joggins area. Assessments of wildlife populations and beach conditions (e.g., litter and pollution) will be conducted annually and reported by the Joggins Fossil Institute.

7.3 Indicators of sustainable administrative practices

The low-impact infrastructure necessary to enhance the property and enable its pursuit of the Joggins Fossil Institute goals (e.g. fossil protection, safe visitation, promotion of heritage values, interpretation and education) will respect the inclusive, prudent and conservational principles. Furthermore, any future development of the property and adjacent lands will be controlled through federal and provincial legislation and through municipal land-use bylaws.

Monitoring of visitor services and experiences will be conducted primarily by the Joggins Fossil Institute. Indicators of site visitation will include the following:

Attribute	Indicator (units of measurement)	Ideal Status	Report by	Report frequency
Visitors to Nominated Site	Number of visits to Website	Stable or increasing	Joggins Fossil Institute (JFI)	Annual
	Visitor Numbers to Joggins shoreline	Stable or increasing	JFI	Annual
	Number of guided tourists on Joggins beach	Stable or increasing	JFI	Annual
	Visitor Numbers to Interpretive Centre	Stable or increasing	JFI	Annual
	Seasonal distribution of visitors	Wider, within site capacity	JFI	Annual
Visitor Experience	Visit satisfaction of visitors to the Protected Site	Stable or increasing	JFI	Annual
Educational Use	Number of educational visits	Stable or increasing	JFI	Annual
Tourism Impact of World Heritage Site	Number of overseas visitors	Stable or increasing	JFI	Annual
	Seasonal distribution of visitors	Wider, within site capacity	JFI	Annual
Safety	Number of incidents requiring emergency response	Decrease	Emerg. Response Planning Grp.	Annual
Use of World Heritage Logo	Use of logo outside of UNESCO guidelines	No instances	JFI – Parks Canada	Annual
	Inappropriate promotion of world heritage in tourism literature	No instances	JFI	Annual

Whereas the coal deposits that lent their name to the period of earth history for which Joggins is the outstanding example in the world both fuelled the Industrial Revolution and are today implicated in issues of global change, the Joggins Fossil Institute has made a concerted effort to attain the highest standards of energy conservation and ecological stewardship. Specifically, the Joggins Fossil Institute has strived to ensure that the Joggins Fossil Centre achieves a silver rating in Leadership in Energy and Environmental Design (LEED: accreditation in Green Building Rating System). The independently powered Centre will house and promote fossils from the Carboniferous Period while releasing a minimum of greenhouse gases and capitalizing on the Bay of Fundy's rich wind resources. Moreover, the Joggins Fossil Institute will undergo an annual International Standards Organization 9001:2000 audit through the Cumberland Regional Development Association.

7.4 Administrative Arrangements for Monitoring the Property

The conservation goals of the Joggins Fossil Institute can only be demonstrated by monitoring its implementation. The responsibility for coordinating the monitoring of the nominated property will be undertaken by the Joggins Fossil Institute. Monitoring data is available through the Director of the Joggins Fossil Institute at:

Joggins Fossil Institute
35 Church Street, P.O. Box 546
Amherst, Nova Scotia
Canada B4H 4A1
902-667-3638

Monitoring results will provide input for an annual progress report on the implementation of the management plan. The progress report will be reviewed by the Scientific Advisory Committee, the Emergency Planning Advisory Group and the Joggins Fossil Institute, and will be made available to the public.

The World Heritage Convention requires State Parties to report on the state of conservation of their World Heritage properties on a six-year cycle. If the nominated property is inscribed on the World Heritage List, the Joggins Fossil Institute will provide to Parks Canada information on the state of conservation, interpretation and visitor experience of the Joggins Fossil Cliffs for inclusion in Canada's report to the World Heritage Committee.

This management plan will also be reviewed periodically to ensure that it provides relevant direction for the conservation and presentation of the site. Plan reviews will also allow the Management Association to respond to the results of ongoing monitoring and the data presented in annual progress reports, and to make any adjustments that may be required to ensure the protection of the site's outstanding universal values.

8.0 IMPLEMENTATION OF THE MANAGEMENT PLAN

This management plan will be implemented by the Joggins Fossil Institute Board of Directors through site managers and staff. In order to fulfil its essential conservation, management, scientific and education mandate and to maximize the tourism potential and economic benefit of the property to the local community, The Joggins Fossil Institute will employ the following staffing complement (Figure 26).

Director

Reporting directly to the Joggins Fossil Institute Board of Directors, the Director is responsible for overseeing all aspects of the Joggins Fossil Centre and property operations. The Director recommends policies and plans to the Board, implements policies and plans approved by the board and reports on the outcome of these plans and policies. The Director has overall responsibility for human resources management, occupational health and safety and management of the operations of the Centre and property through the staff. The Director is responsible for financial management and seeking out sources of ongoing funding, including both private and public sources. The Director serves as the liaison with all levels of government and the local community, and develops strategies to promote the property locally, nationally and internationally. The Director is also responsible for ensuring compliance with the World Heritage Convention and liaising with Parks Canada.

Scientist

The Scientist is responsible for the security, preservation, documentation and interpretation of the palaeontological heritage at the property. The Scientist carries out and facilitates property specific research solely and cooperatively with international researchers, makes that research available to the public and liaises with other researchers and institutions in the scientific community. The Scientist provides curatorial input into the development of exhibitions, advises on content of educational programs and is in part, responsible for the training of interpretive and collections staff. The Scientist leads tours and other educational programs for post-secondary and professional groups. To enhance the visibility of the property with the larger scientific community and to further scientific research, the Scientist publishes scientific papers, attends conferences and conducts lectures on a regular basis.

Manager of Programs

The Manager of Programs is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the property, as well as outreach programs and extension programs. The Manager of Programs develops educational materials to accompany exhibitions and provides input into the development of new and/or temporary exhibitions.

Interpreters

Interpreters are responsible for advancing the educational goals of the Joggins Fossil Institute, for monitoring the site, and enhancing the visitor experience by conducting guided tours of the cliffs and centre. Interpreters will lead workshops and facilitate other educational programs for visitors and groups. Interpreters will help to advance the scientific and research mission of the Joggins Fossil Institute by assisting in the preliminary identification, cataloguing and preparation of fossil specimens. Interpreters assigned to coastal patrol will play a role in ensuring safe beach visitation and compliance with the fossil collecting policy.

Manager of Visitor Services and Marketing
The Manager of Visitor Services and Marketing is responsible for the overall quality of the services offered at the Centre and for ensuring that high standards of customer care are met. The Manager of Visitor Services and Marketing recruits and manages customer service staff (admissions and retail), develops and implements the strategic marketing plan for the Joggins Fossil Cliffs and Centre in conjunction with the director and ensures that the Joggins Fossil Institute responds to multiple markets and changing visitors demands. The Manager designs and implements visitor use monitoring systems and social science research related to visitor satisfaction, expectations and trends. The Manager of Visitor Services and Marketing is responsible for overseeing revenue-generation including the gift shop, food-service concession, internet café and rentals.

Customer Service Assistants
Customer Service Assistants are responsible for greeting visitors, answering general enquiries and introducing visitors to the menu of activities and experiences that can be enjoyed at the Centre and property. Customer Service Assistants process admissions, gift shop transactions and fossil exploration permit purchases, and maintain gift shop and information displays.

Administrative Assistant
The Administrative Assistant provides support services for the Centre and property operations. Responsibilities include: bookkeeping; clerical and filing duties; processing payment for workshops and programs; maintaining a database mailing list; program administration including course registration.

Maintenance Manager
The Maintenance Manger is responsible for overseeing all aspects of facility and property maintenance of the physical plant and grounds of the Centre. Through an ongoing system, the Maintenance Manager will determine the need for repairs and preventative maintenance and will carry out necessary maintenance and repairs or will oversee the procurement and delivery of contracted services as necessary.

In addition to the positions directly associated with the management and operation of the property, managers and staff will have additional support through two advisory groups, a Scientific Advisory Committee and an Emergency Response Planning Group.

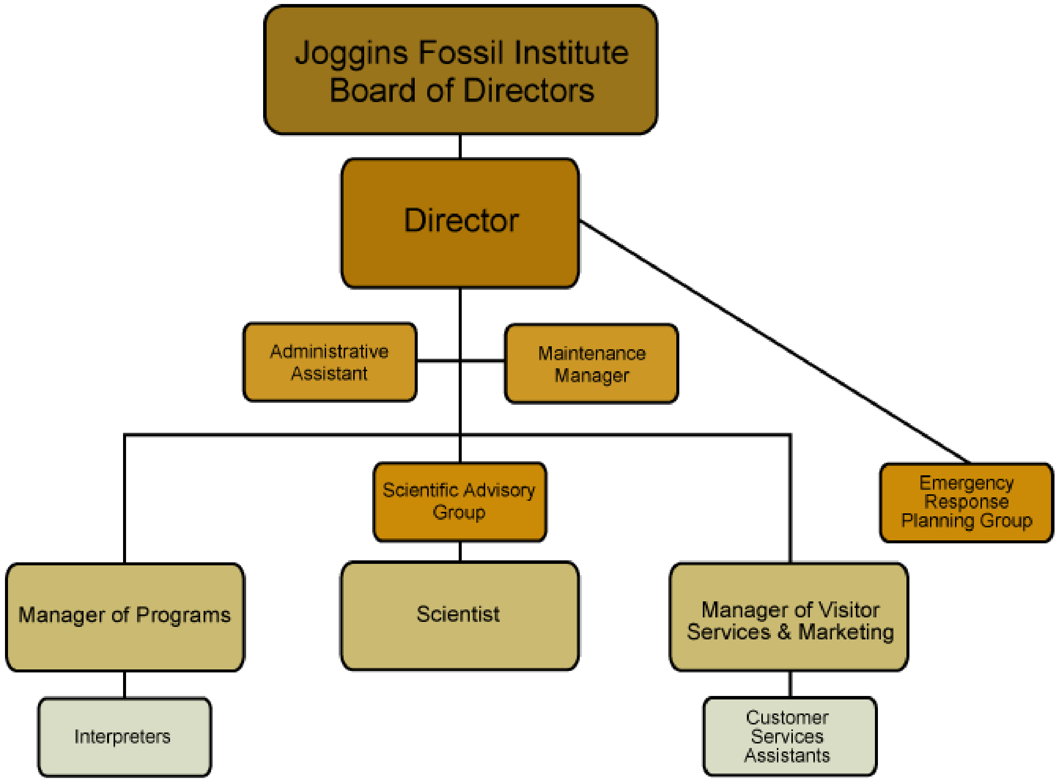


Figure 26

Scientific Advisory Committee

The role of the Scientific Advisory Committee is to report on the state of conservation of the nominated property and to support the advancement of scientific research at the Joggins Fossil Cliffs. The Scientific Advisory Committee advises the Joggins Fossil Institute on scientific matters relevant to managing the nominated property. Members of the scientific community nominate representatives for the committee and are appointed by the Joggins Fossil Institute Board of Directors every three years. The committee meets several times a year to identify and evaluate research needs in all areas of science including the social, geological and biological sciences. The committee also examines and advises on development proposals and perceived threats to the nominated property.

Emergency Response Planning Group

The Joggins Fossil Cliffs Emergency Response Planning Group is committed to the planning, preparation, review and reporting of an emergency response for The Joggins Fossil Cliffs. This group acts in an advisory capacity and reports to the

Director of the Joggins Fossil Institute. The group membership includes representative from the following organizations:

- Emergency Measures Organization of the County of Cumberland;
- Emergency Health Services of Nova Scotia;
- Joggins Fire Department;
- Royal Canadian Mounted Police;
- Springhill Ground Search and Rescue; and
- Nova Scotia Department of Natural Resources.

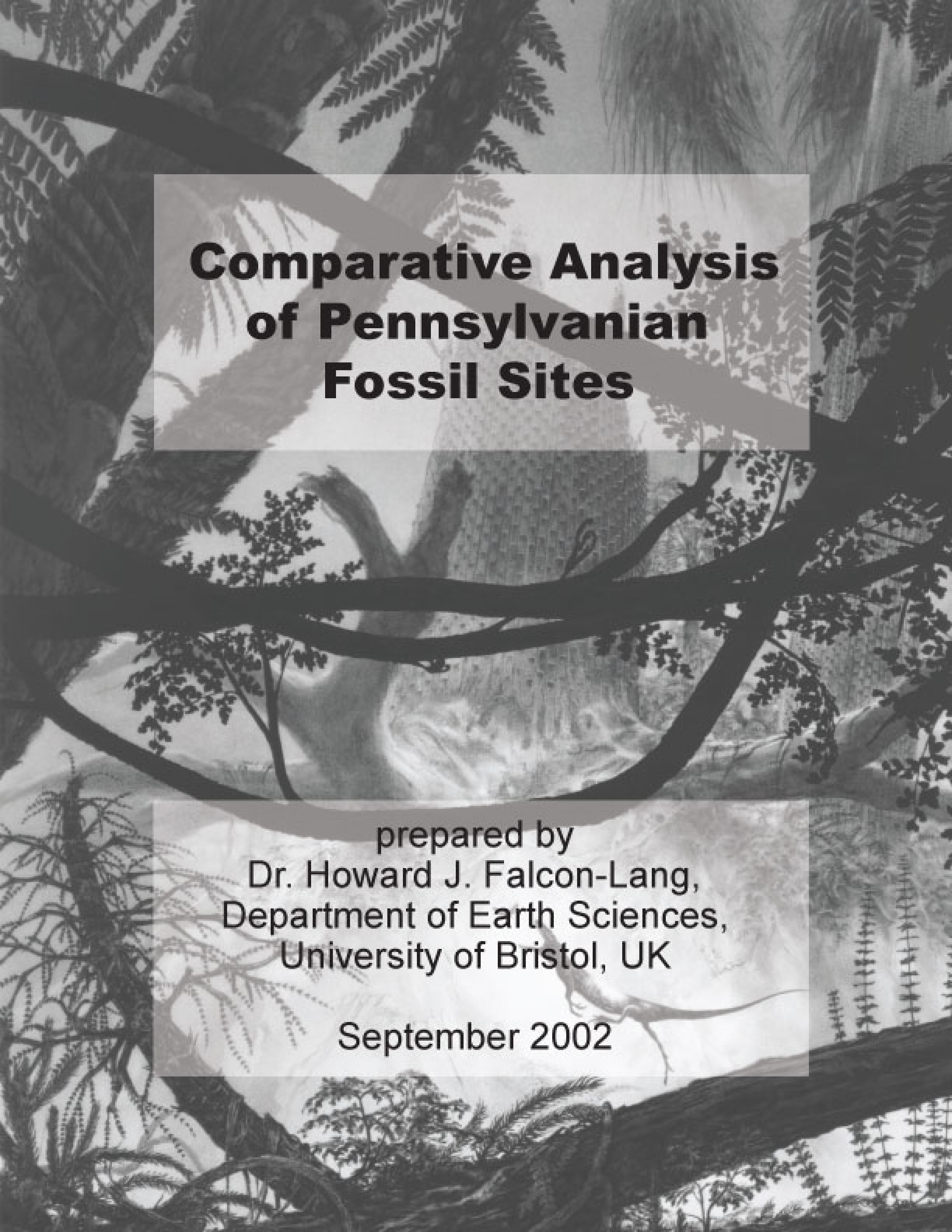
Community volunteer groups, including the River Hebert and Joggins Development Association, and the planned stakeholder group, the "Friends of the Joggins Fossil Cliffs," also play a significant role in the promotion and presentation of the property. Furthermore, provincial and federal government employees have an existing role in providing advice on property management, earth science conservation, reporting and monitoring.

Shared Staffing Opportunities

There are opportunities for shared staffing between Joggins Fossil Cliffs (JFC) and nearby Cape Chignecto Provincial Park (CCPP). The shared staffing positions are envisaged as follows:

• Property and Maintenance Manager:	50% JFC - 50% CCPP
• Manager of Visitor Services and Marketing:	70% JFC - 30% CCPP
• Manager of Programs:	70% JFC - 30% CCPP
• Director:	80% JFC - 20% CCPP
• Scientist:	90% JFC – 10% CCPP

In addition to the 3.9 full-time equivalent management and administrative positions, six full-time seasonal Interpreters and two Customer Service Assistants are employed to provide resources solely for the Joggins Fossil Cliffs property. This staffing complement and commensurate levels of remuneration, ensures that there will be a highly qualified scientific and educational team in place at Joggins, as befits the nominated property's outstanding scientific and educational importance. The structure also puts in place a strong management team, which will be required to oversee the daily operations of the Centre and property, to work closely with the governing board, to work toward ensuring that World Heritage goals are paramount, and toward promoting this property as a world-class destination.



Comparative Analysis of Pennsylvanian Fossil Sites

prepared by
Dr. Howard J. Falcon-Lang,
Department of Earth Sciences,
University of Bristol, UK

September 2002

Executive summary for policy-makers

The Pennsylvanian 'Coal Age', which extended between 299-320 million years ago, was a highly significant episode in the history of life witnessing both the rise of the first rainforests and the appearance of the reptiles. The steamy tropical biome, populated by gigantic, strange insects and bizarre, primeval trees, is depicted in dioramas in major museums worldwide, and has fascinated scientists and lay people alike since the first fossil discoveries were made more than two hundred years ago. Surprisingly, this important and evocative time period is not currently represented by a UNESCO World Heritage Site. To remedy such a critical oversight, this report provides a detailed comparison of nine Pennsylvanian-aged geological sites based on independent, quantitative criteria to assess which locality is most deserving of this honour.

The report identifies the spectacular Joggins Cliffs of Nova Scotia as representing the finest example in the world of a Pennsylvanian-aged fossil ecosystem, and strongly recommends that this classic site be added to Canada's list of potential World Heritage Sites. The criteria used to make this assessment are grouped into three major categories. The first category deals with the biodiversity of the fossil record of each site, and considers both the richness of the biota and its evolutionary significance. Joggins is ranked first in this category, possessing the richest and most varied fossil assemblages of this age in the world. The second category deals with the quality of the fossil archive, and considers the degree to which fossil ecosystems and their response to changing climate and environment may be reconstructed from information preserved at each site. Joggins is ranked first in this category worldwide preserving an unrivalled, high-resolution record of fossil ecosystems, and their dynamic response to millions of years of global environmental change. The third category deals with the integrity and scientific impact of the site, and considers both the past historical significance and the potential for important new discoveries. Joggins is again ranked first in this category worldwide, being an extraordinary natural laboratory from which many fundamental geological principles and insights have emerged, beginning in the early nineteenth century and continuing at an accelerated pace today.

The report emphasizes that the great overall importance of Joggins is based on its strong performance in all three assessment categories. Although the biodiversity of the site, assessed in the first category, is very rich, it is particularly in the second and third categories that Joggins excels. To reiterate, these major strengths are as follows: First, biological remains are uniquely preserved as 'fossil ecosystems' from which detailed insights into the dynamic nature of the Pennsylvanian tropical biome may be ascertained. Consequently, whereas many other sites remain mute about ecological and environmental interactions, Joggins speaks eloquently of tropical forests obliterated by catastrophic floods, of animals desperately fleeing gigantic forest fires, and of the impact of climate change and sea-level rise on ancient terrestrial ecosystems. Second, the site was the focus of seminal research by Sir Charles Lyell, Sir William Dawson and Sir William Logan (amongst the most influential geologists of the nineteenth century), playing a crucial role in the evolving understanding of the Earth's history. Numerous new fossil discoveries at this dramatic three-kilometre-long Joggins cliff section, part of a sweeping 55 km long cliff vista that is hewn by the world's highest tides on the Bay of Fundy, suggest it will continue to exert this important influence.

It is therefore on the basis of the very strongest scientific reasoning that this report fully endorses the inclusion of Joggins on Canada's list of potential World Heritage Sites.

Contents

103 printed pages (including 10 figures) plus an additional 16 pages of data tables

1. Significance of the Pennsylvanian Period

The Pennsylvanian Period (299-320 million year ago)[1] was an extremely important phase in the history of life on Earth (Figure 1 overleaf). Three examples amply substantiate this claim. Firstly, it was the time interval that witnessed the rise of the first tropical rainforests, populated by bizarre tree-sized club-mosses (now extinct), and the evolution of several important modern plant groups, most notably the conifers (Scott 1974; DiMichele & Phillips 1994). The compacted remains of this ancient tropical vegetation now form much of the world's economic coal deposits, the exploitation of which have had an incalculable impact on the development of the industrial world (Pfefferkorn et al. 2000). Secondly, it was during the Pennsylvanian Period that the earliest fully terrestrial reptiles evolved (Reisz 1997; Carroll 2002). This hugely significant biological event finally liberated vertebrate life from aquatic environments, thus paving the way for the colonization of the land and the diversification of terrestrial ecosystems (Benton 2000). Thirdly, the Pennsylvanian was the last time prior to the Quaternary (the past 2 million years) when the Earth was wracked by rapid and repeated global climate change resulting in the advance and retreat of polar ice caps (Collier et al. 1990; Wright & Vanstone 2001). Scientists are now examining the record of Pennsylvanian climate change in the hope that this will improve their understanding of future global climate warming (Falcon-Lang 2001), arguably the most significant issue facing humankind in the coming century.

Despite representing such an important episode of the Earth's History, and in particular encompassing key events in the evolution of life and climate, it is surprising that the Pennsylvanian Period is not yet represented by a UNESCO World Heritage Site. Indeed, of the twelve geological periods of the Phanerozoic Era (the last 550 million years), only seven are currently represented including in descending chronological order, Rocky Mountains Park, Canada (Cambrian), Miguasha, Canada (Devonian), the Devon-Dorset Coast, UK (Triassic-

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[1] Geologists outside the USA have previously referred to this time interval as the Upper Carboniferous Period. A major change in stratigraphic nomenclature occurred in 2001 and the name Pennsylvanian Period has been now adopted as the new global standard name for this interval (Subcommission on Carboniferous Stratigraphy, Unpublished Report 2002). The Pennsylvanian Timescale B (using Ar-Ar radiometric dates) of Menning et al. (2000), which is arguably the most accurate timescale currently available, is used throughout this document.

Cretaceous), Dinosaur Provincial Park, Canada (Cretaceous), the Messel Pit, Germany (Tertiary), and Naracoorte/Riversleigh, Australia (Tertiary/Quaternary) (data from UNESCO website: http://www.thesalmons.org/lynn/world.heritage.html). There is, therefore, a great need for UNESCO to better represent the Earth's History in general, and the Pennsylvanian Period specifically (Figure 1).

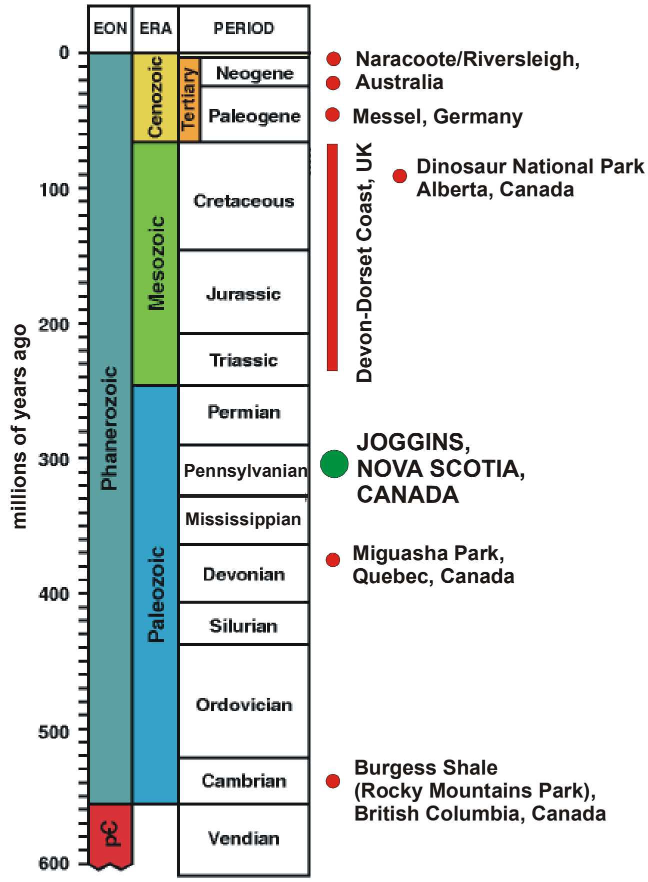

Figure 1. *Geological column showing the major time intervals of the last 600 million years (the Phanerozoic Era). The age of geological sites inscribed on the World Heritage list are shown in red, and the age of Joggins, Nova Scotia is shown in green.*

The aim of this document is two-fold. Firstly, I discuss some of the philosophical difficulties in choosing a single representative World Heritage Site for the Pennsylvanian Period (Section 2), and propose rigorous quantitative criteria to help make this decision in an objective manner (Section 3). These considerations are presented in the hope that they will prove to be a valuable aid for the evaluation of future geological World Heritage Sites. Secondly, I use these criteria to analyze the relative merits of the 9 strongest Pennsylvanian contenders for World Heritage Status (Sections 4-5). The results of this analysis unequivocally point to the Joggins Fossil Cliffs of Nova Scotia, Canada as being the site most worthy of being awarded this much sought after status (Section 6), and fully confirm the opinion of Sir Charles Lyell (1797–1875), the Father of Modern Geology, who wrote in his influential textbook that Joggins represents *"the finest example in the world of a natural* [Pennsylvanian] *exposure"* (Sir Charles Lyell 1871, Student's Elements of Geology, p. 409). A glossary including definitions of technical terms used and giving biographically information about key scientists mentioned is given in Appendix 3.

2. Philosophical difficulties in choosing geological World Heritage Sites

There is of course a major philosophical problem in attempting to choose a single geographical site as representative of a period of geological time. This difficulty relates to the simple fact that the Earth today exhibits great spatial variability in its environments and ecosystems, and has done throughout its history. Biogeographers refer to those present-day zones that exhibit similar climates and ecosystems at the continent scale as biomes (Walter 1973). Examples of modern biomes include the tropical rainforests, which grow under warm, wet conditions, the tropical savannahs, which exist under warm, dry conditions, and the tundra, which develops under cold, dry conditions (Figure 2).

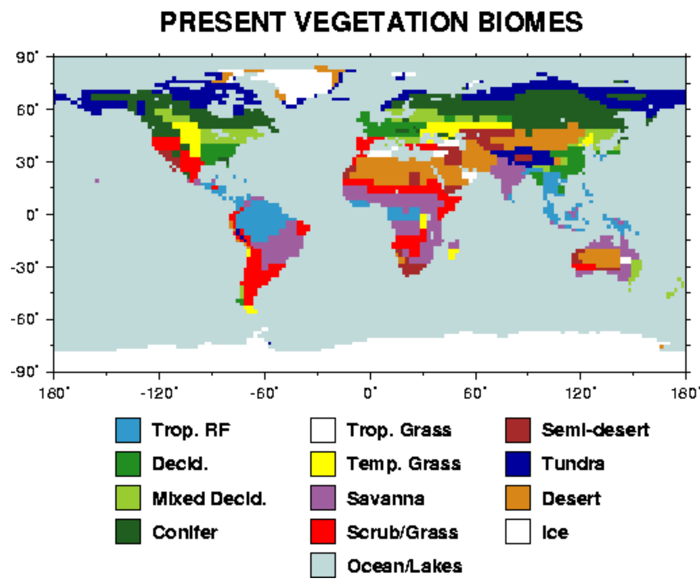

Figure 2. *Distribution of present-day vegetation biomes courtesy of J.W. Crowley downloaded from http://stommel.tamu.edu/~baum/paleoveg.html*

Throughout the last 400 million years of Earth History, biomes, similar to those of today, are known to have existed (Willis & McElwain 2002). The profound philosophical difficulty one faces in proposing a geological World Heritage Site is the problem of how a single geographic site can adequately represent the spatial variability of a particular time period. We might well ask which single site today would be representative of the world's environments and ecosystems. Would we choose the Amazonian rainforest on the basis of its great biodiversity, the deep ocean basin on the basis of its great geographic extent, or perhaps even Mexico City on the basis of being the largest human settlement?

Fortunately, when we approach this question for the Pennsylvanian World, the solution is slightly more straightforward because only a relatively limited range of environments and ecosystems have been preserved over the long years of geological time, and only a small number of those have been investigated in detail by geologists. During Pennsylvanian times, the continents were grouped together into three main landmasses. The supercontinent of Laurasia, which was composed of present-day North America, Europe, and northern Asia straddled the tropical zone; the supercontinent of Gondwana, which was composed of present-day South America, Antarctica, Australia, India and Africa, lay over the South Pole; and a third comparatively small landmass, Angara, composed of China, lay in northern mid-latitudes (Figure 3; Golonka et al. 1994).

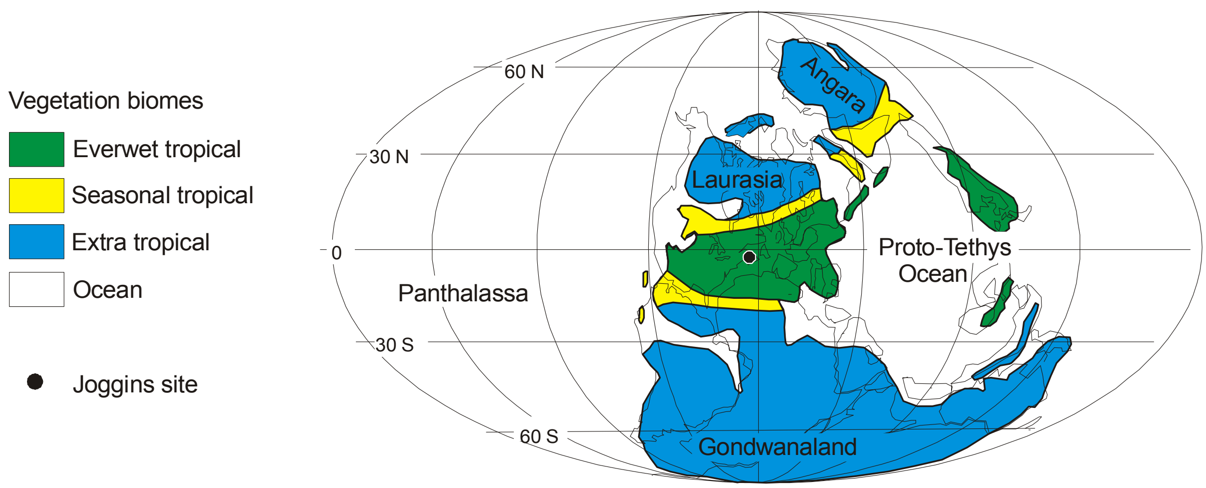

Figure 3. *Global geography and vegetation biomes during Pennsylvanian times based on palaeogeographic data in Golonka et al. (1994), and biome data in Willis & McElwain (2002).*

Although widespread Pennsylvanian deposits and their fossil assemblages have been preserved on Angara (e.g. Li & Wu 1996) and Gondwana (e.g. Kneller et al. in press), the deposits of tropical Laurasia have received vastly greater attention by geologists (Pfefferkorn et al. 2000). The reason for this is two-fold. Firstly, the science of geology initially developed in

Europe and North America and, as a consequence of this 'accident of history', Laurasian rocks have been studied for longer and by a relatively larger community of scientists compared with coeval Gondwanan or Angaran rocks. Secondly, as noted in the introduction, Laurasian Pennsylvanian rocks contain a significant volume of the Earth's economic, high quality, coal deposits, which were utilized to fuel the Industrial Revolution in North America and Europe from the 1700s onwards. Many thousands of coal geologists have been employed to facilitate the exploitation of this important energy resource, and academic research has further been facilitated through the creation of numerous new exposures in mining workings (Pfefferkorn et al. 2000).

It is therefore no exaggeration to say, that the tropical coal-forming coastal wetlands of equatorial Laurasia represent by far the best-understood ecosystems of the Pennsylvanian World (DiMichele et al. 2001), and probably the best-understood terrestrial ecosystem in the entire pre-Tertiary geological record (Falcon-Lang in press). The late Prof. Stephen J. Gould has pointed out that, in both popular and scholarly circles, the 'story' of the evolution of life is commonly told by means of a series of pictorial reconstructions through time, which he refers to as iconographs. Although this is a highly subjective approach, it does reflect the fundamental way human beings process information (being primarily visual beings), and it probably represents the most powerful means of conceptualizing Earth History (Gould 1993). Without doubt, tropical coal swamps are classically iconographic for Pennsylvanian times, represented in literally hundreds of museum dioramas around the world as dense, steamy, boggy rainforests populated by bizarre plants and animals (DiMichele et al. 2001). One example of many such dioramas is illustrated in Figure 4 overleaf.

Figure 4. *A reconstruction of Pennsylvanian coal swamps displayed at the Field Museum of Natural History, Chicago. Sixteen other Pennsylvanian dioramas may be viewed online at http://www.uni-muenster.de/GeoPalaeontologie/Palaeo/Palbot/seite12.html*

The Pennsylvanian Period (299-320 Ma; 21 million years long) is divided into three time-intervals for European and northern Asian strata; the earliest interval being the Upper Namurian (316-320 Ma, 4 million years long), the medial interval being the Westphalian (305-316 Ma, 11 million years long), and the latest interval being the Stephanian (299-306 Ma, 7 million years long) (Menning et al. 2000, Scale B). A different scheme is used for North American strata, and the relationship between the two schemes is shown in Figure 5 overleaf.

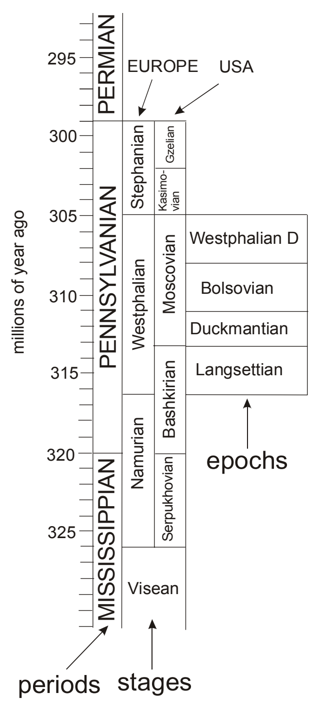

Figure 5. *Pennsylvanian timescale based on calibrated chronostratigraphy of Menning et al. (2000) (Scale B utilizing the best Ar/Ar radiometric dates).*

By far the best examples of Pennsylvanian tropical coal swamp ecosystems are restricted to the Westphalian interval because during this time, humid ever-wet climates were best developed over tropical Laurasia (DiMichele & Philips 1994). In contrast, during the earlier Namurian and later Stephanian intervals, climate was more seasonally dry and the biotas were most similar to those of the Mississippian and Permian Periods, respectively (Falcon-Lang 1999a; DiMichele & Philips 1994; Ziegler et al. 2002). This report therefore only deals with the tropical coal swamps, and associated environments and biota, which existed during the Westphalian interval, a stage which itself is subdivided into four sub-intervals, the Langsettian (313-316 Ma), the Duckmantian (311-313 Ma), the Bolsovian (308-311 Ma), and the Westphalian D (305-308 Ma) (Menning et al. 2000; Figure 5). In limiting the scope of this comparative study to the Westphalian tropical biomes of Laurasia, provision is made for potential future World Heritage nominations of the poorly-known temperate biome of Angara and the taiga biome of Gondwana of the Pennsylvanian Period, as well as Mississippian biomes, which could comprise shallow marine carbonate reef communities, and Pennsylvanian (Stephanian)-Permian biomes, which could comprise arid continental ecosystems.

3. Assessment criteria

Having established that the Westphalian-aged tropical coal swamps are most representative, and indeed iconographic, of the Pennsylvanian World in general, we must now consider which geographic site best represents that tropical biome, and is most worthy of World Heritage Status. Criteria for selecting palaeontological World Heritage Sites have been presented in three recent publications (IUCN 1994, Wells 1996, Cloutier & Lelievre 1998). These criteria, hereafter referred to as the WHS criteria, are fully listed in Appendix 1. Not all the WHS criteria are relevant (or equally significant) for assessing Pennsylvanian sites because they were primarily developed for palaeontological sites of a very different nature to those discussed here (see below). Nevertheless, they do provide some very important considerations. In this section, the WHS criteria are critically reviewed, and twelve selection criteria directly related to the WHS but specifically oriented to Pennsylvanian sites are adopted. [Reference to specific WHS criteria in the text is given by means of the publication year of the specific document followed by the criteria number, e.g. 1996-3 refers to Well's third criteria (see Appendix 1)].

3.1. Review of existing WHS criteria

The WHS criteria relevant to Pennsylvanian comparative studies may be grouped into three major categories as shown in Table 1. The first category of criteria deals with the biodiversity[2] of potential World Heritage palaeontological sites, and is viewed as the most important aspect by all three WHS documents. A key concern of the first WHS category is that sites should contain abundant fossil specimens (1998-7) comprising very large numbers of species (1994-2, 1996-1, 1998-1), which represent the broadest possible range of major taxonomic groups (1996-7, 1998-2). These are very important criteria, which ensure that the chosen site represents paleoecosystems with the richest diversity and of the greatest variety. Related to these criteria is the recognition that sites should, where possible, also encompass important 'events' in evolutionary history, e.g. the first appearance of reptiles, or the extinction of the dinosaurs (1998-3). This criterion is also important because it emphasizes major watersheds in the history of life, and its adaptation to (and modification of) the environment.

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[2] A brief summary of the scientific scheme used to classify life (Linnean taxonomy) is given in Figure 6 (overleaf) to introduce the reader to key terms such as species and genera, which are widely used in the following discussion.

Taxonomical hierarchy	**Assessment criterion**
Superkingdom: Eukaryota	
Kingdom: Metazoa (multi-cellular animals)	
Phylum: Chordata (animals with spinal cords)	Criterion 1
Subphylum: Craniata	
Class: Mammalia (mammals)	Criterion 1
Subclass: Eutheria (placental mammals)	
Order: Primatae (primates)	
Suborder: Catarrhini	
Family: Hominidae (apes)	Criterion 5
Genus: Homo	Criterion 3
Species: sapiens (humans)	Criterion 2

Figure 6. *The classification of life using Linnean nomenclatural using* Homo sapiens *(humans) as an example (left-hand column). Those taxonomic levels used in this study are highlighted in bold, with the related selection criteria (introduced in Section 3.2.1) listed in the right-hand column.*

The second category of WHS criteria deals with the nature, quality, and variability of the 'archive' in which the fossil record is preserved, i.e. the rock section itself (Table 1). These criteria include an initial consideration of the time interval represented by particular sites (1994-1, 1994-10, 1996-1, 1996-6). A key question asked is, ‘Does the site merely represent an instantaneous 'snap shot' of an ecosystem, or a million years of history’? Sites at which fossil ecosystems are preserved over a sustained time period are to be preferred, because they will likely better record the typical range of ecosystem types, and the community's dynamic response to changing environments and climates (potentially providing analogues for present-day global change). An additional related criterion is that sites should encompass the greatest possible variety of depositional environments (1998-4). In other words, sites preserving the deposits of marine, freshwater, and terrestrial environments and their ecosystems, are to be preferred to those with a more limited range of settings. In adhering to this criterion, sites are selected on the basis of their capacity to paint the broadest picture of the world at a particular time interval. A third criterion is that sites should record aspects of the paleobiology of the ecosystems (1998-5). For example, insect bite marks on leaves (Scott et al. 1992), the contents of coprolites (i.e. fossil faeces; Scott 1977; Chin and Gill 1996), and vertebrate dentition (Milner 1987; Sues and Reisz, 1998) may all provide indirect evidence concerning food chains. In addition, ecological disturbance by wildfires may be indicated by the presence of fossil charcoal (Falcon-Lang 2000) and flood disturbance may be indicated by the relationship of fossil life assemblages to enclosing sedimentary deposits (Falcon-Lang et al. 2001). This criterion is important because it emphasizes fossil assemblages as interconnected communities. The quality of preservation of fossils is a final criterion in this group (1994-9, 1996-3, 1998-6). Sites where the original 'soft tissue' of animals and plants is preserved (as opposed to just decay-resistant mineralized tissue, e.g. bones), or where complete, articulated fossils occur (as opposed to isolated bones, or leaves), are to be preferred, because such fossils provide the richest sources of paleobiologically important information. Sites exhibiting this kind of exceptional preservation are termed Conservation-Lagerstätten (Seilacher et al. 1985).

The third category of WHS criteria relate to the nature and significance of the site itself (Table 1). A first important consideration is the degree to which the site has been investigated, and discoveries curated (1994-5, 1994-7, 1996-8). In particular, these criteria attempt to assess how historically significant a given site was/is in contributing to our knowledge of the time interval in consideration, whether it has attracted international research teams (as opposed to merely local/national researchers), and to what degree fossil material collected is properly curated, displayed and available for future study. Related criteria examine the permanency (integrity) of the site and the probability of future discoveries (1994-6, 1996-8). If a site that has once yielded an important palaeontological collection no longer exists (e.g. backfilled coal mining operations), its eligibility for World Heritage Status should be significantly reduced because UNESCO recognizes World Heritage *sites* not *collections*. Geological sites continuously subject to natural erosion (e.g. sea-cliffs) are to be preferred over artificial excavations because they are of greater permanency and are most likely to continuously yield new fossils in the future.

Lastly, a miscellaneous group of WHS criteria are not directly relevant to a Pennsylvanian comparative study because they either deal with geographic aspects of potential sites not found in the Pennsylvanian (1994-3, 1994-8), refer specifically to Precambrian sites (1996-4, 1996-5) or represent general administrative (rather than scientific) recommendations (1996-9). These criteria are not considered further in this report (Table 1).

3.2. Assessment criteria proposed for evaluating Pennsylvanian sites

General and specific principles directly arising from the WHS criteria (above) are used to propose criteria suitable to evaluate Pennsylvanian sites for World Heritage Status. Firstly, some general "factors" are formulated to rapidly narrow a short-list of potential sites from the huge number of Pennsylvanian outcrops. Secondly, specific "criteria" are identified to evaluate the relative value of the short-listed sites. These specific criteria should, where possible, be quantifiable so that competing sites can be ranked in a repeatable, objective manner.

3.2.1. General factors to erect a short-list of sites

Two factors are used in this study to short-list representative Pennsylvanian fossil sites. These operate to identify those sites which, in the first place, contain the greatest range of major taxonomic groups, and in the second place, are representative of the two most significant evolutionary themes of the Pennsylvanian world, namely (1) the appearance of reptiles and the diversification of tetrapod communities, and (2) the rise of the first coal-forming rainforests (Section 1). Ideally, of course, a site should be superbly representative of both key aspects of Pennsylvanian ecosystems, possessing both tetrapods and trees. The primary focus on ancient biodiversity and key evolutionary events (phenomena of outstanding universal value) reflects the major importance of this facet in the WHS criteria reviewed in Section 3.1. The two factors are as follows:

Factor (1): The site must contain body-fossil representatives of each of the three major macrofossil taxonomic groups, namely (i) vascular plants, (ii) invertebrate animals, and (iii) vertebrate animals. [cf. 1994-2, 1996-1, 1996-7, 1998-1].

Factor (2): The site must contain either a major accumulation of tetrapod remains (namely amphibians and/or reptiles) or contain a major example of upright coal-age trees (i.e., multiple fossil forests), or preferably both [cf. 1998-3].

3.2.2. Specific criteria to evaluate short-listed sites

An additional twelve criteria (numbered 1-12) are proposed to assess the relative merits of the sites (9 in total; see Section 4) short-listed by Factors 1 and 2. It should be again carefully stressed that these are not *new* criteria, but in fact are directly related to the WHS criteria. They merely represent the application of the general WHS criteria to the specific aspects of the Pennsylvanian world. Table 1 clearly shows how the criteria used in this study relate to the WHS criteria. These criteria may be ordered into three categories, each directly related to the three major categories of concerns raised by the WHS criteria reviewed in Section 3.1. Category 1 relates to the fossil record of biodiversity (Criteria 1-5), Category 2 relates to the nature, quality and variability of the fossil record archive (Criteria 6-9), and Category 3 relates to aspects of permanence (integrity) and scientific impact (both past and future) of the site itself (Criteria 10-12). Each criterion is designed to be quantifiable, allowing sites to be ranked relative to one another. In the analysis presented in Section 5, the site ranked first for a particular criterion scores 9, while a site ranked ninth (and last) will score 1. The site with the highest score when scores for all twelve criteria are summed, will be considered the most representative Pennsylvanian locality, and the site most worthy of World Heritage Status.

CATEGORY 1. Fossil record of biodiversity

Criterion (1): *Diversity at Phylum/Class taxonomic level* (cf. 1994-2, 1996-1, 1996-7, 1998-2): This criterion assesses the diversity of the three major taxonomic groups present at a given site (i.e. plants, invertebrates, and vertebrates). The number of Phyla present in invertebrate animal assemblages, and the number of Classes present in vertebrate animal and plant assemblages is ascertained for each site. The site with the greatest number of Phyla/Classes will be ranked first (cf. Figure 6). [NB: Taxonomic representativeness is ascertained at a higher taxonomic level for invertebrate animals because this group is much more diverse than the other two.]

Criterion (2): *Species richness* (cf. 1994-2, 1996-1, 1996-7, 1998-1): This criterion measures the total number of species present in the whole fossil assemblage at a site (cf. Figure 6). Sites will be ranked accordingly, with the site containing the greatest number of species being ranked first.

Criterion (3): *Tetrapod specimen abundance* (cf. 1998-7): The rarest components of all Pennsylvanian fossil sites are tetrapod skeletons (amphibians and reptiles). Precise reconstructions of tetrapod biology and ecology are possible only at sites where a large number of specimens has been collected, and are available for study. The number of tetrapod specimens is therefore assessed for each site based on data in Milner (1987). In addition, the diversity of tetrapod assemblages at the generic level is assessed (cf. Figure 6). The site scoring highest when the results of these two analyses are summed will be ranked first (cf. Factor 2).

Criterion (4): *Fossil forest abundance* (cf. 1994-9, 1998-5): Upright trees are an unusual, iconographic and important part of Pennsylvanian ecosystems. This criterion measures the number of fossil trees discovered in growth position and reported in the literature for each site (cf. Factor 2).

Criterion (5): *Evolutionary significance* (cf. 1998-3): This criterion assesses the evolutionary significance of the fossils at a given site. Specifically, it ascertains how many taxonomic groups at the Family level are represented for (i) the first time (first appearance), and (ii) the last time (last survivor) at the site. The site with the most first and last appearances of families will be ranked first (cf. Figure 6).

CATEGORY 2. Nature, quality and variability of fossil archive

Criterion (6): *Size of geological window* (cf. 1994-1): This criterion measures two factors. The first is the length of geological time represented by the site, expressed as a percentage of the entire Westphalian stage of the Pennsylvanian Period (11 million years long). This analysis uses the latest and most up to date Pennsylvanian geological time scale, that of Menning et al. (2000). The second is the thickness of strata represented at the site (in metres). The site recording the longest time interval and containing the thickest sedimentary accumulation will be ranked first.

Criterion (7): *Range of major depositional environments (fossil habitats) represented* (cf. 1998-4): This criterion assesses the range of different major depositional environments represented by the fossil archive. Specifically, sites are scored by the presence or absence of representatives of (i) Open marine deposits, (ii) Restricted brackish bay or estuarine deposits, (iii) Freshwater lake deposits, (iv) Peat mire deposits, (v) Poorly-drained floodbasins and associated river deposits (grey beds), and (vi) Well-drained floodbasins and associated river deposits (red beds). The site containing representatives of the greatest number of these six palaeoenvironmental groups will be ranked first.

Criterion (8): *Paleobiological representativeness* (cf. 1994-10, 1996-1, 1998-5): This criterion assesses the presence or absence of a wide variety of potential palaeobiological data, specifically (i) ecosystem response to global change, (ii) autochthonous plant communities, e.g. upright trees (life assemblages; cf. Criterion 4), (iii) charcoal as evidence for wildfire[3], (iv) coprolites, vertebrate dentition, and leaf bite marks as evidence of food chains, (v) tetrapod footprints as evidence of locomotion and gait, and (vi) invertebrate trace fossils as evidence of behavior.

Criterion (9): *Quality of fossil preservation* (cf. 1994-9, 1996-3, 1998-6): This criterion measures the presence or absence of various kinds of exceptional fossil preservation at a site. Specifically, these are (i) Soft-tissue preservation of vertebrates or invertebrates, (ii) articulated skeletal preservation of vertebrates, (iii) soft-tissue cellular preservation of plants. The site representing the broadest range of exceptionally preserved fossils will be ranked first.

CATEGORY 3. Permanence (integrity) and scientific impact of site

Criterion (10): *Degree of site investigation* (cf. 1994-5, 1994-7, 1996-8): This criterion measures three independent parameters related to the degree of site investigation, these being (i) the length of time the site has been studied in years, (ii) the number of scientific books and papers that have resulted from this research, and (iii) the number of countries in which those articles have been published. Sites will be ranked for each parameter, and will receive a final rank based on the sum of the three individual scores. The site, which has been studied longest, detailed in most publications, and examined by the broadest international community, will be ranked first.

Criterion (11): *Permanence of site* (cf. 1996-8): This criterion measures the permanence (or integrity) of the site. Sites score '0' if they no longer exist (e.g. backfilled strip

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[3] Fire was a very important component of Pennsylvanian ecosystems because atmospheric oxygen levels were much higher than at present, and consequently vegetation was more flammable (Scott and Jones 1994).

mine), '1' for sites that exist but are in poor condition (e.g. degraded quarry face), '2' for sites that exist in good condition, but that condition is dependent on continued human activity (e.g. active quarry face), '3' for sites in good condition and continually renewed by natural processes (e.g. eroding sea-cliffs). The site with the most permanent and fresh exposures will be ranked first.

Criterion (12): *Probability of continued discoveries* (cf.1994-6) This criterion assesses the likelihood of future discoveries. Two types of discoveries are distinguished; these are (a) general geological discoveries, and (b) palaeontological discoveries. Ascertainment of future discovery probability is achieved by calculating the square of the number of published papers at a site over the past decade divided by either the total number of papers from the site (for general discoveries) or the total number of palaeontological papers from the site (for palaeontological discoveries). Although the number of published papers is not a flawless means of quantifying the number of past discoveries at a site, it nevertheless represents the most easily measurable proxy. The site with the highest yield of new discoveries under both categories will be ranked first.

4. Short-list of comparative sites

Standard database searches of fossiliferous sites where 'palaeoecosystems' of the Pennsylvanian (Westphalian) tropical coal-forming world are preserved were undertaken using the Web of Science and GeoRef. Sites of two kinds were recognized in these searches, the first being single locality sites, composed of a single geographic outcrop area (e.g. a single continuous cliff-section, or a single mine), and the second being composite locality sites, composed of several fossiliferous outcrops within a small geographic area (e.g. a cluster of closely adjacent strip mines). Whilst obviously there is some subjectivity in the way one chooses to cluster sites into composite groups, about 250-300 fossiliferous Pennsylvanian sites (either single sites or composite sites) were identified using the two geological databases. A list of these sites (presented as raw unprocessed data) may be obtained on request from the author as an electronic file. Non-tropical/non-coal-forming fossil sites of this age were excluded from the list because these settings are not 'iconographic' of Pennsylvanian (Westphalian) times (Section 2).

Of the 250-300 sites identified, only about 90 fulfilled all the requirements of Factor 1, the remainder either lacking one or two of the three main fossil groups. Factor 2, which requires sites to contain either major tetrapod remains or major fossil forest-bearing intervals, further significantly reduced this list (cf. Section 3.2.1). In his comprehensive review of Westphalian-aged tetrapods, Milner (1987) identified only 27 sites worldwide. These are in fact geographically clustered, and therefore only represent a total of 16 distinct composite localities. Milner (1987) considered 7 of these to be major tetrapod localities (i.e., yielding more than 20-30 skeletons each), the remainder possessing only rare, scattered remains. These 7 sites are therefore selected for the comparative study; they are as follows: Durham (UK), Freeport (USA), Joggins (Canada), Leinster (Ireland), Mazon Creek (USA), Nyrany (Czech Republic), and Sydney (Canada) (see Table 2). In his comprehensive review of Westphalian-aged fossil forest sites, Gastaldo (1986) identified 7 major localities worldwide where at least twenty upright trees had been discovered at multiple intervals; they are as follows: Durham (UK), Joggins (Canada), Lancashire (UK), Mary Lee (USA), Ruhr (Germany), Sydney (Canada), and Yorkshire (UK). Of these, only 5 sites still exist (the others having been recorded in short-lived excavations, i.e. Lancashire and Ruhr), and these are selected for the comparative study and listed in Table 2. Three of these fossil forest sites (Durham, Joggins, and Sydney) also contain major tetrapod accumulations, so that in total only 9 Pennsylvanian sites were short-listed for comparative study.

The nine selected sites include 3 of the 5 Westphalian-aged sites on the provisional World list of IUGS (International Union of Geological Sciences) Palaeozoic Paleobotany Geosites as erected by Chris Cleal and Barry Thomas; these are Joggins, Mazon Creek, and Sydney, i.e. Point Aconi (http://iop.biodiversity.org.uk/iopnews/59f/10.htm). The remaining two Westphalian Palaeobotany Geosites (Glynneath Ammanford, South Wales, UK, and New River Gorge, West Virginia, USA) lack both tetrapods and upright trees and thus do not qualify for the short-list. A comparable list of Geosites for Pennsylvanian vertebrate sites is currently in preparation but not yet available.

4.1. Description of short-listed sites

The geographic boundary, stratigraphy, age, and geological significance of the 9 sites selected for comparative study (see Tables 2 and 3) are described in the following section in detail. The sites are listed in order of age, being arranged from oldest to youngest. The range of ages encompassed by each site is summarized in Figure 7 (overleaf). Every major time interval of the Pennsylvanian (Westphalian) is represented as follows: Langsettian (Leinster Coalfield composite site, Mary Lee Coal Zone composite site), Langsettian-Duckmantian (Joggins Cliffs single site, Yorkshire Coalfield composite site, Durham Coalfield composite site), Bolsovian-Westphalian D (Sydney Coalfield composite site), and Westphalian D (Freeport Coalfield composite site, Mazon Creek composite site, Nýřany Member composite site). The 9 selected sites span two continents and five countries, namely North America (Canada and USA) and Europe (UK, Ireland, and Czech Republic), and their general location is shown on Figure 8 overleaf. Recently UNESCO has expressed an interest in recognizing a greater number of World Heritage Sites in the Third World. It should therefore be emphasized that Pennsylvanian-aged palaeo-tropical deposits are almost entirely geographically restricted to Europe and North America (distribution shown on Figure 8), hence it is not possible to consider any Third World sites in this Comparative Study. The only major geographic region not represented by short-listed sites is in eastern and southern Russia. Although thick Pennsylvanian rock sequences occur in this region, they are poorly exposed, and understood to a much lesser degree than coeval North American and European strata (Wagner et al. 1996).

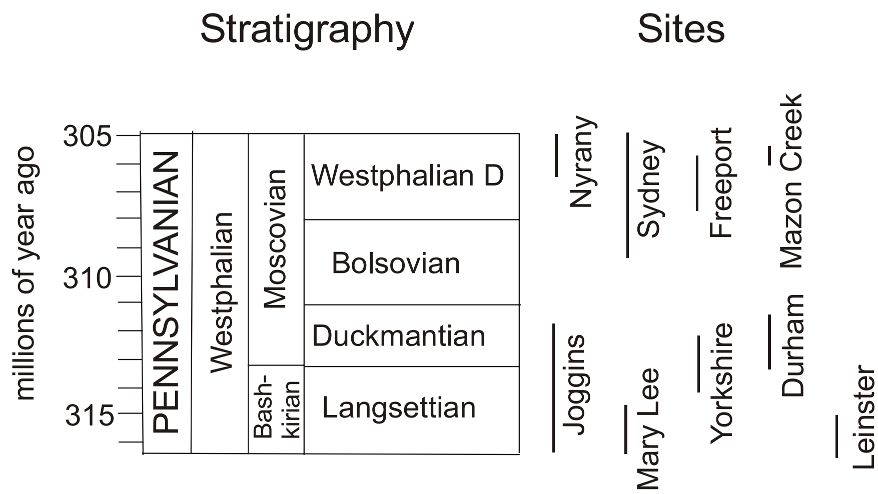

Figure 7. *Stratigraphic range of the nine sites selected for Comparative Study*

(NB: As the 9 sites are described in the following section, the overall ranking each site finally receives in the Comparative Study (Section 5) is given after the site name in bold Arial font, e.g. Leinster Coalfield **[8th place].** This information is added so the reader can begin to assess the sites as s/he reads the site descriptions.)

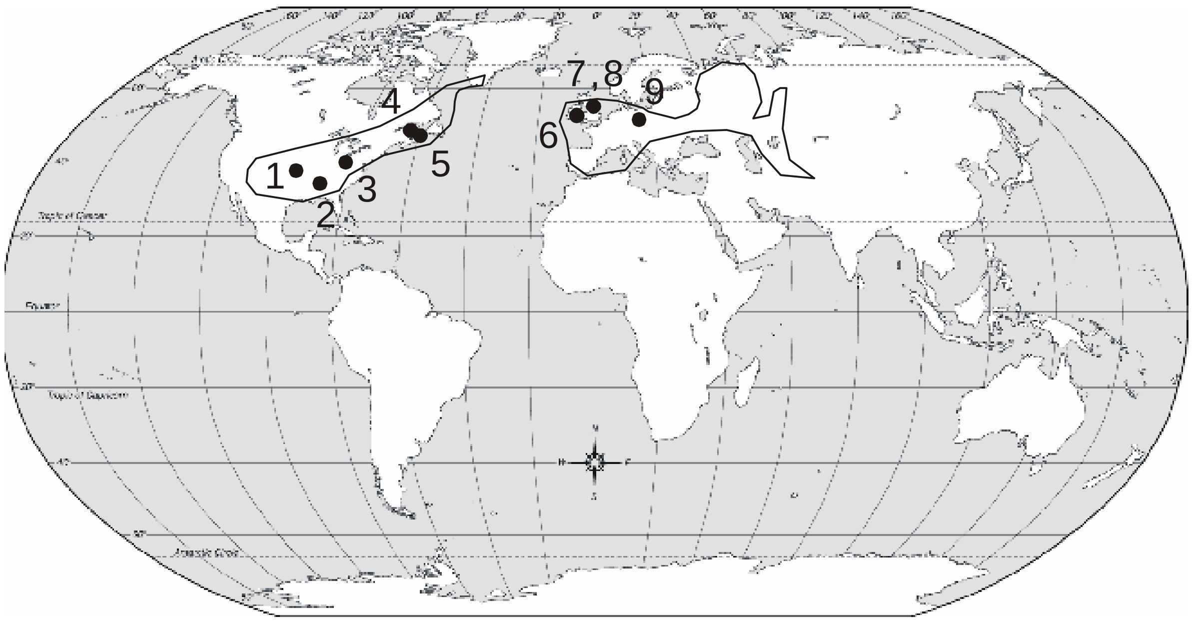

Figure 8. Location details of the nine sites considered in the Comparative study, from east to west: (1) Mazon Creek, (2) Mary Lee, (3) Freeport, (4) Joggins, (5) Sydney, (6) Leinster, (7) Yorkshire, (8) Durham, and (9) Nýřany. Global distribution of main Pennsylvanian palaeotropical deposits is indicated by areas delimited by bold lines.

4.2 Mary Lee Coal Zone composite site, Alabama, USA [9th place]

Geographic site description

This is a composite geographic site comprising numerous strip mines in northwestern Alabama, USA spread across an area 70 km by 100 km (Pryor & Gastaldo 2000). The strip mines are now largely inactive with key exposures backfilled, hence no longer visible. Other outcrops include several road cuts, all of which now are highly degraded exposures. More precise location details of those mines active a decade ago may be obtained from Demko & Gastaldo (1992) and Gastaldo (1983, 1986).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The fossiliferous section occurs within the up to 3000 m thick Pottsville Formation of the Black Warrior Basin. Only the Mary Lee Coal Zone, a stratigraphic unit c. 40-50 m thick, within the middle-to-upper part of the Pottsville Formation, has been investigated in detail for its fossil content. Other mid-to-upper Pottsville intervals have sporadically yielded important faunas. In general, the fossil sites can be grouped together into a rock interval straddling the mid-to-late Langsettian stage, and representing a period of time <0.5 million years in duration. The strata were deposited in a coastal plain setting (Demko & Gastaldo 1992, 1996).

Significance of the site

The Pottsville Formation represents one of the few early Pennsylvanian fossil localities investigated in the USA. The Mary Lee Coal Zone became famous in the late 1970s following the discovery and detailed description of its spectacular floral assemblages including, most notably, numerous forests of standing lycopsid trees (Gastaldo 1983, 1984, 1990). A modest invertebrate fauna has also been described (Gibson 1990; Rindsberg 1990). At a slightly higher stratigraphic interval exposed in the Union Chapel Mine, the most prolific Pennsylvanian tetrapod trackway site in the world was found in the 1930s, yielding an important tetrapod behavioral record, comprising some 900 individual trackways (Pyenson & Martin 2001).

Sources consulted

Numerous articles are available, and only a small selection have been consulted as follows: Churnet (1996); Demko and Gastaldo (1992, 1996); Eble et al. (1994); Gastaldo (1983, 1984, 1990); Gastaldo et al. (1990, 1993); Pashin and Carroll (1993); Pyenson and Martin (2001); Read and Mamay (1964); Rindsberg (1990).

4.3 Leinster Coalfield composite site, Ireland [8th place]

Geographic site description

This is a composite site comprising several inactive opencast and underground shaft coal mines and at least 35 boreholes, distributed over an area approximately 20 km by 12 km in the Leinster (also known as Castlecomer) Coalfield of County Kilkenny, SE Ireland (Sevastopulo 1981). No up-to-date information exists concerning the present condition of the mine sites, but the exclusive use of borehole data in the most recent reviews (dated 1981 and 1999) of the Leinster Pennsylvanian strata strongly implies that they are now either highly degraded exposures or non-existent. Precise location details for all localities (historic or modern) in this small coalfield may be obtained from Nevill (1961) and Orr & Briggs (1999).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The fossiliferous succession is c. 170 m thick, and consists of rocks assigned to the basal portion of the Lower Coal Measures Formation. These strata represent one of a very small number of Pennsylvanian outliers in Ireland (Nevill 1961), and encompass the lower half of the Langsettian stage, a period of about 1 million years duration (see Figure 5). The strata were dominantly deposited in a coastal plain environment characterized by meandering channels, which twice became flooded for a short period by a shallow marine gulf following sea level rise.

Significance of the site

The site was originally made famous in 1864 by the discovery of numerous fish and tetrapod skeletons in the Jarrow Colliery (Jarrow Coal Zone; Milner 1980b). These findings were subsequently studied by Prof. Thomas Henry Huxley (Huxley & Wright 1867), one of the most important scientists of the nineteenth century (perhaps best known for his energetic and eloquent support of Darwin). More recently, adjacent beds have yielded an important arthropod-dominated Conservation-Lagerstatten (Orr & Briggs 1999). An additional point of interest is the two marine bands near the base of the succession that contain an abundant and diverse invertebrate fauna (Nevill 1961). However, in general, the value of this potentially important site has been limited by a dearth of research, as exemplified by the fact that a comprehensive floral list still does not exist for these strata (Crookall 1955-1976; Eager 1964; Sevastopulo 1981).

Sources consulted

There are few up to date references from this locality. The following were consulted in the preparation of this report: Crookall (1955-1976); Eagar (1964); Huxley and Wright (1867); Jackson and Monaghan (1995); Milner (1980b, 1987); Nevill (1961); Olson (1979); Orr and Briggs (1999); Sequeria (1996); Sevastopulo (1981).

4.4 Yorkshire Coalfield composite site, UK [7th place]

Geographic site description

This is a composite geographic site consisting of two brick pits (Swillington and Thorpe), and four opencast coal mines (Low Moor, Toftshaw, Lodge Hill, and Lowther North), which are located over a 10 km by 10 km area of West Yorkshire, UK. Precise location details may be found in Panchen & Walker (1961), and Scott (1978, 1984). Active mining continues at only two of the sites, and of the inactive mines, at one, faces are now highly degraded, while the others have all been destroyed by backfilling (Scott 1978). Active mining at the remaining two sites (Swillington and Thorpe) is unlikely to continue for more than a decade (Quarry Manager, George Armitage & sons, pers. comm., 1995).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The total fossiliferous succession is about 120-150 m thick and straddles part of the Lower and Middle Coal Measures Formations, a stratigraphic interval assigned to the late Langsettian to early Duckmantian stage, and estimated to represent c. 1.5 million years of time. The strata were deposited on coastal plains characterized by large braided river channels, an environment which was periodically flooded by a shallow marine gulf at times of high sea-level.

Significance of the site

The sites are most famous for their rich flora (Kidston, 1890-1898), and in particular, the occurrence of numerous standing trees (Sorby 1875; Scott 1984) exhibiting ecologically important flood scour structures (Leeder et al. 1984), and the discovery of the earliest known conifer from the Swillington brick pit (Scott 1974; Scott & Chaloner 1983). Studies of significant coprolite deposits have augmented our knowledge of Pennsylvanian food chains (Scott 1977), and early studies of the role of fire in Pennsylvanian communities were also undertaken here (Scott 1989; Scott & Jones 1994). A few minor tetrapod skeletal remains have been recovered from the Low Moor and Toftshaw sites (Panchen & Walker 1961). The Clay Cross marine band, which defines the Langsettian-Duckmantian boundary in the region, also contains a rich and diverse invertebrate fauna (Scott 1978).

Sources consulted

The following principal references were consulted in this report: Bartram (1987); Eden et al. (1957); Kidston (1890-1898); Leeder et al. (1984); Milner (1987); Scott (1974, 1977, 1978, 1979, 1989); Panchen and Walker (1961); Scott and Chaloner (1983); Scott and Hemsley (1991); Scott and Jones (1994); Trueman (1955)

4.5 Nýřany Member composite site, Czech Republic [6th place]

Geographic site description

This is a composite site comprising at least seven open cast and underground mines (mostly now inactive with degraded faces, or destroyed by backfilling), and poor stream sections near Nýřany in the Czech Republic (Setlik 1973). More precise location details and descriptions could not be obtained from the scant literature available in english for the region.

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The fossilliferous interval consists of the 200-450 m thick Nýřany Member of the Lower Grey (or Kladno) Formation, which is assigned to the upper part of the Westphalian D stage (c. 1.5 million year duration) (Wagner 1973). The strata were deposited in a floodplain environment bounded to the east by alluvial fans. The most fossiliferous beds were deposited within a geographically restricted zone (8 km by 2 km in extent) of lacustrine and swamp environments (Milner 1980a).

Significance of the site

The site is most famous for its prolific tetrapod locality at the Humboldt Mine (and an associated site at Tresmosna) first reported by 1876, which has yielded one of the world's most important accumulations of Pennsylvanian tetrapods (Milner 1980a). These fossils were restricted to a 30 cm thick cannel shale interval, which is now believed to be exhausted; there have been no new discoveries for more than 100 years. The Nýřany Member also contains a reasonably rich flora, although to date it has only been superficially investigated (Setlik 1973).

Sources consulted

The following references were consulted: Hoffman (1963); Milner (1980a, 1987); Rayner (1971); Reisz (1975); Setlik (1973); Simunek (1994); Wagner (1973). A more extensive literature exists for the site, but much of this was inaccessible to the author, being written in Russian and Czech.

4.6 Durham Coalfield composite site, UK [5th place]

Geographic site description

This is a composite geographic site, consisting of three underground collieries (named Newsham, Killingworth, and Usworth), an opencast coal mine (Priory North), and two grindstone quarries (of which Wideopen is the most geologically famous). With the exception of the Priory North opencast mine (Johnston 1999; Falcon-Lang & Scott, 2000), all these sites are now abandoned and exposures non-existent. In addition to these artificial exposures, a 2 km long coastal sea-cliff section near Newbiggin, Northumberland exposes an interval through the same stratigraphic section as the mines. All the sites occur in an area 15 km by 17 km in Northumberland and Durham, northeastern UK. Precise location detail may be extracted from Boyd (1994), Falcon-Lang & Scott (2000), Lindley & Hutton (1831), and Wood (1831).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The fossiliferous section encompassed by the various sites is about 500 m thick, a stratigraphic interval which belongs to the Middle Coal Measure Formation, and is of lower to middle Duckmantian age. The most fossiliferous interval is the unit associated with the High Main Coal Seam, which is exposed across the entire basin. In total, about 1.5 million years of time is represented by the Duckmantian strata in this area. The strata were deposited on coastal plains characterized by large braided river channels, an environment periodically flooded by a shallow marine gulf at times of high sea-level (O'Mara & Turner, 1999).

Significance of the site

These localities have yielded very important floral assemblages, including gigantic cordaite logs in the trunk channel sandstone deposits of braided rivers at Wideopen and Priory North (Johnson 1999; Falcon-Lang & Scott 2000) and upright trees (Wood 1831) associated with the High Main Coal unit; these remains were amongst the first fossil plants to be studied using the thin section technique (Lindley and Hutton 1831). In addition, very important tetrapod material has been extracted from Newsham colliery (and to a much lesser extent from Usworth), which has contributed greatly to our knowledge of early tetrapod ecosystems (Milner 1987)

Sources consulted

The following references were consulted in this report: Boyd (1984, 1985); Clack (1987); Falcon-Lang and Scott (2000); Johnston (1999); Land (1974); Lindley and Hutton (1831); Milner (1987); O'Mara and Turner (1999); Panchen (1972); Scott (1979); Smith and Francis (1967).

4.7 Mazon Creek composite site, Illinois, USA [4th place]

Geographic site description

This is a composite geographic site, comprising fifteen major open cast (strip) coal mines, within a 50 km by 30 km area in NE Illinois (Baird 1997). Most of the fossils collected from these localities were located in siderite nodules piled up on the mines' spoil heaps rather than from the rock outcrop itself. All the strip mines are now backfilled, with the most productive (Peabody No.11) now serving as a nuclear reactor cooling pond. Only a few degraded spoil heaps, and a few poorly exposed stream sections exist for continued collecting.

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The main fossiliferous unit belongs to the Francis Creek Member (c. 3-26 m thick) of the Carbondale Formation (Baird 1997), which represents a short interval of the Westphalian D stage, less than 0.5 million years long. The strata were deposited in a deep coastal gulf whose salinity ranged laterally from brackish to marine.

Significance of the site

This is one of the most famous Pennsylvanian fossil localities in the world, containing an extremely rich and variable biota including abundant plants, invertebrate animals, and vertebrate animals. The site has been continuously studied for nearly 150 years since Dana published the first paper on the assemblage in 1864 (Nitecki 1979), but the gradual backfilling of the mines has resulted in a marked drop off in the rate of new discoveries since the 1960s. Today, almost all Mazon Creek ongoing research relates to extensive Museum collections made in the 19th and early 20th century (Shabica & Hay 1997). Although biodiversity is extremely high, the palaeoecological significance of the site has been limited by the fact that few fossils are preserved in their original environmental context, having been transported to their depositional site, a brackish bay deposit (Shabica & Hay 1997), and by the complete absence of terrestrial deposits.

Sources consulted

The main sources consulted were Nitecki (1979) and Shabica & Hay (1997), two authoritative books providing an up to date summary of the some 323 journal papers, books, reports, theses, and abstracts relating to the Mazon Creek site and its extraordinary biota.

4.8 Freeport Coalfield composite site, east Ohio/west Pennsylvania, USA [3rd place]

Geographic site description

This is a composite geographic site comprising at least 8 underground coal mines (at least 7 are now abandoned and inaccessible) together with limited surface outcrop within a 70 km by 40 km area straddling the border between Ohio and Pennsylvania States in Eastern USA. Remaining surface rock exposures are in a very degraded state (Hook & Baird 1986). In addition to the poor outcrops, a very large number of borehole cores, and commercial stockpiles of coal are available for sampling. Precise location details for the sites are given in Hook & Baird (1986, 1988, 1993) and Valero-Garces et al. (1997).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The rock succession belongs to the Kittaning and Freeport Formations of the Allegheny Group (Weedman 1994), and comprises a ca. 60 m stratal thickness spanning the lower two-thirds of the Westphalian D stage (approximately 2 million years) (Hook & Baird 1993; Figure 5). The strata were deposited in a coastal wetland complex characterized by anastomosing floodplains, deep perennial lakes, and peatlands (Valero-Garces et al. 1997). The most fossiliferous deposits accumulated in abandoned river channels (ox bow lakes; Hook & Baird 1993).

Significance of the site

The site is most famous for three thin intervals, exposed at Linton, Cannelton, and Five Point mines, which have collectively yielded the most profilic and diverse tetrapod fauna in the world (28 genera; >700 specimens) since their discovery in 1856, 1891, and 1983, respectively (Hook & Baird, 1986, 1993). In comparison, associated invertebrates and plants have been recorded but have received relatively little attention (Durden 1969; Hannibal 1997; Hoffman 1963; Read & Mamay 1964; Williams 1960). The occurrence of important new discoveries in the future is highly dependent on continued mining in the area (Hook & Baird 1993).

Sources consulted

The following references were consulted: Carroll (1964); Case (1917); Durden (1969); Hannibal (1997); Hoffman (1963); Hook and Baird (1984, 1986, 1988, 1993); Hook and Ferm (1985); Hook and Hower (1988); Read and Mamay (1964); Valero-Garces et al. (1997); Williams (1960)

4.9 Sydney Coalfield composite site, Nova Scotia, Canada [2nd place]

Geographic site description

This is a composite geographic site comprising seven main coastal cliff sections (15-20 m high) in Cape Breton, Nova Scotia (namely those sections at Point Aconi, Table Head, Sydney Mines, New Victoria, Dominion, Schooner Pond, Long Beach), representing in total a 30 km long section. The cliffs exhibit excellent rock exposure, being subject to continuous erosion by Atlantic breaker waves. An additional site is an opencast mine at Florence (faces now degraded), numerous underground shaft mines (now closed and inaccessible), and abundant drill cores. Full location details may be found in Carroll et al. (1972), White (1992), and Gibling & Bird (1994).

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The fossiliferous section belongs to the Sydney Mines Formation (c. 300 m thick), and spans the uppermost Bolsovian stage and the entire Westphalian D stage (extending up into the lower Stephanian), a time period approximately 3.5 million years long (Calder 1998). The strata were deposited in coastal plains characterised by meandering rivers, alluvial plains characterised by anastomosing rivers, and occasionally in brackish bays during periods of high sea-level.

Significance of the site

The site is particularly famous for its upright fossil trees, which occur in large numbers at several localities (Calder et al. 1996). The trees locally contain tetrapod skeletal material (Carroll et al. 1972; Godfrey & Holmes 1990), and have been studied since the work of Brown (1846). Over the past 150 years, this excellently and dramatically exposed rock interval has yielded an exceptionally rich flora and vertebrate/invertebrate fauna (White 1992) and, although not internationally famous, certainly should be ranked as one of the most important Pennsylvanian sites worldwide. The site has proved to be an important natural laboratory for exploring the impact of Pennsylvanian climate change (specifically glacial-interglacial rhythms) on the development of stratigraphy (Gibling et al. in press).

Sources consulted

The following references were consulted in this report: Baird (1958); Bell (1938, 1944); Brown (1846, 1850); Calder et al. (1996); Carroll (1967); Carroll et al. (1972); Copeland (1957); Dawson (1868); Falcon-Lang (2001); Gibling and Bird (1994); Gibling et al. (in press); Godfrey and Holmes (1995); Masson and Rust (1983, 1984); White (1992); Wightman et al. (1993).

4.10 Joggins Cliffs single site, Nova Scotia, Canada [1st place]

Geographic site description

This is a single geographic site comprising a spectacular 3 km long coastal cliff section with 25 m high cliffs stretching from Lower Cove to McCarron's Creek on the Bay of Fundy, Nova Scotia, Canada (for precise location details see Gibling, 1987). It occurs in the context of a much larger (55 km long) continuous Pennsylvanian-aged cliff section, the remaining parts of which have a lower fossil content than the selected site. The cliffs exhibit excellent rock exposure, considered by Sir Charles Lyell (1871) to be the best Pennsylvanian exposure in the world. This site is subject to continuous erosion by the world's highest tides, and includes a very wide (500 m) wave-cut platform that is easily accessible at low tide. Inland, numerous drill cores of the corresponding strata exist, whereas once extensive underground mine workings are now closed.

Stratigraphy, age and palaeoenvironmental interpretation of rock succession

The section contains the type sections of the Joggins and Springhill Mines Formations of the Cumberland Group (c. 2000 m thick rock succession), which span the entire Langsettian stage and half of the Duckmantian stage, a time period approximately 4 million years in duration (Calder 1998; Figure 5). The strata were deposited in coastal plains characterized by meandering rivers, alluvial plains characterized by anastomosing rivers, and occasionally in brackish bays following short-lived sea-level rise.

Significance of the site

Joggins is one of the most famous Pennsylvanian localities in the world, widely known for its spectacular fossil forests, arguably the best examples of fossil trees of this age in the world (Scott 1998), its extensive vertebrate fauna which includes the earliest reptile (Reisz 1997; Benton 2000) curiously entombed within the once hollow trees, as well as its rich invertebrate fauna. Importantly, fossils are commonly preserved more or less in their original environmental niche (rather than being transported to a depositional basin unrelated to their occurrence in life, as at Mazon Creek), which permits the detailed reconstruction of palaeoecosytems (Calder, in press). The breadth of the section and its substantive window on geologic time permit evaluation of ecosystem response to global environmental change (Falcon-Lang, in press).

Joggins was first brought to international attention by Sir Charles Lyell, the 'Father of Modern Geology', and his colleague Sir William Dawson, during the early Victorian Era (Lyell 1843; Dawson 1871), and has since continuously yielded a spectacular diversity and abundance of fossil plants and animals. The site shows no sign of being exhausted; in fact, the rate of geological discoveries has markedly accelerated over the past decade and is probably now at its most productive (Appendix 2). At time of writing, at least 16 geologists, representing five countries, are engaged in active field research at the site. The site is a protected fossil site under Nova Scotian provincial legislation.

Sources consulted

A complete list of the 208 books, journal papers, book chapters, reports, theses, conference papers and abstracts concerning research at the site is given in Appendix 2. Important recent overviews of aspects of the Joggins ecosystems include the following papers: Calder (1998, in press); Calder et al. (in press); Davies and Gibling (in press); Falcon-Lang (1999b); Wagner (in press).

5. Comparative study

In this section, the 9 short-listed sites are compared in detail with each other using each of the twelve quantitative criteria given in Section 3.2.2 (Criteria 1-12). The results of these analyses are given in Tables 4-15 (see following text for explanation) and summarized in Table 16.

CATEGORY 1. Fossil record of biodiversity (Criteria 1-5)

5.1. Diversity at Phylum/Class taxonomic level (Criterion 1): Table 4

Criterion 1 assesses the biotic variability of each site at a high taxonomic level (Phylum level for invertebrate animals, Class level for vertebrate animals and plants), and thus provides a good indication of the range of organisms present.

The results of this analysis are shown in Table 4 and clearly demonstrate that Mazon Creek contains the most diverse Pennsylvanian biota in the world, although much of this derives from the marine environment, the implications of which are discussed later. The much greater range of organisms found at Mazon Creek compared to the other sites, reflects the unusual taphonomic conditions at Mazon Creek, which have resulted in the preservation of a high abundance of soft-bodied invertebrate animals (Shabica & Hay 1997). Invertebrate animals lacking mineralized skeletons are only very rarely encountered at the other sites, and consequently many invertebrate phyla that were presumably present at these other localities, have simply not been preserved. An additional factor favoring very high diversity at Mazon Creek was the nature of the depositional environment. Mazon Creek sediments were solely deposited in a brackish to marine gulf. Whilst brackish to marine environmental conditions periodically existed at the other sites, they represent relatively short-lived marine incursions into otherwise dominantly terrestrial deposits. Diversity is generally greater in brackish/marine environments compared with terrestrial environments, hence the greater diversity seen at Mazon Creek. In comparison, Joggins has a relatively diverse biota that is dominantly terrestrial, and is ranked in third equal position.

5.2. Species richness (Criterion 2): Table 5

Criterion 2 is concerned with the total number of species contained within each site. Whereas Criterion 1 assessed the variability of the fossil assemblages, Criterion 2 assesses the richness of the assemblages.

The results of this investigation are shown in Table 5 and demonstrate that the Mazon Creek site possesses the greatest species richness of any Pennsylvanian locality (n=338). However, as noted in Section 5.1, almost all of this elevated biodiversity is attributable to the unusual preservation of soft-bodied invertebrate animals, which account for 32% of the total species complement (Shabica & Hay 1997), and to the great number of marine organisms. Species richness values for vertebrate animals at Mazon Creek are not substantially higher than those for Joggins and Freeport, while plant species richness at Mazon Creek is actually lower than that of Sydney and not substantially greater than that of Joggins. Joggins is ranked third overall using this criterion (n=156).

5.3. Tetrapod specimen abundance (Criterion 3): Table 6

This criterion quantifies the diversity and abundance of tetrapod specimens collected from each site. Tetrapods are an extremely rare element of Pennsylvanian deposits (Rayner 1971), but the preservation of relatively large numbers of individuals and taxa is needed to understand aspects of the ecology and population biology of these organisms in detail. At all of the sites it is difficult to establish precisely how many individuals are represented by skeletal remains because (1) individual skeletons typically become disarticulated and mixed together, and (2) several of the tetrapod faunas collected and documented in the nineteenth century have been partially lost (Milner 1987). Consequently, all the figures given in Table 6 are estimates only, and may be accurate only to ±10%. Tetrapod diversity appears to be closely related to specimen abundance with the sites containing the largest numbers of specimens generally possessing the greatest number of genera.

The results of this analysis are shown in Table 6, and demonstrate that the Freeport Coalfield locality is the best tetrapod locality in the world, containing both the most abundant and diverse faunas of this age. There are three major tetrapod-rich localities within the Freeport composite site which collectively have yielded 28 genera: these are Linton (600 specimens), Five Points (c. 130 specimens) and Cannelton (c. 50 specimens). Nyrany (600 specimens; 24 genera) and Joggins (200 specimens, 12 genera) are ranked second and third, respectively. Mazon Creek, although rich in total biodiversity, possesses relatively few tetrapods (30 specimens; 8 genera). Mary Lee is the only locality assessed that completely lacks tetrapod skeletal material, although abundant tetrapod trackways do occur (Pyenson and Martin 2001).

5.4. Fossil forest abundance (Criterion 4): Table 7

This criterion quantifies the number of upright trees recorded in the published literature for each site. Upright trees are very important, evocative, and iconographic components of the Pennsylvanian World (Section 2).

The results in Table 7 clearly demonstrate that Joggins is the most productive tree-bearing site, followed by Sydney and Mary Lee is second and third places, respectively. Three sites, namely Nyrany, Leinster, and Mazon Creek, lack trees entirely, and are ranked in equal last place.

5.5. Evolutionary significance (Criterion 5): Table 8

This criterion considers the number of important evolutionary events encompassed by each site. It does so by determining the total number of taxonomic families, which appear for the first time or go extinct at each site. Data were extracted from the authoritative and exhaustive fossil record database of Benton (1993).

The results are shown in Table 8 and the main conclusions are as follows: Mazon Creek is by far the most important of the 9 sites, recording either the first or last appearance of 59 taxonomic families. In contrast Joggins was an important site for only 8 families, marking the first appearance of 1 arthropod family, 1 molluscan family, 3 amphibian families and 1 reptile family, and marking the last appearance of 1 bivalve family and 1 chrondrichytian fish family. It is ranked in only fourth place overall using this criterion. However, it should be emphasized this kind of reductive analysis does not do justice to the Joggins locality because amongst its evolutionary innovations the site contains the earliest known reptile (*Hylonomus lyelli*), which as noted in Section 1, was one of the most important "events" in the Pennsylvanian Period.

CATEGORY 2. Nature, quality and variability of fossil archive (Criteria 6-9)

5.6. Extent of the geological window (Criterion 6): Table 9

This criterion assesses first, the thickness of the rock interval at each site, and second, the amount of time it represents, expressed as a proportion of the entire Westphalian stage. The second parameter is problematic to measure because the time-scale for the Westphalian stage is currently undergoing considerable revision (Menning et al. 2000) and rock sequences are typically dated with low precision. Consequently, it is impossible to assess the length of time represented by a site to a greater accuracy than c. 0.5 million years.

The results of these analyses are shown in Table 9 and indicate that Joggins possesses both the thickest and most temporally extensive rock sequence (1500 m of strata representing some 4.0 million years of time, i.e. about a third of the Westphalian interval). Sydney and Durham are ranked joint second[4]. All three of these sites, but especially Joggins, provide an invaluable long-term record of changing environments and ecosystems in response to global climate change and evolutionary developments. In contrast, Mazon Creek and Mary Lee are sites where fossil-rich beds are restricted to a small stratigraphic thickness and represent only a very small proportion of the Pennsylvanian (<4.5%). These sites provide high resolution 'snap shots' of ecosystems at certain points in Pennsylvanian time, but do not yield data concerning long-term evolutionary processes and ecosystem response to global environmental change.

5.7. Range of major depositional environments represented (Criterion 7): Table 10

This criterion assesses the range of depositional environments represented at a particular site. This parameter is important because it provides a record of the number of different habitats that have been preserved. The greatest amount of palaeoecological information may be extracted from fossil assemblages preserved in the context of their original habitat.

The results of this analysis are shown in Table 10 and show that the Joggins and Sydney sites have preserved the greatest range of depositional environments (or habitats), ranging from continental drylands, coastal wetlands, to marine-influenced nearshore environments, while Mazon Creek has preserved the smallest environmental range, representing only marine-influenced offshore settings. Although the biodiversity of Mazon Creek is high, the organisms

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[4]Post-Westphalian (i.e. Stephanian) successions at Sydney are not considered in this analysis because the Stephanian is not considered iconographic of Pennsylvanian times (see Section 2).

are not preserved in the environment in which they lived, having been transported into an offshore gulf prior to fossilisation.

5.8. Paleobiological representativeness (Criterion 8): Table 11

This criterion assesses the amount of palaeobiological information which may be extracted from each site, with particular focus on ecosystem dynamics and food chains. A list of fossil taxa alone is not very useful in reconstructing ancient biomes; this goal can only be achieved where geological information concerning the interrelationship of organisms and their interaction with the environment has been preserved.

The results of this analysis are shown in Table 11 and demonstrate that Joggins and Sydney are the richest sites for palaeobiological information, providing multifaceted insight into the nature of Pennsylvanian ecosystems. Mazon Creek, whose fauna and flora have largely been transported from their location in life, consequently provide little palaeobiological data beyond its importance as a record of biodiversity and evolutionary change (Sections 5.1, 5.2, and 5.4).

5.9. Quality of fossil preservation (Criterion 9): Table 12

This criterion considers the degree to which the fossils at each site yield exceptional preservation of soft (readily degradable) anatomy**.** Fossils exhibiting soft anatomical preservation preserve a much richer palaeobiological data resource compared to those where only mineralized tissue is preserved. For example, anatomically preserved wood fragments may contain tree-ring records, which allow palaeoclimatic inferences to be drawn (e.g., Falcon-Lang 1999a), and soft-bodied vertebrate preservation may provide important data about the physiology and thermoregulation of an animal (Morell 2000). However, in practice, this criterion offers little genuine discrimination because most of the sites fulfill 2 out of the 3 sub-criteria, and are thus all ranked together in joint first place (Table 12).

CATEGORY 3. Permanence (integrity) and scientific impact of site (Criteria 10-12)

5.10. Degree of site investigation (Criterion 10): Table 13

This criterion attempts to quantify the degree to which the sites have been investigated. Evidently this is a very complex and subtle phenomenon, and one that is extremely difficult to quantify satisfactorily. As noted in Section 3.2.1, three parameters are analyzed.

The first parameter considers the length of time the site has been studied. It does so by ascertaining the year in which the first significant discovery (as summarized in Section 4) was made at each site. The rationale behind this approach is simply this: the earlier the date of that first discovery, the greater the amount of time has been available to fully investigate the site. This is a far from satisfactory methodology because, of course, some sites may become famous at an early date, but are subsequently studied only minimally (e.g. the Leinster Coalfield, famous since 1866), whilst others may become famous equally early, yet receive continuous and sustained study over that time period (e.g. Joggins, made famous in 1842; Appendix 2). The results of this analysis are shown in Table 13 and reveal another problem with the approach: 8 out of the 9 sites became famous over a relatively short interval between 1829 and 1876, suggesting that differences in the length of time each site has been studied may be, in most cases, too short to have had a meaningful impact on the degree of investigation. Consequently, the 8 sites discovered in the nineteenth century are simply all ranked joint first, whilst the only site (the Mary Lee Coal Zone of Alabama, USA) discovered in the twentieth century is ranked ninth.

The second parameter considers the number of published documents written about each site as a proxy for the degree of site investigation. Data were collected using the Georef and Web of Science online databases. The raw data (publication lists) from which the figures in Table 13 are derived are available on request from the author as Word 2000 files. The discerning reader will note that the number of publications given for Joggins (n=119) is considerably less than the exhaustive list of Joggins publications given in Appendix 2, in fact only representing 57% of the total documents in existence (n=208). This is because only the most major and most accessible publications are listed on the Georef/Web of Science database. However, a comparison between the actual number of publications for Mazon Creek (as exhaustively documented in Nitecki 1979 and Shabica & Hay 1997) and the Georef/Web of Science output indicates a very similar 'hit rate' for this locality; 53% of Mazon Creek documents are listed. These data suggest that although the databases only locate c. 50-60% of the total available geological literature, there are probably no major biases in output for different sites. Consequently, although the publication figures given in Table 13 underestimate the total number of publications, they probably accurately reflect the relative abundance of publications related to each site. One probable exception to this might be the Mary Lee site. The databases used have the poorest document recovery rates for pre-twentieth century literature. As noted above, all sites were discovered during a similar period in the nineteenth century, with the exception of Mary Lee, which was discovered much later. It is likely that the databases have recovered a relatively greater proportion of documents for the younger Mary Lee site relative to the other eight older sites, and consequently, that Mary Lee publications may be overestimated in Table 13.

The third parameter outlined in Section 3.2.2 aims to determine how international the level of interest was at a site. The ideal approach to quantifying this parameter would be to assess the number of countries represented by authors in the publication list for each site. Unfortunately, the Georef/Web of Science databases do not exhaustively provide author addresses, so this assessment proved impossible. The alternative approach suggested in Section 3.2.2 was to determine the number of countries represented by the journals in which the papers from each site were published. The results of this analysis, however, did not prove to be very informative because publishing houses in a very small number of countries process the vast majority of scientific papers (houses in the US, UK, Canada and the Netherlands account for >97% of publications), and significant differences between individual sites were not encountered.

Combining the results of the three parameters (of which only the second provides valuable discrimination) demonstrate that Mazon Creek is the most investigated site, being by far the most published on site and being studied for 138 years. The sites of Joggins and the Freeport Coalfield are ranked second and third, respectively (Table 13).

5.11. Permanence (Integrity) of site (Criterion 11): Table 14

This criterion attempts to quantify the probable permanence or integrity of each site (i.e., the probability of its continued existence). This is calculated by categorizing the type of rock exposure using the quantitative criteria given in Section 3.2.2.

The results of this analysis are given in Table 14 and clearly show that Joggins and Sydney represent the most permanent site. Only at these localities is the rock outcrop almost entirely composed of coastal cliffs. These sites are undergoing continuous erosion by natural processes (attrition by waves and tides) and consequently the fossil-bearing beds are rejuvenated annually. Lying in third place in the analysis is the Durham Coalfield which includes both naturally eroding coastal sections in Northumberland, and inland coal mines, which given the collapse of the British Coal Mining Industry, are likely to have only a relatively short lifetime prior to the onset of rock face degradation and/or backfilling. The least permanent of the 9 sites is Mazon Creek, the vast majority of outcrop having already been destroyed by backfilling of old strip mines, with only a few very poor stream sections still yielding new material (Shabica & Hay 1997; www.neiu.edu/~mcproj/frame.html).

5.12. Probability of continued discoveries (Criterion 12): Table 15

This final criterion attempts to assess the likelihood of continued significant discoveries in the future. Of course such predictive analyses are inherently speculative, but are nevertheless a requirement of the WHS criteria (Table 1). The potential for ongoing discoveries is assessed in this report by comparing the number of papers written about each site over the past decade (separated out into palaeontological papers, and general papers) with the total number of publications produced in the entire history of site investigation. Sites yielding a relatively large proportion of recent papers compared to the historical total are likely to be those where discoveries are still being made most frequently. Although a single publication does not necessarily precisely correspond to a single discovery, using this approach does provide a relatively easy, objective means for quantifying discovery rate, an otherwise elusive parameter. This parameter (d) is calculated by the equation $d=y^2/x$, where y is the number of papers published in the last decade, and x is the total number of papers. This parameter is referred to as the Discovery Index in this report. The square of y is used so as to emphasize sites with a relatively large number of publications. Without this accommodation, a site where x=10 and y=1, would yield the same Discovery Index as a site where x=100 and y=10.

The results of this analysis are given in Table 15 and show that the Sydney Coalfield possesses by far the greatest general Discovery Index, with the Mary Lee Coalfield and Joggins coming second and third respectively. As exposure at Mary Lee is dependent of mining operations, this high discovery rate is certain to drop off drastically in the near future as mining activity winds down. The three British coalfields (Durham, Yorkshire, Leinster) possess the lowest general Discovery Indices, an expected result given these are no longer sites of active coal mining. In terms of palaeontological Discovery Index, Mazon Creek and Joggins are ranked first and second, respectively. However, these two sites have high indices for very difficult reasons. In the case of Mazon Creek, ongoing 'discoveries' relate to the reinterpretation of museum collections rather than actually representing the discovery of new fossil material (which is the underlying source of Joggins' high palaeontological Discovery Index). In a sense, therefore, Mazon Creek's first place ranking is rather misleading because discoveries of new fossil specimens are not being made. Overall, Joggins and Sydney are ranked joint first when both discovery parameters are considered.

6. Discussion

This report has presented a detailed, quantitative comparison of the 9 most significant localities that provide insight into the biodiversity, ecology and evolutionary development of the Pennsylvanian-aged tropical biome. These sites have been compared using twelve rigorous criteria. The final results of this analysis, summarized in Table 16, demonstrate that the Joggins Fossil Cliffs of Nova Scotia comprise the most significant and broadly representative fossil site within the entire Pennsylvanian tropical biome. Significantly, this conclusion contrasts with the opinion of Wells (1996), who recommended to the IUCN (The World Conservation Union) that Mazon Creek was probably the strongest contender for a Pennsylvanian-aged World Heritage Site, making no reference at all to Joggins (p. 32). In the comparative study presented here, Mazon Creek was ranked in only fourth position, perhaps a surprising result given that the assessment criteria used were partly derived from Wells' own (1996) recommendations (see Table 1). The rest of this document is therefore devoted to discussing the relative merits of Joggins and Mazon Creek, and to clarifying the reasons why Joggins is in fact much more representative of Pennsylvanian times than Mazon Creek, and therefore supremely worthy of receiving World Heritage Status.

Breaking down the results of the comparative study into the three main categories of criteria helps to emphasis the relative strengths and weaknesses of Joggins and Mazon Creek. In terms of the first category (Criteria 1-5), which is concerned with the fossil record of biodiversity, Mazon Creek and Joggins have very closely similar scores (34 and 36, respectively). Clearly in terms of the diversity, richness, and evolutionary significance of the fossil record (Criteria 1, 2, and 5), Mazon Creek far outranks Joggins. (As already discussed, Mazon Creek's greatly elevated biodiversity compared with all other Pennsylvanian sites reflects inclusion of marine fossils and the unusual depositional environment of the rocks, which resulted in the preservation of soft-bodied invertebrates; Shabica and Hay 1997). However, in terms of the two iconographic aspects of the Pennsylvanian world emphasized in Factor 2, namely tetrapod abundance and diversity and abundance (indeed presence) of upright trees, Joggins outranks Mazon Creek convincingly (Criteria 3 and 4).

Sites such as Mazon Creek are referred to as Lagerstätten, a term that refers to unusually 'rich' fossil deposits. Two main types of Lagerstätten are currently recognized: Concentration-Lagerstätten are fossil deposits which are considered 'rich' because fossils are so abundant, while Conservation-Lagerstätten are fossil deposits which are considered 'rich' in terms of their high quality preservation of soft-anatomy (Seilacher et al. 1985). Under this classification scheme, Mazon Creek would be primarily considered a Conservation-Lagerstätten because its uniqueness mostly relates to the extraordinary soft-bodied preservation of its invertebrate fauna, although secondarily the term Concentration-Lagerstätten could also be applied because of the relatively high abundance of fossils. However, the Lagerstätten concept fails to take into account a third way in which a fossil deposit may be considered 'rich'; this is the unusual preservation of fossil assemblages in their original environmental context (life assemblages *sensu lato*), so that they yield crucial information about ecosystem composition and dynamics (Falcon-Lang et al. 2001). In this report, the term Eco-Lagerstätten is proposed to refer to fossil deposits unusually rich in ecological information.

Although Joggins is less significant than Mazon Creek when assessed under Criteria 1, 2 and 5 (i.e. as a Conservation-Lagerstätten), it possesses a much greater richness in terms of the Eco-Lagerstätten concept. This parameter is gauged by the second category of criteria used in the comparative study (Criteria 6-9), which ranks Joggins in first place and Mazon Creek in last (9th) place. Whereas most of the Mazon Creek fossils were transported into a coastal marine gulf prior to preservation, the Joggins fossils have mostly been preserved within the environmental context in which they lived. Consequently, recent studies have been able to paint detailed pictures of the diverse ecosystems of Joggins, which variously inhabited open water, brackish bays (Archer et al. 1995), coastal wetland swamps (Calder et al., in press), and dryland, continental-interior river plains (Falcon-Lang, in press). Whereas Mazon Creek provides a snap shot of biota at a particular moment in time, Joggins provides a four million year record showing how ecosystems responded to changing climates and environments (a potentially important record considering the concern surrounding the impact of future global change on tropical biotas). Mazon Creek yields only a list of the animal species present, but Joggins with its rich fossil trackways, indicates how they moved, behaved and interacted (Calder, in press).

This second category of criteria (Criteria 6-9) is as important as the fossil record of biodiversity, providing rich information which teaches about ancient ecosystems and communities much more effectively than lists of species alone. Canada's eminent geologist, Sir William Dawson, well understood the significance of studying fossils in their palaeoenvironmental context, writing that it is better to study fossils "as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum" [excerpt from a letter from Sir William Dawson to Sir Charles Lyell, 13 August 1868]. Indeed it was this very attribute that allowed Lyell and Darwin to use Joggins as a proving ground for their geological and evolutionary principles, and which has led to the description of Joggins as a 'Coal Age Galapagos' (Calder, 2002). In his excellent report to the UICN, Wells (1996) does emphasize the importance of choosing sites that teach about ancient communities and ecosystems, so one can only assume that his selection of Mazon Creek as a potential Pennsylvanian site was based on limited knowledge of the deposits of this time period.

The third category of criteria (Criteria 10-12) used in the comparative study also ranks Joggins in first place worldwide, far above Mazon Creek, which is ranked only fourth. This last category considers three separate but related parameters. The first assesses the probable lifetime of a site, that is its permanence or integrity. (It must be an important consideration when erecting a World Heritage Site that the locality will continue to survive for the foreseeable future). In this regard, Joggins stands head and shoulders over Mazon Creek. Joggins is a sea-cliff section, hewn by the world's highest tides on the Bay of Fundy, and barring global catastrophes will remain in a pristine state for tens of thousands of years to come. In contrast Mazon Creek barely exists as an actual site, the original strip mines where the important fossil biota was collected have now been filled in, and one is even currently being used as a nuclear reactor cooling pond! Only some poor stream sections remain. Mazon Creek is important as a fossil *collection* scattered about hundreds of museums worldwide but by definition it cannot be considered an important fossil *site*. This factor effectively excludes all possibility of Mazon Creek being selected for World Heritage Status.

The third category of criteria also considers the scientific impact of the site, both historically, and its probability of continuing to yield significant discoveries in the future. Whilst Mazon Creek certainly represented one of the most important Pennsylvanian fossil sites in the past as indicated by the huge volume of literature (323 documents in total), the virtual destruction of the site in the 1960s means that it will play only a limited role in the future, as scientists continue to work on the large museum collections made in the nineteenth and early twentieth century. Like Mazon Creek, Joggins also has had an illustrious past. It was first brought to international attention in 1843 by Sir Charles Lyell (arguably the most influential geologist in history), whose universal and fundamental insights into the geological evolution of the earth were profoundly influenced by Joggins (Lyell 1871). Charles Darwin was also fascinated by aspects of the site, drawing on Lyell and Dawson's first-hand observations to speculate on the origin of coal seams (Letter from Darwin to Joseph Hooker, dated 1 May 1847).

Unlike Mazon Creek, however, Joggins should continue to play a significant role in our future evolving knowledge of the Pennsylvanian world. Analysis of the probability of ongoing discoveries suggests that Joggins is by far the most productive site for new specimens, the high Discovery Index of Mazon Creek largely resulting from publications reassessing pre-existing museum collections. In fact, if the number of publications per decade is an accurate indication of the rate at which discoveries are being made at a site, then Joggins is currently at its most productive! Figure 9 plots the bibliographic data from Appendix 2 against time and shows that the 1980s and 1990s witnessed the greatest number of publications per decade in the site's history. Projections based on publications from 2000 to the present indicate there will be an even greater number of publications in the coming decade (red bar). An unexpected finding of this comparative study is that the Sydney fossil cliffs in Cape Breton, Nova Scotia is ranked second overall in the world after Joggins (Table 16). In many ways Sydney and Joggins are complementary Pennsylvanian sites; the wider Joggins section spanning the entire early part of the Pennsylvanian (late Namurian-Duckmantian; 311-320 million years ago) and the wider Sydney section spanning the majority of late part of the Pennsylvanian (late Bolsovian-Stephanian; 299-309 million years ago). Combined, these two excellent sections in Nova Scotia represent all but 2 million years of the 21 million year long Pennsylvanian Period. With this in mind, there would seem to be potential for a serial nomination of both Joggins and Sydney, which collectively tell the story of the whole Pennsylvanian time period. Whilst this report primarily supports Joggins as a potential Pennsylvanian World Heritage, it also recommends that consideration be given to the possibility of a subsequent serial nomination of the Sydney site.

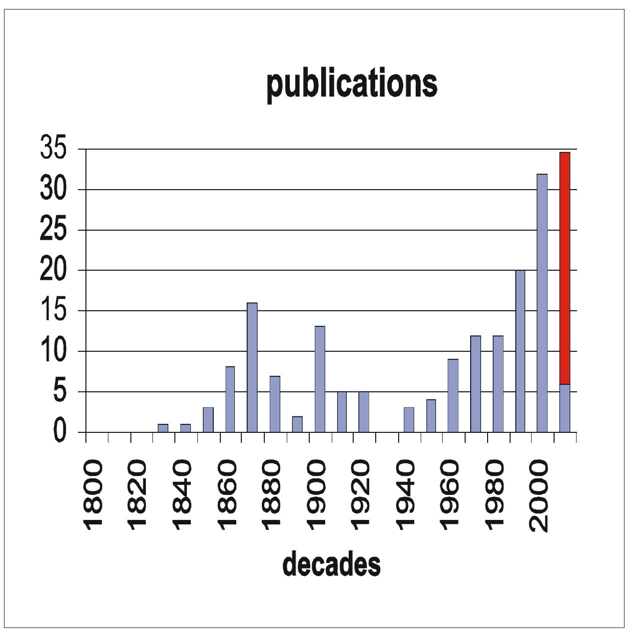

Figure 9. *Graph plotting Joggins publication per decade based on data in Appendix 2*

7. Conclusions

This report based on a rigorous comparative study of all major palaeotropical Pennsylvanian fossil sites finds the Joggins Cliffs to be the most representative of this time period. Three features combine to make the site globally unique, of outstanding universal value, and very worthy of World Heritage Status:

Category 1 - Joggins contains a very high diversity fossil biota, in fact amongst the top three in the world. Although other sites such as Mazon Creek are richer than Joggins when certain aspects of biodiversity are considered, Joggins still ranks first overall. Even though Joggins performs very strongly in this category, this nevertheless represents the weakest aspect of the site's nomination bid.

Category 2 - Joggins' ancient biota is preserved, not as individuals isolated from one another, but as 'fossil ecosystems' from which detailed insights into the dynamic nature of the Pennsylvanian tropical biome may be ascertained. So whereas some other sites remain mute about ecological and environmental interactions, Joggins speaks eloquently of tropical forests obliterated by catastrophic floods, of animals desperately fleeing gigantic forest fires, and of the impact of climate change and sea-level rise on terrestrial ecosystems.

Category 3 - Joggins' towering sea-cliffs, hewn by the World's highest tides, are permanent actively eroding features that will persist for millennia to come. Consequently, the important discoveries, which began with the seminal geological work of Sir Charles Lyell, Sir William Dawson, and Sir William Logan in the early nineteenth century, will doubtless continue in the future. Indeed, the limited data that exist implies that the site is more productive now than at any other time during its scientific study.

For two centuries, countless scientists and laypeople from over a hundred countries worldwide have made the pilgrimage to Joggins to marvel at, and to study, its outstanding diversity of fossilized forests and animals. Whilst reductive criteria, such as those utilized in this report, are needed to demonstrate the uniqueness of Joggins to a scientific audience, they fail to capture the fullness of the site's importance. To walk the classic 3 km long coastal cliff section from Lower Cove to McCarron's Creek (Figure 10 overleaf) is to be transported back 310 million years to an ancient forested floodplain inhabited by bizarre, long extinct creatures. Kneel down and place your hands in the faint tracks that cross a sandstone bed, and consider the passage of the gigantic, two metre-long arthropods that made them. Touch one of the upright fossil trees; its fresh sooty residue will teach you of the catastrophic forest fires that obliterated this region in a former age.

Figure 10. *The Joggins Fossil Cliffs, Nova Scotia: A window into the Pennsylvanian*

Joggins is indeed a rare site; not only is it important for developing our knowledge of the Pennsylvanian tropical biome in a dry scientific way, but also it is profoundly evocative, stimulating our senses and imagination to perceive a faint glimmer of a long vanished world. It is therefore in the very strongest terms that I am delighted to recommend the inclusion of Joggins on Canada's tentative list of potential World Heritage Sites.

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Appendix 1. Summary of selection criteria and recommendations used in earlier comparative studies of potential World Heritage palaeontological sites

1.1. IUCN checklist (1994)

1994-1: Does the site provide fossils, which cover an extended period of geological time? i.e. how wide is the geological window?

1994-2: Does the site provide specimens of a limited number of species or whole biotic assemblages? i.e. how rich is the site in species diversity

1994-3: How unique is the site in yielding fossil specimens for that particular time period? i.e. would this be the type locality for study or are there similar areas that are alternatives?

1994-4: Are there comparative sites elsewhere that contribute to the understanding of the total story of that point in time/space? i.e. is a single site nomination sufficient or should a serial nomination be considered?

1994-5: Is this site the only or main location where major scientific advances were (or are being) made that have made a substantial contribution to the understanding of life on earth?

1994-6: What are the prospects for on-going discoveries at the site?

1994-7: How international is the level of interest?

1994-8: Are there features of natural value (e.g. scenery, landform, vegetation) associated with the site? i.e. does there exist in the adjacent area modern geological or biological processes that relate to the fossil resouce?

1994-9: What is the state of preservation of the specimens yielded from the site?

1994-10: Do the fossils yielded provide an understanding of the conservation status of contemporary taxa and/or communities? i.e how relevant is the site in documenting the consequences to modern biota of gradual change through time?

1.2. Wells Criteria (1996)

1996-1: Choose sites that contain well-preserved fossil accumulations of high species diversity, which in combination best document the story and environmental change through time.

1996-2: The event to be represented in the history of life should, where possible, encompass the iconography of a tree of life not a ladder of progress.

1996-3: Choose fossil Lagerstatten and make provision for expanding the list or substituting sites/fossils to best tell the story.

1996-4: Separate PreCambrian history from Phanerozoic history (the roots from the upper branches of the evolutionary tree respectively). Present PreCambrian history as major events, such as the origin of life, multicellularity etc, and present Phanerozoic history in terms of communities and/or stages in the evolution of major groups.

1996-5: All published PreCambrian sites should be reviewed by an expert panel to select those worthy of evaluation for World Heritage listing.

1996-6: Phanerozoic sites should be chosen so as to be representative in time and space of both community structure and selected phylogenetic lingeages.

1996-7: Any fossil Lagerstatten chosen from the Phanerozoic should whereever possible be of high diversity and include significant invertebrate as well as vertebrate assemblages.

1996-8: A condition for granting World Heritage status should make provision for curation, study and display of any sites/fossils.

1996-9: Specialists in the major Phanerozoic groups and time periods should be consulted to refine and update the indicative list.

1.3. Cloutier & Lelievre Criteria (1998)

1998-1: Site should have high biodiversity, i.e. a great number of species.

1998-2: Site should have high 'faunal representativeness', i.e., a broad range of higher taxonomic groups represented, e.g. invertebrates, vertebrates and plants

1998-4: Site should record the broadest possible range of environments and ecosystems.

1998-5: Site should provide information about the biology of the fossils preserved, e.g. the food chain, ecology, reproduction.

1998-6: Site should possess well preserved fossils, showing little fragmentation, and ideally soft-bodied preservation.

1998-7: Site should have yielded specimens in high abundance.

Appendix 2. Complete bibliography of scientific publications concerning the Pennsylvanian Joggins Fossil Cliffs, Nova Scotia

This bibliography has been compiled with the aid of Georef and Web of Science databases by Dr. John H. Calder (Department of Natural Resources, Halifax, Canada), and was last checked, revised, and extended by Dr. Howard J. Falcon-Lang (University of Bristol, UK) in July 2002. It comprises 100 refereed journal papers, 13 book chapters, 19 textbooks/memoirs, 28 government/museum reports, 14 theses, 12 conference papers, and 22 abstracts, a total of 208 documents published between 1829 and the present. These are arranged alphabetically as follows:

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Appendix 3: Glossary of terms used

Words preceded by an asterix (*) are also defined in the glossary

Angara: This was one of three major landmasses during the *Pennsylvanian time Period. Angara lay in the northern temperate zone (also see *Laurasia and *Gondwana).

Biome: A major biogeographic zone such as desert, tropical *rainforest, savanna, or temperate forest.

Bolsovian: The third sub-division of the *Westphalian time interval (see Figure 5).

Charcoal: Burned plant matter.

Class: *Taxonomic hierarchy (see Figure 6).

Coal Age: Synonymous with *Pennsylvanian Period, especially refers to coal-forming tropical zone.

Coprolite: Fossilized faeces!

Cordaites: An ancient type of plant similar to the modern conifers.

Dawson, William (1820-1899): Understudy of Lyell and one of the most important geologists of the nineteenth century. He specialized in the geology of Joggins, and is largely responsible for documenting its fossil record, including discovery of the world's oldest reptile. His most significant work, entitled *Acadian Geology*, is still widely read by academics and students.

Diorama: A visual reconstruction of an ancient landscape, usually a painting.

Duckmantian: The second sub-division of the *Westphalian time interval (See Figure 5).

Ecosystem: Refers to a biological community, and emphasized interactions between different organisms, e.g. a coral reef ecosystem refers to the coral reef, and all organisms that live in, feed on, and interact with the reef.

Formation: Rock sequences are divided into major divisions termed *Groups, which are subdivided into Formations e.g. the Joggins Formation is a division of the Cumberland Group.

Gondwana: Also known as Gondwanaland, this was one of three major landmasses during the *Pennsylvanian time Period. Gondwana lay over the South Pole (also see *Laurasia and *Angara).

Gould, Stephen Jay (1937-2002): One of the most influential evolutionary biologists and essayists of the modern age, best known for his evolutionary theory of Punctuated Equilibria.

Group: Rock sequences are divided into major divisions termed *Groups, which are subdivided into Formations.

Invertebrates: Animals without a backbone.

Lagerstatten: An exceptional rich fossil deposit.

Langsettian: the earliest subdivision of the *Westphalian time interval (Figure 5).

Laurasia: One of three major landmasses during the *Pennsylvanian time Period. Laurasia lay in the tropical zone and was covered by *rainforests (also see *Gondwana and *Angara).

Logan, William (1798-1875): The first Director of the Geological Survey of Canada, and one of Canada's most famous geologists. His first project at GSC was to measure the entire Joggins cliff section for the first time, a monumental achievement only recently revised by Davies & Gibling (2002) and Calder.

Lyell, Charles (1797-1875): The most influential geologist in history. His most important work was entitled *Principles of Geology*, certain chapters of which drew considerably on fieldwork at Joggins, Nova Scotia.

Mire: A boggy environment in which peat forms.

Namurian: The earliest part of the *Pennsylvanian Period (see Figure 5).

Opencast mine: A surface mine in which the overlying soil and rock is stripped away to reveal the target deposit. Synonymous with *strip mine.

Pennsylvanian Period: An important geological time interval extending between 299-320 million years ago which witnessed the rise of the first tropical *rainforests and the appearance of the first reptiles (see Figure 1).

Phanerozoic Era: A major division of geological time encompassing the last 550 million years (see Figure 1).

Phylum: *Taxonomical hierarchy (see Figure 6).

Rainforest: A *biome which develops under warm and wet tropical conditions, and is characterized by high biodiversity.

Species: The lowest *taxonomic division (see Figure 6).

Species richness: Refers to the number of *species in an assemblage.

Stephanian: The latest part of the *Pennsylvanian Period (see Figure 5).

Strip mine: A surface mine in which the overlying soil and rock is stripped away to reveal the target deposit. Synonymous with *open cast mine.

Taxonomy: The science of classifying life into groups.

Tetrapod: Animals with four "feet" such as dogs, frogs and humans.

Vascular plants: Plants characterized by an upright woody stem, as opposed to lower plants such as liverworts which are not self-supporting.

Vertebrates: Animals with a backbone.

Westphalian: The middle part of the *Pennsylvanian Period (see Figure 5).

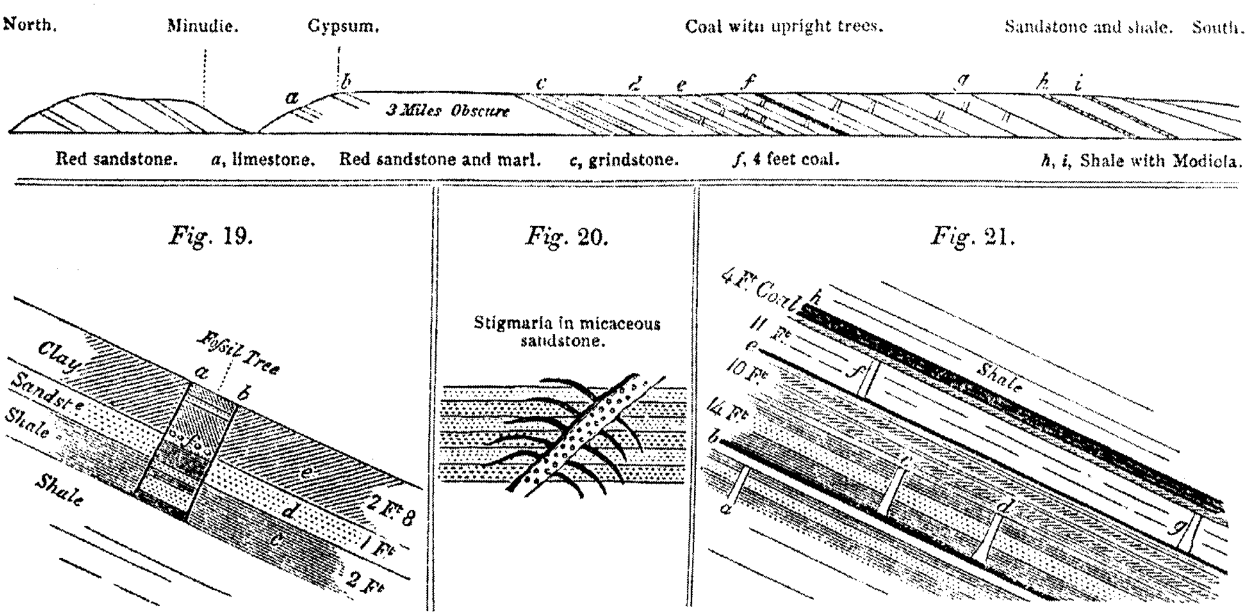
Westphalian D: The last sub-division of the *Westphalian time interval (see Figure 5).

Appendix 4: Statement of Significance for the Nomination of Joggins as a UNESCO World Heritage Site.

"The classic fossil cliffs of Joggins, part of an extensive 50 kilometre coastal section, are of outstanding universal value[1]. Joggins contains an unrivalled fossil record[2] preserved in its environmental context[3], representing the finest example in the world[4] of the terrestrial tropical environment[5] and ecosystems[6] of the Pennsylvanian 'Coal Age' of the Earth's history[7]. Nowhere is this record of plant, invertebrate and vertebrate life within now fossilized forests rendered more evocatively, as exemplified by the earliest reptiles[8] entombed within once hollow trees.

Joggins has played a seminal historic role in the development of important geological and evolutionary principles[9], including those of Sir Charles Lyell[10] and Sir Charles Darwin[11], to whom Joggins was a 'Coal Age Galapagos'[12]. Ongoing discovery[13] and research[14] at this dramatic natural site, hewn and replenished by the world's highest tides[15], ensures that this history will continue[16]."

Section of the cliffs of the South Joggins, near Minudie, Nova Scotia.



Annotation to Statement of Significance

1 Article 2 of *The Convention Concerning the Protection of the World Cultural and Natural Heritage,* UNESCO, 1972. "Natural features consisting of physical and biological formations or groups of such formations, which are *of outstanding universal value* from the aesthetic or scientific point of view..."

"i. [be] *outstanding examples representing major stages of the earth's history, including the record of life..."* Operational Guidelines, UNESCO

2 IUCN Site Evaluation Checklist Q3; Wells (1996) Recommendation 1,2,3,4.

3 UNESCO Operational Guidelines, paragraph 44 b (i); Wells (1996), p. 8 'Reconstructing the events that shaped any branch of the family tree necessitates the use of other historical evidence. For the fossil record the encapsulating sediments provide this evidence, they represent an extraordinary account of past environments, their geographic distribution and relative age. All this information is used to build an historical account of life on Earth.'

4 Allusion to Sir Charles Lyell: 'But the finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia.' *Students Elements of Geology*, 1871; N (i), Operational Guidelines.

5 References concept of 'biome', introduced in the Joggins nomination dossier; ref. IUCN Q4; Wells (1996) p. 10, R3, also 4, 6.

6 Wells (1996), R 1, 2, 4, 6, 7; IUCN Q2.

7 UNESCO Operational Guidelines, paragraph 44 a (i); Wells (1996), R4, 6.

8 See 1, above ("... *outstanding examples representing major stages of the earth's history, including the record of life...")*, also IUCN Q3.

9 IUCN Q 5, also 3, 7. See also Lyell (1871) and Darwin (1859), among others.

10 Sir Charles Lyell (1871). *The Student's Elements of Geology*. John Murray, London, 624 pp.

11 Charles Darwin (1859). *The Origin of Species by Means of Natural Selection*. (Chapter IX. *On the Imperfection of the Geological Record*, p. 296.) John Murray, London, 513 pp.

12 Calder (2002), p. 16 in Nova Scotia Department of Natural Resources Report ME 2002-1, p.15-22.

13 IUCN Q 6.

14 IUCN Q 7,5.

15 IUCN Q 8.

16 Integrity of Site: UNESCO Operational Guidelines, paragraph 44.

Appendix 5. The fossil record of Joggins (from Calder, in press).

Table 5.1. The Westphalian A fauna of Joggins. Note that systematic taxonomy for many of these groups in the fossil record is problematic, and many variations exist, particularly for the vertebrates (From *Calder, J.H. In prep. The Fossil Record and Paleoecology.of the Classic Upper Carboniferous Section at Joggins, Nova Scotia*.)

KINGDOM ANIMALIA

PHYLUM PROTISTA (single-celled organisms)

Class SARCODINA

Order FORAMINIFERA

Trochammina sp.

Ammobaculites sp.

Ammotium sp.

PHYLUM ANNELIDA (segmented worms)

Class POLYCHAETA

Spirorbis carbonarius

PHYLUM ARTHROPODA (jointed-leg invertebrates)

Subphylum CRUSTACEA

Class OSTRACODA

Carbonita altilis

C. elongata

C. fabulina

C. humilis

C. pungens

C. rankiniana

C. secans

Hilboldtina rugulosa

Candona bairdiodes

C. salteriana

Class MALACOSTRACA (soft-shelled: cray-fish *et al*.)

Superorder EOCARIDA

Order PYGOCEPHALOMORPHA

Pygocephalus (Anthrapalaemon) dubius (=Diplostylus dawsoni)

Subphylum CHELICERATA (pincer-bearing)

Class MEROSTOMATA

Order XIPHOSURIDA (sword-tailed: horseshoe crabs *et al.*)

Belinurus sp.

Subclass EURYPTERIDA (wing-like legs)

indet. cuticle, *cf. Hibbertopterus/Mycterops*

Class ARACHNIDA (spiders, scorpions)

Order ANTHRACOMARTIDA

Coryphomartus triangularis

Order PHRYNICHIDA (whip spiders)

Graeophonus carbonarius (=Libellula carbonaria)

Order SCORPIONIDA

indet. cuticle

Subphylum MYRIAPODA

Class DIPLOPODA (millipedes)

Order EURYSTERNA

Xyloiulus (Xylobius) sigillariae

Archiulus xylobioides [c]

Incertae sedis

ARTHROPLEURIDA[1]

Arthropleura sp.[t]

Subphylum INSECTA

Class PTERYGOTA (winged insects)

Order MEGASECOPTERA *incertae familiae*

Phylum MOLLUSCA

Class BIVALVIA (Pelecypoda: clams)

Order UNIONOIDA

Archanodon (*Asthenodonta*) *westoni* [s]

Order PTERIOIDA [Dysodonta]

Naiadites carbonarius Dawson[l]

N. longus [h]

Curvirimula sp.

Class GASTROPODA (snails)

Subclass PULMONATA (Stylommatophora) (land snails)

Order ORTHURETHRA

Dendropupa vetusta

Pupa bigsbii [c]

Incertae sedis

Zonites priscus [h]

Phylum Chordata

Subphylum VERTEBRATA

Superclass PISCES

Class ACANTHODII

incertae sedis

GYRACANTHIDAE

Gyracanthus duplicatus [t]

Class CHONDRICHTYES (cartilaginous fishes)

incertae sedis

Ageleodus (Callopristodus) pectinatus[1]

Subclass ELASMOBRANCHII (sharks)

Order XENACANTHIDA

Xenacanthus sp.

Order CTENACANTHIFORMES

Ctenacanthus sp.

Subclass HOLOCEPHALI

Order CHIMAERIDA

Helodus sp.

Incertae sedis 'PETALODONTIDA' (ray-like fishes)

Ctenoptychius cristatus

Class OSTEICHTHYES (bony fishes)

Subclass ACTINOPTERYGII (ray-finned fishes)

Order PALAEONISCIFORMES

Haplolepis cf. corrugata

H. cf. canadensis

Subclass SARCOPTERYGII (lobe fins)

[Order ACTINISTIA]

Order CROSSOPTERYGII

Rhizodopsis/ Strepsodus sp.

Megalichthys sp.

Suborder COELACANTHINI

(indet. scales)

Superfamily DIPNOI (lungfish)

Sagenodus cristatus

S. plicatus

Superclass TETRAPODA Goodrich, 1930

incertae sedis

Hylonomus ociedentatus = Smilerpeton aciedentatum nomen vanum

Hylonomus wymani

Class NEOTETRAPODA Gaffney, 1979

Order BAPHETOIDEA (Cope, 1875)

Family BAPHETIDAE Cope, 1875 (=Loxommatidae Lyddeker, 1889 (as Loxommatinae), Loxommidae Watson, 1917)

'*Baphetes minor*'

Class AMPHIBIA

Subclass BATRACHOMORPHA (true amphibians)

Order TEMNOSPONDYLI

Dendrerpeton acadianum [t] (=*D. oweni, Platystegos loricatum, Dendryazousa dikella*)

Dendrerpeton confusum

Dendrepeton helogenes (=*Dendrysekos helogenes*)

indeterminate Cochleosauridae

Order MICROSAURIA

Asaphestera (Hylerpeton) intermedium [h]

Hylerpeton dawsoni [h]

Leiocephalikon problematicum [h] (?=*Trachystegos megalodon*)

Ricnodon sp.

Subclass REPTILIOMORPHA

Order ANTHRACOSAURIA (EMBOLOMERI)

Calligenethlon watsoni

Class REPTILIA

Subclass ANAPSIDA

Order* CAPTORHINOMORPHA (protorothyrids & captorhinids)

Hylonomus lyelli [t] *(=Fritschia curtidentata)*

Archerpeton anthracos [h]

Subclass SYNAPSIDA

Order PELYCOSAURIA

Protoclepsydrops haplous [h]

Incertae sedis

Novascoticus (Hylonomus) multidens

["*Eosaurus acadiensis*"= exotic ichthyosaur?]

[1] uncertain taxonomic affinity

[h] holotype; [s] syntype; [c] cotype; [l] lectotype

[t] inferred from trace fossils

Table 5.2. The record of vertebrate trace fossils of the Joggins Formation (after Matthew, 1903, 1905; Sarjeant and Mossman, 1978; with affinities after Haubold, 1971). Asterix (*) denotes new report, this paper.

Phylum Chordata
Subphylum VERTEBRATA
Superclass TETRAPODA Goodrich, 1930
Class AMPHIBIA
Order MICROSAURIA
Barillopus arctus Matthew, 1905
B. confusus Matthew, 1905
B. (Baropus) unguifer Matthew, 1903
Salichnium (Ornithoides) adamsii (Matthew, 1905) Haubold, 1970
Ornithoides (Hylopus) trifudus (Dawson, 1895) Matthew, 1903
Dromillopus quadrifidus Matthew, 1905
D. (Dromopus) celer (Matthew, 1903) Matthew, 1905
Order TEMNOSPONDYLLI (Edopoidea, Eryopoidea)
Anthichnium (Nanopus) obtusum (Matthew, 1905) Haubold, 1970
A. (Nanopus) quadratum (Matthew, 1905) Haubold, 1970
Baropezia (Sauropus) sydnensis (Dawson 1863) (=*Baropezia abscissa* Matthew, 1905)
Cursipes dawsoni Matthew, 1903b
Hylopus minor Matthew, 1905
?Limnopus (Theranopus?) mcnaughtoni (Matthew, 1903c) Haubold, 1970
Amphibia indet.
Matthewichnus (Dromopus) velox (Matthew, 1905) Haubold, 1970
Quadropedia (Cursipes) levis (Matthew, 1905) Haubold, 1970
Class REPTILIA
Order CAPTORHINOMORPHA
Asperipes avipes (Matthew, 1903c)
A. flexilis Matthew, 1905
Pseudobradypus (Sauropus) caudifer (Dawson, 1882) Haubold, 1971
= *Asperipes caudifer* (Matthew, 1905)
Familiae incertae
**Pseudobradypus (Sauropus) unguifer* (Dawson, 1872) Matthew 1903

Table 5.3. The fossil record of invertebrate traces of the Joggins Formation (after Dawson, 18–; Archer et al., 198- and Calder et al., 1999).

KINGDOM ANIMALIA

PHYLUM ANNELIDA

Arenicolites Salter, 1857
Haplotichnus Miller, 1889
Cochlichnus Hitchcock,1858
Treptichnus pollardi Miller, 1880
Taenidium barretti Heer, 1877

PHYLUM ARTHROPODA

Protichnites Owen, 1852

Subphylum CHELICERATA
Class MEROSTOMATA
Order XIPHOSURIDA
Kouphichnium Nopsca,1923

Subphylum MYRIAPODA
Order ARTHROPLEURIDA
Diplichnites Dawson, 1873

Table 5.4. The fossil macrofloral record of Joggins, following the revised taxonomy of R.H. Wagner, 1999. (Fro
Calder, J.H. In prep. The Fossil Record and Paleoecology.of the Classic Upper Carboniferous Section at Joggins, Nova Scotia.)

KINGDOM PLANTAE

PHYLUM TRACHEOPHYTA

Class PROGYMNOSPERMOPSIDA
- Order CORDAITALES
  - *Cordaites principalis*
- Order NOEGGERATHIALES?
  - *Palaeopteridium rhomboideus* (Ettingshausen) comb. nov.
  - (= *Adiantites adiantoides, A. obtusus, Sphenopteris rhomboidea, S. lineata* of Bell)

Class CYCADOPSIDA Barnard & Long
- Order TRIGONOCARPALES Seward
- Family POTONIEACEAE
  - *Paripteris pseudogigantea* (Potonié) Gothan
- Family TRIGONOCARPACEAE
  - *Neuropteris obliqua* (Brongniart) Zeiller
  - *Neuropteris (Laveineopteris) tenuifolia* (Schlotheim) Brongniart
  - *Neuralethopteris schlehanii* (Stur) Cremer
  - *Alethopteris discrepans* Dawson (= *Alethopteris lonchitica* auct. pars)
  - *Alethopteris urophylla* Brongniart
  - (= *Alethopteris lonchitica* of Bell)
  - *Alethopteris decurrens* (Artis) Zeiller
  - *Mariopteris? abnormis* Gothan
  - (= *M. sp.* of Bell)
  - *?Mariopteris comata* Bell
  - *?Mariopteris disjuncta* Bell
  - *Sphenopteris valida* (Dawson) Stopes (= *Sph. artemisiaefolioides* Crépin)
  - *Karinopteris (Mariopteris) grandepinnata* (Huth) Boersma
- Family LAGENOSTOMACEAE
  - *?Eusphenopteris obtusiloba* (Brongniart) Novik
  - *Eusphenopteris trigonophylla* (Behrend) Van Amerom
  - (= *S. nummularia* forma *dilatata* of Bell)
  - *Palmatopteris furcata* (Brongniart) Potonié
  - (= *Rhodea wilsonii* of Bell)
  - *Palmatopteris alata* (Brongniart) Potonié (= *Diplothmema subfurcatum* (Dawson) Stopes)

Class FILICOPSIDA
- Order BOTRYOPTERIDALES
- Family TEDELACEAE
  - *Senftenbergia plumosa* (Artis) Stur
- Family URNATOPTERIDACEAE
  - ? *Zeilleria delicatula* (Sternberg) Kidston
  - (= *S. (?Zeilleria) sp.* of Bell)
  - *Zeilleria frenzlii* (Stur) Kidston
  - (? = *S. fletcheri* of Bell)
  - *Zeilleria hymenophylloides* Kidston
  - (= *S. (Zeilleria) hymenophylloides* of Bell)
  - *Zeilleria pilosa* (Dawson) comb. nov.
  - (= *Pecopteris pilosa* of Bell)

Zeilleria schaumburg-lippeana (Stur) Zeiller
Renaultia crepinii (Stur) Zeiller
(= *Sphenopteris deltiformis* of Bell)
Renaultia gracilis (Brongniart) Zeiller
Renaultia rotundifolia (Andrae) Zeiller
Renaultia schatzlarensis (Stur) Zeiller
Sphenopteris (Renaultia?) schwerinii (Stur) Zeiller
(= *S. (Renaultia) schatzlarensis* of Bell, 1966, pl. XI, fig. 4)
cf. *Boweria schatzlarensis* Kidston
Oligocarpia brongniartii Stur (= *O. splendens* (Dawson) Stopes)
Sphenopteris deltiformis Kidston
Sphenopteris dixonii Kidston
Sphenopteris fletcheri Bell (cf. *Zeilleria frenzlii*)
?Sphenopteris moyseyi Kidston
(questionable taxon)
Sphenopteris sp. indet (= *S. stipulataeformis* (Stur) Gothan)
Sphenopteris sp.
(= *S. mixta* of Bell)

Order COENOPTERIDALES
Family CORYNEPTERIDACEAe
Corynepteris angustissima (Sternberg) Nemejc
(= *Corynepteris sternbergii* (Ettinghausen) Arber)
(= *Alloiopteris (Corynepteris) sternbergii* of Bell)

Class SPHENOPSIDA (Equisetopsida)
Order EQUISETALES
Family CALAMOSTACHYACEAE
Calamites (Calamitina) sp.
(rhizome = *C.* group *varians* of Bell)
Calamites cf. *goeppertii* Ettingshausen
Annularia aculeata Bell
Annularia asteris Bell
Annularia latifolia (Dawson) Kidston (= *A. jongmansii* Walton ?)
Annularia acicularis (Dawson) Matthew (= *A. radiata* Brongniart)
Annularia cf. *stellata* (Schlotheim) Wood
Asterophyllites charaeformis (Sternberg) Göppert
Asterophyllites grandis (Sternberg) Göppert
Asterophyllites equisetiformis (Schlotheim) Brongniart

Order BOWMANITALES
Family BOWMANITACEAE
Sphenophyllum cf. *kidstonii* Hemingway

Class LYCOPSIDA
Order LEPIDOCARPALES
Lepidodendron aculeatum Sternberg
"Lepidodendron" bretonense Bell (= *L. dissitum* Sauveur?)
Lepidodendron cf. *fusiforme* Corda
(= *L. rimosum* of Bell)
cf. *Lepidodendron lycopodioides* Sternberg
(= *L. lanceolatum* of Bell)
Lepidodendron cf. *obovatum* Sternberg
Lepidodendron worthenii Lesquereux
Lepidophloios laricinus Sternberg
Ulodendroid branch scar

Lepidostrobus ornatus Brongniart (= *Lepidostrobus variabilis* Lindley & Hutton)
Lepidostrobus olryi Zeiller
Lepidostrobophyllum lanceolatum (Lindley & Hutton) Bell
Lepidostrobophyllum majus (Brongniart) Hirmer
Lepidostrobophyllum morrisianum (Lesquereux) Tenchov
(= *Lepidostrobophyllum fletcheri* Bell)
Sigillaria mamillaris Brongniart
(incl. *S. elegans* of Bell)
Sigillaria scutellata Brongniart
Sigillaria cf. *scutellata* Brongniart *(= Sigillaria fundiensis* Bell)
Syringodendron sp.
lycophyte (unidentifiable)
(= *S. reticulata*? of the *S. brardii* group of Bell)

Order ISOETALES?

Omphalophloios? sp.
(= *Lepidodendron jaraczewskii* of Bell, 1944, pl. LI, fig.1 ~ figured upside down?)

Erosion Analysis of the Joggins Area

A Preliminary Investigation

Nelson M. Bezanson
February 22, 2006
The Municipality of the County of Cumberland

Introduction

There has been significant interest in the Joggins area recently, both pertaining to a drive to have it nominated as a UNESCO World heritage Site and a municipal land use planning initiative. The Municipality of Cumberland agreed to perform a costal erosion analysis to support those efforts.

Two sets of air photos covering the area from Downing Cove southward to Ragged Reef Point were obtained from which the analysis was performed. The first set was from 1964, the second from 2005, covering a 41 year span from which to do the comparison.

Method

All air photos were scanned at resolution of 300dpi using a flatbed scanner. The air photos were then georeferenced to real world coordinates using the ArcMap 9.1 GIS software based on the location of buildings, roads, trails and watercourses.

The coastlines were then drawn using heads-up digitizing, tracing the top of cliffs or banks.

Limitations

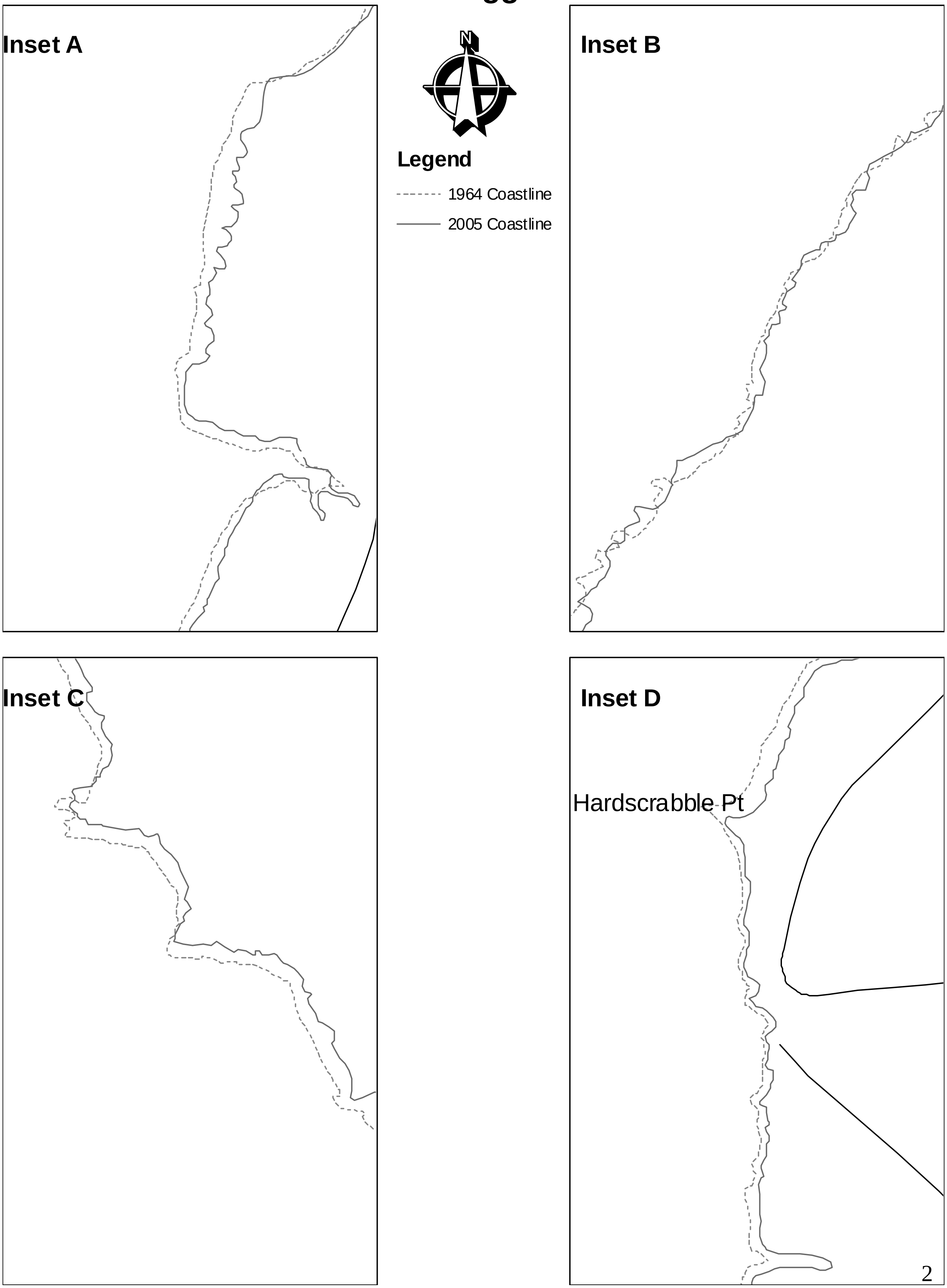
There are two main sources of error in producing coastlines from air photos.

The first occurs when georeferencing the photos. Accuracy is largely dependant on finding points in the photo that can be precisely identified in the mapping. Older photos invariably have fewer points when can be identified with any certainty. Some portions of the study area are predominantly forested and are significantly lacking in points for comparison. Other georefferencing errors are more difficult to pinpoint. One of the more critical areas from the perspective of the Municipality is the built-up area of Joggins. Despite using 48 reference points to georeference the air photo which covers an area 2.1 x 2.3 kilometers there exists a RMS (root mean square) error of 3.16. With a photo cell size of 0.9 meters, this translates into an error of over 2.8 meters. With calculated erosion rates varying between 12 to 50 cm per year, georefferencing error represents as much as a 60% source of error.

The second source of error is during the digitizing. Interpreting the shoreline can be hampered by trees and shadows, colour photos are easier to interpret than black and white.

Some examples are shown in the map insets on the following page. In Inserts A and D the 2005 coastline follows a predictable line consistent with the 1964 coastline except for a small portion on the south side of the inlet in Insert A, likely caused by dark shadows or tall trees obscuring the bank.

Coastline Erosion: Joggins Area Insets



Insert B however displays significant errors as the two coastlines cross repeatedly, when this occurs, no conclusion can be drawn from the mapping as the various errors are more significant than erosion rates.

Insert C demonstrates a georeferencing error where the 2005 coastline appears shifted north of the 1964 coastline. Despite repeated attempts to improve the georeferencing, the error remains and is a significant source of error.

Due to the combination of errors, it would be safe to assume a 5-7 cm per year error in erosion rates, some areas will be less or greater.

Observations

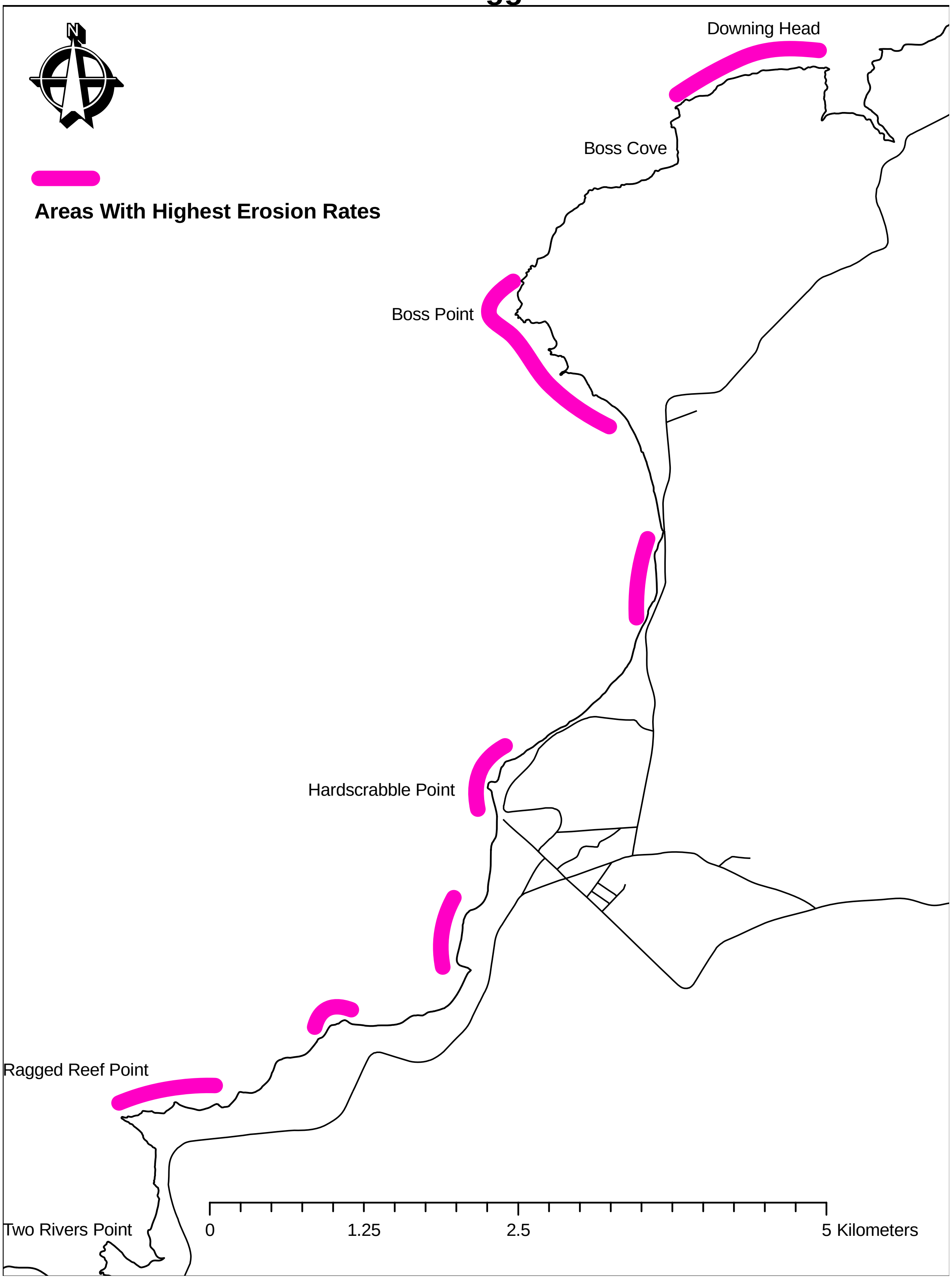
Most parts of the study area have minimal to moderate erosion rates ranging from undetectable to 25 cm per year. In general the points and headlands have higher erosion rates (up to 37 to 50 cm per year). The greatest rates of erosion occur in the vicinity of Downing Head and southwards from Boss Point towards Lower Cove Beach. The map on the following page highlights those areas with the highest erosion rates.

In the central Joggins area, Hardscrabble Point and McCarrens River Point have the highest erosion rates, both losing about 50cm per year.

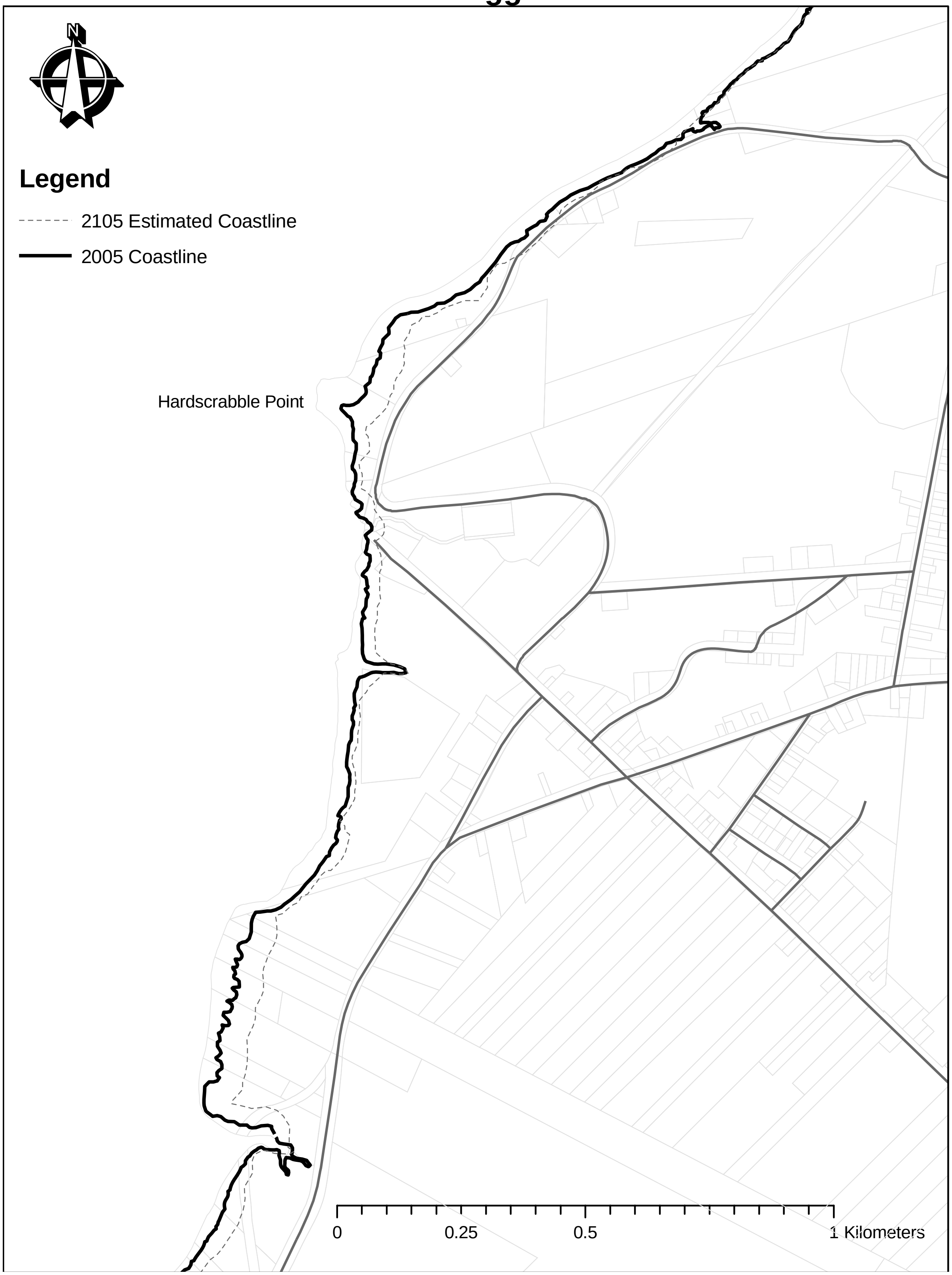
Conclusion

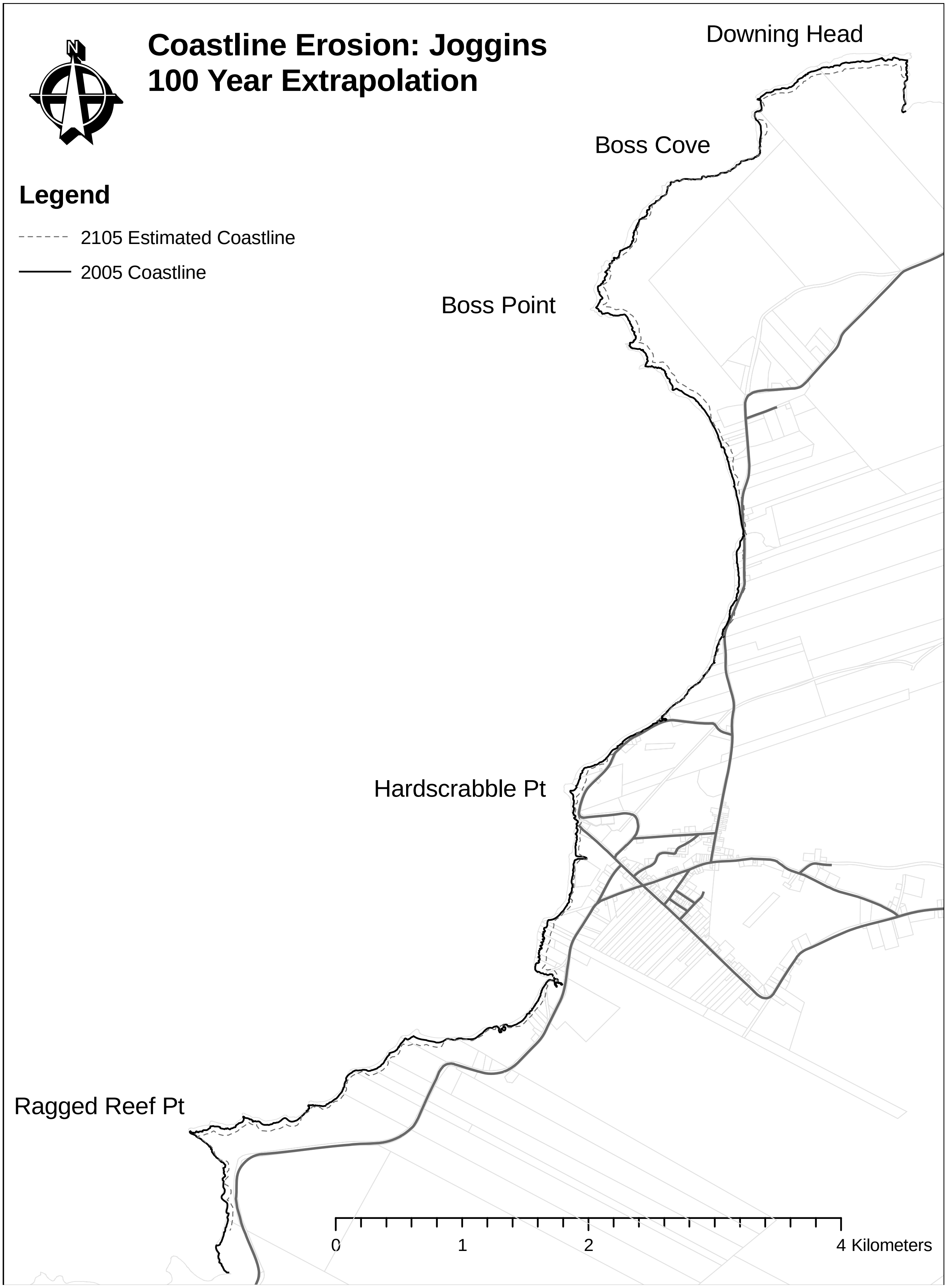
General erosion trends and areas of higher erosion are quite evident from the research. Most of these will likely have little effect on buildings, roads or infrastructure over the next century. Areas of most concern are Hardscrabble Point, the Hardscrabble Road towards Lower Cove and the road along the Lower Cove beach. These face significant threat from erosion over the next few decades.

Coastline Erosion: Joggins Area Overview



Coastline Erosion: Joggins Central Area




Coastline Erosion: Joggins
100 Year Extrapolation
N
Legend
2105 Estimated Coastline
2005 Coastline
Downing Head
Boss Cove
Boss Point
Hardscrabble Pt
Ragged Reef Pt
0
1
2
4 Kilometers

Joggins Fossil Cliffs
Emergency Response Plan
(Draft*)

Cumberland Regional Economic Development Association
&
Joggins Fossil Institute

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*The Joggins Fossil Institute will continue to work with the appropriate agencies to finalize the draft plan, pending the completion of the new Joggins Fossil Centre.

Joggins Fossil Cliffs Emergency Response Plan Index

Section D “Responses to Emergency Situations”

Section A

The Joggins Fossil Cliffs Emergency Plan

1) Forward

The purpose of the Joggins Fossil Cliffs Emergency Response Plan is to provide officials, personnel and emergency response agencies with a set of general guidelines to aid in response to an emergency situation at the Joggins Fossil Cliffs Centre and adjoining developments. For this plan to be effective it is imperative that all officials, departments and agencies be aware of their respective roles and be prepared to carry out their assigned responsibilities in the event of an emergency situation caused by the forces of nature, an accident, or an intentional act that constitutes a danger to life and or property.

2) Mission

Our Vision:

"The Joggins Fossil Cliffs Emergency Response Planning Group will be committed to proactive planning and preparation in support of an Emergency Response Plan for the Joggins Shore and the Joggins Fossil Centre, seeking to provide quick and assured emergency response through the teamwork of the various Emergency Services of Cumberland County, the Province of Nova Scotia and the Government of Canada."

Our Mission:

"To evaluate, understand, plan, and prepare for the unexpected while teaming actively with other Emergency Services in supporting an effective response, mitigating further hazards, and assisting in recovery. This includes educating and informing the community of Joggins of issues and actions taken on their behalf. The Joggins Fossil Cliffs Emergency Response Planning Group fosters the 'Team' approach through education, coaching and partnering with each member. Members include: Staff of the Joggins Fossil Cliffs Interpretive Centre, staff of Cape Chignecto Provincial Park, the Cumberland Regional Economic Development Association, (CREDA) and the Municipality of the County of Cumberland, the Joggins Volunteer Fire Department, the Advocate Fire Department, the Royal Canadian Mounted Police, (RCMP) the Emergency Health Services of Nova Scotia, (EHS) Emergency Measures Organization, (EMO) the Nova Scotia Department of Natural Resources, (DNR) Special Hazards Response Unit (SHRU) and the Springhill Search and Rescue Group. Joggins Fossil Cliffs Emergency Response Planning Group will provide direction and obtain resources to members of the team in events of emergency response in order to assure the safety and security of the visitors of the Joggins and Fundy Shores and for the staff of the Joggins Fossil Cliffs Interpretive Centre and Cape Chignecto Provincial Park."

3) Emergency Policy

The Joggins Fossil Cliffs Institute organizes, coordinates and directs available resources toward emergency response planning. The primary purpose of the *Emergency Response Policy* is to provide guidelines for the prevention of emergency situations and to provide a quick, effective and efficient means of dealing with any given emergency that may arise on the Joggins Fossil Cliffs site.

For the policy to be effective, all Joggins Fossil Centre personnel must be made aware of their duties and responsibilities in the event of an emergency situation. To be efficient in performing these duties all site personnel must have or receive proper training, (i.e. First Aid and CPR). Moreover, visitors to the site must also be made aware on the inherent danger of the site and guidelines for visitor use of the site.

The following documentation provides the fundamental organization and emergency response process required to prevent and respond to an emergency. The emergency response team does not necessarily consist of one particular group or individual, rather it consists of the site personnel immediately involved with the emergency situation and a pre-determined response strategy based on the operation's organizational chart and internal communications plan.

4) The Emergency Response Planning Group

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A. Group Mandate

The *Joggins Fossil Cliffs Emergency Response Planning Group* will be committed to planning and preparation in support of an Emergency Response Plan for the *Joggins Fossil Institute* which seeks to provide quick and assured emergency response through the teamwork of the various Emergency Services of the County of Cumberland, the Province of Nova Scotia and the Government of Canada.

The *Joggins Fossil Cliffs Emergency Response Planning Group* will not make direct policy change, but will make recommendations on policy change to the *Joggins Fossil Institute* through liaison with Director of the Joggins Fossil Centre.

B. Group Membership

B.1 Structure

Membership of the *Joggins Fossil Cliffs Emergency Response Planning Group* shall consist of not more than seven (7) persons, to be chosen as follows:

a) One (1) member to be proposed by the Emergency Measures Organization of the County of Cumberland (EMO);

b) One (1) member to be proposed by Emergency Health Services of Nova Scotia (EHS);

c) One (1) members to be proposed by Joggins Fire Department;

d) One (1) member to be proposed by the Royal Canadian Mounted Police (RCMP);

e) One (1) member to be proposed by Springhill Ground Search and Rescue;

f) One (1) member to be proposed by the Nova Scotia Department of Natural Resources;

g) One (1) member to be proposed by the Joggins Fossil Institute;

B.2 Sub-Groups

The following standing sub group of the Joggins Fossil Cliffs Emergency Response Planning Group will be established: *Emergency Response Plan Audit Group.*

Emergency Response Plan Audit Group will be responsible for the "end of season" review of the Emergency Response Plan for the *Joggins Fossil Institute*, reporting to the *Joggins Fossil Cliffs Emergency Response Planning Group* on policy changes to Joggins Fossil Cliffs Emergency Response Plan.

Membership of the *Emergency Response Plan Audit Group* shall consist of not more than three (3) persons elected from within in the body of the *Joggins Fossil Cliffs Emergency Response Planning Group.*

C. Operational Guidelines

C.1 Major Duties of the Group

- Review the Joggins Fossil Cliffs Emergency Response Plan after every major incident and reporting any and all recommendations to the Director of the Joggins Fossil Centre;
- Review and evaluate annually the performance of the Joggins Fossil Cliffs Emergency Response Plan to insure the safely of the staff and visitors to the Joggins Fossil Cliffs;
- Ensure prudent and proper management of the *Joggins Fossil Cliffs Emergency Response Planning Group* resources;

C.2 Due Diligence - Responsibilities of Individual Group Members

Each Group Member is expected to become an active participant in a body that functions effectively as a whole. In addition each Group Member is expected to assist in the exercise of the major duties of the Group as outlined above. Members are responsible to exercise due diligence in the performance of their duties. They are responsible to:

- Be informed of the articles, under which the Group exists, its mission, values, code of conduct, and policies as they pertain to the duties of a Group member.
- Keep generally informed about the activities of the Group, and general trends in the business in which it operates.
- Attend Group meetings regularly serve on sub-Groups of the Group and contribute from personal, professional and life experience to the work of the Group.
- Exercise the same degree of care, diligence, and skill that a reasonably prudent person would show in comparable circumstances.
- Offer their personal perspectives and opinions on issues that are the subject of Group discussion and decision.
- Voice, clearly and explicitly at the time a decision is being taken, any opposition to a decision being considered by the Group.
- Maintain solidarity with fellow members in support of a decision that has been made in good faith in a legally constituted meeting, by members in reasonably full possession of the facts.
- Ask the members to review a decision, if she/he has reasonable grounds to believe that the Group has acted without full information or in a manner inconsistent with its fiduciary obligations, and, if still not satisfied after such review, ask that the matter be placed before the membership.
- Work with the staff of the *Joggins Fossil Institute* or the *Cumberland Regional Economic Development Association* on sub-groups of the Group;
- Know and respect the distinction in the roles of Group and staff consistent with the principles underlying these policies;
- Exercise vigilance for and declare any apparent or real personal conflict of interest in accordance with the Group's policies.

C.3 Oath of Office and Confidentiality

Respect for confidentiality is the cornerstone of trust and confidence as well as an obligation. Group members must at all times respect the confidentiality of any individual's names and/or circumstances that might identify that individual. Similarly, all matters dealt with by the Group during in-camera meetings and matters related to personnel and/or collective bargaining must be held in strictest confidence. Confidentiality means members may not relate such matters to anyone including immediate family members. The duty of confidentiality continues indefinitely after a member has left the Group. Group members shall agree to an Oath of Office and Confidentiality upon joining the *Joggins Fossil Cliffs Emergency Response Planning Group*.

OATH OF OFFICE AND CONFIDENTIALITY AGREEMENT

(Joggins Fossil Cliffs Emergency Response Planning Group)

This agreement made this _______ day of ____________, 20____,

between

____ (the "Individual")

and

The Joggins Fossil Institute

As a member of the Joggins Fossil Cliffs Emergency Response Planning Group, I may be entrusted with knowledge of the affairs of the Joggins Fossil Institute.

I hereby undertake neither to divulge any of this knowledge nor to discuss it at any time, or any place with an unauthorized person, except in the course of my duties relating to the business of the Institute or with the express consent of the Joggins Fossil Centre Site Director.

I also agree not to criticize the actions, decisions, resolutions or positions taken by the Joggins Fossil Institute, its Board of Directors and Officers, in any public forum, including the print media, radio, television, internet and any other media whatsoever.

I also acknowledge that a breach of this undertaking could result in disciplinary measures with possible removal from the Group as determined by the Joggins Fossil Institute's Board of Directors.

The Individual

___________________________ ___________________________
Name (Please Print) Signature

___________________________ ___________________________
Date Signature of Witness

I have explained the implications of signing the **Declaration of Confidentiality** to the Individual noted above and am fully satisfied he/she is aware of the necessity to hold the affairs of the Joggins Fossil Cliffs Emergency Response Planning Group and the Joggins Fossil Institute in absolute confidence.

___________________________ ___________________________
Name (Please Print) Signature

C.4 Code of Conduct

Group members are expected to comply with the prescribed Code of Conduct that encourages the development of a spirit of collective decision-making, shared objectives and shared ownership of and respect for Group decisions. The Code of Conduct should be a succinct statement of essential principles intended to govern the conduct of the Group and staff of the Joggins Fossil Centre.

Group members and staff of the Society will at all times conduct themselves in a manner that:
- Supports the objectives of the *Joggins Fossil Cliffs Emergency Response Planning Group;*
- Serves the overall best interests of the Group rather than any particular constituency;
- Brings credibility and good will to the Group;
- Respects principles of fair play and due process;
- Demonstrates respect for individuals in all manifestations of their cultural and linguistic diversity and life circumstances;
- Respects and gives fair consideration to diverse and opposing viewpoints;
- Demonstrates due diligence and dedication in preparation for and attendance at meetings, special events and in all other activities on behalf of the Group;
- Demonstrates good faith, prudent judgment, honesty, transparency and openness in their activities on behalf of the Group;
- Ensures that the financial affairs of the Group are conducted in a responsible and transparent manner with due regard for their fiduciary responsibilities and public trusteeship;
- Avoids real or perceived conflicts of interest;
- Conforms to the policies approved by the Group, in particular this Code of Conduct, the Oath of Office and Confidentiality and Conflict of Interest Policy;
- Publicly demonstrates acceptance, respect and support for decisions legitimately taken in transaction of the Group's business.

C.5 Conflict of Interest Policy

Members of the Group shall act at all times in the best interests of the *Joggins Fossil Institute* rather than particular interests or constituencies. This means setting aside personal self-interest and performing their duties in transaction of the affairs of the Group in such a manner that promotes public confidence and trust in the integrity, objectivity and impartiality of the Group. Members of the Group shall serve without remuneration. No member shall directly or indirectly receive any profit from his/her position as such, provided that members may be paid reasonable expenses incurred by them in the performance of their duties. The pecuniary interests of immediate family members or close personal or business associates of a director are considered to also be the pecuniary interests of the director.

I. Definition of Conflict of Interest:

a) Group members are considered to be in a "conflict of interest" whenever they themselves, or members of their family, business partners or close personal associates, may personally benefit either directly or indirectly, financially or otherwise, from their position on the Group;
b) A conflict of interest may be "real", "potential" or "perceived"; the same duty to disclose applies to each;
c) Full disclosure in itself, does not remove a conflict of interest.

D. Roles of the Officers of the Group

The Officers of the Group shall be a Chairperson, a Vice-Chairperson, and a Secretary. The offices of the Treasurer and Secretary may be combined, or may be separately held.

D.1 Chairperson

The role of the Chair is to ensure the integrity of the Group's processes. The Chair is the only Group member authorized to speak for the Group, unless this is specifically delegated to another Group member.
- The Chair presides as the 'manager' of the Group's activities, ensuring that the Group follows its own rules and those legitimately imposed upon it by statute or regulation. Since most of the work of the Group will be done during regularly scheduled Group meetings, the Chair is responsible for ensuring that the work is conducted efficiently and effectively. The Chair has no authority to make decisions outside the by-laws or the parameters of policies created by resolution of the Group.
- The Chair will set the agendas for meetings of the Group with input from the members of the Group.
- The Chair will plan the conduct and timing of Group meetings in conjunction with the Site Director and will chair meetings of the Group.
- The Chair will ensure that the Group is properly informed about the operations of the *Joggins Fossil Institute* and has the information and opportunity necessary to come to decisions on matters within its purview.
- The Chair will be the Group's primary liaison with the Director of the Site, who is responsible for the execution of Group policy and directives, and for determining the means, organizational structure and management processes necessary to achieve the corporate objectives.

D.2 Vice Chairperson

The Vice-Chairperson shall, at the request of the Chairperson or the Group of Directors and subject to its discretion, perform the duties of the Chairperson during his or her absence, illness or incapacity or during such period as the Chairperson or the Group may request

In addition to assuming the duties of the Chair during his/her absence, the Vice-Chair shall perform other duties prescribed from time to time by the Group, coincident to the office.

D.3 Secretary

The Secretary shall ensure that all secretarial functions are performed for the Group and Executive Group, and that records are kept of all proceedings and transactions.
- Oversee the keeping of records of meetings, policies, membership and any other records required by Policy;
- Ensure that minutes are taken at all regular and special meetings of the Group;
- Ensure that copies of minutes and agendas are circulated to Group members prior to each meeting;
- Maintain, or ensure the maintenance of, the files and records of the Group to be passed on to future officers and ensure the security and confidentiality of all such files and records.

The Group may appoint a recording secretary, not a member of the Group, who shall cause minutes to be recorded, prepared and entered into books or records designed.

E. Group Management

E.1 Meetings

Meetings of the *Joggins Fossil Cliffs Emergency Response Planning Group* will, unless otherwise determined by the Group, be held twice a year, at the beginning of the operating season and at the end, and after every major incident. Meetings shall at the Joggins Fossil Centre's Boardroom or other such designated place. All meetings will be conducted in private session. Robert's Rules of Order will be followed unless the Group has explicitly substituted an alternative procedure. Discussion at meetings of the Group will be confined to those issues that clearly fall within the Group's authority according to its policies. Group deliberation at meetings will be timely, fair, orderly, thorough, and efficient.

E.2 Group Member Attendance

Carrying out the work of the Group effectively requires a commitment to attend all Group meetings as required. Group members who are absent, without excuse, from two consecutive meetings are automatically considered to have resigned their position. In the event such a member wishes to be reinstated, a letter of request must be sent to the Group. The Group shall then make a decision by motion regarding reinstatement as well as any terms associated with a decision to reinstate if such is the decision.

E.3 Group Self-Evaluation

The Group shall periodically review its own progress on work plan objectives and its effectiveness. It shall conduct a formal assessment of its own performance annually and shall take any steps for improvement in its governance practices suggested by such review.

E.4 Conflict Resolution

Group members are commonly recruited to bring diverse views on issues to Group debates and decision-making. Constructive disagreements between Group members are encouraged in a well-functioning Group. They can generally be managed by following proper rules of procedure and encouragement of good listening skills. However, in the heat of Group debate, disagreements sometimes degenerate into serious conflict on issues or between personalities.

The Group chair is responsible for managing such conflicts. A neutral Group member or third party should be selected if the Group chair is a party to the conflict. It is important to identify early on whether the conflict is based on the immediate issue at hand or has deeper roots based on differences in personal values and history, personalities, personal or political agendas, gender or culture.

E.5 Group Member Expenses

Group members are entitled to be reimbursed for expenses occurred during activities required to carry out their duties on behalf of the Group;

- The Group, in accordance with accepted community standards, shall annually decide the rate at which mileage expenses are reimbursed;
- The rate at which all other expenses are reimbursed (such as child care during meetings, Group training, honoraria, all other transportation costs or limits for meals) shall be decided annually by Group motion;
- All Group member expenses must be documented on a Group Member Expense form and be authorized by the Site Director;
- The Site Director is responsible to recommend, to the Group, appropriate rates of reimbursement for Group member expenses.

E.6 Decision-Making Process

Decisions of the Group are made as a group at Group meetings at which a quorum of the Group of four (4) is present. A quorum is required for the transaction of any business of the Group. Decisions will ideally be made through a consensus development process leading to a formal vote to record the decision. This process is intended to encourage full discussion and development of a decision that all or at least the largest possible majority of Group members can support prior to a vote. Where disagreements continue to exist, dissenting members may request that their objections be recorded in the minutes. A favourable vote of a majority of the members present, regardless of abstentions, is required for approval.

Group Members have the right to discuss questions before the Group and make their decisions in an uninhibited atmosphere. These Governance Policies, the Code of Conduct and procedural guidelines will govern Group deliberations. Members will welcome and respect the diverse views of their colleagues, maintain confidentiality as required and support Group decisions.

Section B

Emergency Preparedness Assessment

Section C

Prevention

6) Education and Awareness

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7) Promotion of Safety

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a.1) Appropriate Clothing and Equipment for Staff

Clothing for the Beach:

- JFC windbreaker, vest or fleece jacket (see JFC uniform)
- Florescent safety vest
- Sweater (with hood) or sweat shirt
- Standard Joggins Fossil Centre short sleeve shirt (see JFC uniform)
- Hiking shorts for warm weather
- Denim jeans or hiking pants for cooler weather
- Headgear: JFC “tilly” style hat or JFC ball cap (see JFC uniform)
- Hard hat, if you are to venture near the cliffs
- Hiking boots

Equipment for the Beach:

- Back pack
- GPS Unit
- FRS Radio
- Fanny pack aid kit
- Whistle
- Flashlight
- Note pad
- Clipboard (with maps and *Refusal of Care Form*)
- Pencil
- Multitool

Other Items:

- Sun block
- Sunglasses
- Insect repellent
- Water
- Food rations (trail mix, candy, fresh fruit etc.)

a.2) Appropriate Clothing and Equipment for Visitor

Recommended Clothing for the Beach:

The visitor to the Joggins Fossil Cliffs should be made aware that weather conditions along the Bay of Fundy can be extreme and can change within a very short period of time. It is suggested that the visitor should dress in layers as in the following:

- Water resistant windbreaker with hood
- Sweater
- Shirt
- Hiking shorts for warm weather
- Denim jeans or hiking pants for cooler weather
- Headgear: “tilly” style hat or some other form of brimmed hat to block the sun and or rain.
- Hard hat, for those with a heritage permit who are venturing near the cliffs.
- Hiking boots or shoes or some other form of sturdy footwear. Sandals, hard soled shoe or shoes with a high heal are not recommended.

Other Recommended Items:

- Light backpack
- Sun block
- Sunglasses
- Insect repellent
- Water
- Food rations (trail mix, candy, fresh fruit etc.)

b) Safe Behaviour

The visitor should be made aware that the Fossil Cliffs of Joggins are beautiful, however they are inherently dangerous. Here you have the world's most powerful tides and towering cliffs of unstable sedimentary rock that are constantly eroding and crumbling to the beach below. However, if you instruct the visitor with care the Joggins Fossil Cliffs will pose little or no danger to our guests.

Rules for Safe Behavior on the Beach:

- The visitor must stay away from the cliff edge. The cliffs are actively eroding and unstable. Falling rock or mud can cause serious harm or death. Also beware that in the spring ice and water runoff can also be a serious danger. Due to constant erosion of the cliff face, it is recommended that all persons stay at least 10 meters from the cliffs. Avoid overhangs and caves. A hard hat is to be worn if you are to venture near the cliffs.
- Be careful of the cobblestones on the beach and sandstone reefs. Wet, loose and/or seaweed covered rocks underfoot are hazardous. Rocks covered in green algae are also extremely slippery. You and your visitors should avoid these rocks.
- Check the daily tide charts for the Joggins Shore. Try to leave the beach about two hours before high tide. The best time to visit the site is from mid-tide to mid-tide (approximately between three hours to low-tide and three hours to high tide).
- The weather can be extreme on the beach. Dress in layers and consider carrying a bottle of water and food rations with you.
- The visitor should be made aware that cell phone coverage on the Joggins shore can be spotty. It is a good idea to inform them to let someone know when they are expected to be off the beach if they are venturing out on their own.

8) General Training for Staff

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9) Training for Selected Staff

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Section D

Reponses to Emergency Situations

10) Procedure (Checklists)

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Response to Bomb Threat via Telephone (Check List)

Incident: Bomb Threat Received over the Telephone

In the event of identification of a Bomb Threat over the telephone the following procedures will be applied:

Response:

Upon receiving a report of an immediate bomb via telephone, the person receiving the call should:

- **listen carefully**
- **be calm and courteous**
- **do not interrupt the caller**
- **obtain as much information as possible**

(Place a check mark as each response take place)

_____ Asked these question if possible:

a) What time will the bomb explode? ______________________________

b) Where is the bomb? ____

c) What does the bomb look like? _________________________________

d) Where are you calling from? ___________________________________

e) Why did you place the bomb? __________________________________

f) What is your name? ____

_____ If it is possible, write a note to a colleague to call 911

_____ Call 911 when caller hang-ups.

_____ Advise the Supervisor of the Day of the bomb threat.

_____ Evacuation order will be sounded.

_____ Evacuation will take place.

_____ All staff and visitors are relocated outside of the Centre.

_____ The area will be isolated and await Emergency Services response.

Response to Bomb Threat **via E-mail or other Written Media** (Check List)

Incident: Bomb Threat Received via E-mail or other Written Media)

In the event of identification of a bomb threat via e-mail or other written media the following procedures will be applied:

Response:

_____ Advise the Supervisor of the Day of the bomb threat.

_____ Evacuation order is to be sounded (if appropriate to do so – see full text).

_____ Evacuation will take place.

_____ All staff and visitors will be relocated outside of the Centre.

_____ The area has been isolated and await Emergency Services response.

Response to a Disgruntled Visitor (Check List)

Incident:

In the event that staff are made aware of an individual or individuals who express discontent with policies and/or services at the site including, but not limited to retail services, fossil collecting policy and other activists.

Response:

_____ The discontent person is approached and asked how we can rectify the situation.

_____ If situation warrants, the Supervisor of the Day will be called in to intervene and aid in the resolution the situation.

_____ The person is to be taken to a non-public area to discuss the matter in private.
(no staff member shall be alone at any given time with a disgruntled person).

_____ Centre polices will be explained to the visitor and he or she will be asked for compliance.

_____ The person is asked to leave if he or she becomes unruly.

_____ Call 911 if situation can not be resolved.

Response to a Fire at the Centre (Full Text)

Incident: Fire at the Joggins Fossil Centre

In the event of identification of a fire at the Joggins Fossil Centre the following procedures will be applied:

Response:

_____ A fire is identified at the Centre.

_____ The fire alarm is sounded. 911 is called.

_____ Evacuation order is given.

_____ Fire suppression will be attempted if safe to do so.
DO NOT JEPORDIZE PERSONAL SAFTY!

_____ If the fire can not be extinguished, full evacuation of the centre will be sounded

_____ A full evacuation will take place.

_____ All staff and visitors are relocated outside of the Centre.

_____ The area is isolated and await Emergency Services response.

Response to an Area Forest/Brush Fire (Check List)

Incident: Fire near the Joggins Fossil Centre

In the event of identification of a fire near Joggins Fossil Centre the following procedures will be applied:

Response:

_____ Supervisor of the Day is contacted when a report of a fire near the Centre is made.

_____ 911 is called.

_____ If the fire is near the Centre, the evacuation order is given.

_____ Evacuation will take place.

_____ All staff and visitors will be located outside of the area of danger.

_____ The area is to be isolated and await Emergency Services response.

Known Injury or Illness on Site (Check List)

Incident:

In the event that staff is made aware of an individual or individuals who are injured of ill, the following procedures will be applied:

Response:

_____ An injured person is found.

_____ A preliminary medical assessment is made.

_____ The Supervisor of the Day is contacted and asked to how to proceed.

_____ If the person feels that they do not need assistance, they are asked sign the *Refusal of Care Form.*

_____ 911 is called if Supervisor of the Day feels it's necessary.

_____ The task is handed over to the emergency service first to arrive. (EHS, JVFD, RCMP)

Response to Missing Persons (Check List)

Incident:

In the event that staff are made aware of an individual or individuals who can not be accounted for the following procedures will be applied:

Response:

_____ The Supervisor of the Day uses the Emergency Code System to advise staff of the potential situation.

_____ All available staff will contact the Supervisor of the Day and inform him or her of their availability and to await instructions.

_____ Information for *911 Check List for Missing Persons* will be collected by Administrative Assistant.

_____ Internal resources will be organized for the search.

_____ A brief sweep of the area where the person was last seen will take place.

_____ If person is found, and a safe recovery is possible, staff will proceed.

_____ If safe recovery is not possible, call 911 and await response.

_____ If the person is not found within 10 minutes, call 911 and await response

_____ Staff will assist first responders if necessary.

Response to Hazardous Material or Item (Check List)

Incident:

In the event of identification of a Biological, Chemical and or Toxic Agent hazard the following procedures will be applied:

Response:

_____ A hazard is detected (dead animal, bird, marine creature or suspicious agent).

_____ Identification of this hazard is made by a cursory inspection. (if possible)

_____ The Supervisor of the Day is notified.

_____ The area is immediately isolated from the public.

_____ The Supervisor of the Day takes appropriate action. (see full text)

11) Procedure (Full Text)

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Response to Bomb Threat via Telephone (Full Text)

Incident: Bomb Threat Received over the Telephone

In the event of identification of a Bomb Threat over the Telephone the following procedures will be applied:

Response:

1. Upon receiving a report of an immediate bomb via telephone, the person receiving the call should:

- **listen carefully**
- **be calm and courteous**
- **do not interrupt the caller**
- **obtain as much information as possible** (see questions to be asked)

Questions to be asked:

a) What time will the bomb explode? ______________________________

b) Where is the bomb? ____

c) What does the bomb look like? _________________________________

d) Where are you calling from? ___________________________________

e) Why did you place the bomb? __________________________________

f) What is your name? ____

2. If it is possible, write a note to a colleague to call 911 or do so as soon as the call hang-ups.

3. Advise the Supervisor of the Day of the bomb threat. He or she will then issue an evacuation order.

4. Evacuation will follow according to the evaluation plan.

5. All staff members and visitors will remain outside of the Centre in a predetermined area for response from emergency organizations.

6. The area will be monitored until the appropriate Emergency Organizations respond.

Response to Bomb Threat (Full Text)

Incident: Bomb Threat Received via E-mail or other Written Media)

In the event of identification of a bomb threat via e-mail or other written media the following procedures will be applied:

Response:

1. Upon receiving a report of an immediate bomb via e-mail or other written media, Supervisor of the Day is contacted.

2. The Supervisor of the Day will then review the contents of the threatening statement and call 911.

3. If Supervisor of the Day feels that it is prudent, given the severity of the potential threat, evacuation will follow according to the evaluation plan

4. All staff and visitors will remain outside of the Centre in a predetermined area for response from emergency organizations.

5. The area will be monitored until the appropriate Emergency Organizations respond.

Response to a Disgruntled Visitor (Full Text)

Incident:

In the event that staff are made aware of an individual or individuals who express discontent with policies and or services at the site including, but not limited to retail services and Centre policies.

Response:

1. The staff member will approach or ask the visitor the reason for their discontent and how they could rectify the situation.

2. If the situation warrants and is not provided for in the *Human Resources Policy,* the Supervisor of the Day will be asked to intervene to aid in the resolution the situation.

3. If the visitor is loud or disruptive, he or she will be invited to discuss the matter in a private area **(no staff member shall be alone at any given time with a disgruntled person).**

4. Appropriate policies will be explained to the visitor and their compliance to conflicting policies will be requested.

5. If the visitor becomes unmanageable, then he or she will be asked to leave the Centre Property.

6. If the visitor persists and the situation can not be resolved by the Supervisor of the Day will called 911 and awaits response by the R.C.M.P.

Response to a Fire at the Centre (Full Text)

Incident: Fire at the Joggins Fossil Centre

In the event of identification of a fire at the Joggins Fossil Centre the following procedures will be applied:

Response:

1. A visitor notifies a staff member or a staff member identifies a fire. The fire alarm is immediately sounded if the automatic detection system hasn't already done so. Evacuation of all persons involved will take place according to the evaluation plan.

2. An immediate site survey will be completed and an appropriate fire suppression response will be determined. DO NOT JEPORDIZE PERSONAL SAFTY!

3. If the fire can not be dealt with or extinguished, a full evacuation of the centre will follow according to the evaluation plan.

4. All staff and visitors will remain outside of the Centre in a predetermined area and await response from emergency organizations.

Response to an Area Forest/Brush Fire (Full Text)

Incident: Fire near the Joggins Fossil Centre

In the event of identification of a fire near Joggins Fossil Centre the following procedures will be applied:

Response:

1. Upon finding or having received a report of a forest or brush fire near the Centre and/or on the adjoining JFC development, the staff member will contact the Supervisor of the Day who will assess the danger to the Centre.

2. 911 is called and will be provided with any and all information available.

3. If the fire is near the Centre and is deemed dangerous, evacuation will follow according to the evaluation plan.

4. All staff members and visitors will remain outside of the Centre in a predetermined area and await response from emergency organizations

Known Injury or Illness on Site (Full Text)

Incident:

In the event that staff is made aware of an individual or individuals who are injured of ill, the following procedures will be applied:

Response:

1. If a staff member finds or informed of an injured person. A preliminary medical assessment is made by use of training provided by St. John Ambulance.

2. The staff member contacts the Supervisor of the Day to be advised on how to proceed.

3. If the person feels that they do not need further assistance other than what a staff member maybe able to provide, the person will be informed to seek medical attention as soon as possible and are asked to sign the *Refusal of Care Form*. If the person does not wish to sign, then the staff member signs the form and explains reason for the refusal.

4. If the incident is of a serious nature, 911 is called and services are dispatched.

5. The task is handed over to the emergency service first to arrive. (EHS, JVFD, RCMP)

6. All appropriate documentation will be completed and a debriefing will be conducted with all staff members involved. The parties involved will also be contacted for information gathering purposes.

Response to Missing Persons (Full Text)

Incident:

In the event that staff are made aware of an individual or individuals who can not be accounted for the following procedures will be applied:

Response:

1. The Supervisor of the Day will use the Emergency Code System to advise the staff of the potential situation. All those not engaged with a visitor, are to contact the Administrative Assistant and will inform him or her of their availability and will await instructions.

2. The Administrative Assistant will begin the *911 Check List for Missing Persons* using all available information provided to him or her over the radio system.

3. The Supervisor of the Day will organize internal resources necessary for the search.

4. All available staff is to perform a brief sweep of the area where the person was last seen (if not affected by tidal waters) and report their findings back to command centre.

5. Working with the individual who reported the missing person from their party, the Administrative Assistant will complete the *911 Check List for Missing Persons.*

6. If the person(s) are found and a safe recovery is possible, the Supervisor of the Day will determine a plan of action and co-ordinate staff.

7. If safe recovery is not possible a call to 911 will be made.

8. If the missing person is not found within ten (10) minutes a call to 911 will be made.

8. Staff will assist first responders if necessary.

9. All appropriate documentation will be completed and a debriefing will be conducted with all staff members involved. The parties involved will also be contacted for information gathering purposes.

Response to Hazardous Material or Item (Full Text)

Incident:

In the event of identification of a Biological, Chemical and or Toxic Agent hazard the following procedures will be applied:

Response:

1. A dead animal, bird, marine creature or suspicious agent is found by staff member (beach monitor, interpreter, visitor service worker etc.) or by a visitor and is reported, identification of the hazard is made by a cursory inspection which will be done through staff training provided by the RCMP and the Nova Scotia Department of Natural Resources.

2. That staff member notifies the supervisor of the day and the area is immediately isolated from the public.

3. All staff are notified of a hazard by use of the Emergency Code System. All staff members, not engaged with a visitor, will contact the Supervisor of the Day and inform him or her of their availability and wait for instructions. The Supervisor of the Day becomes incident commander at that time and coordinates staff and resources.

4. If it is a biological hazard (dead land animals, birds etc.) the Nova Scotia Department of Natural Resources is called and the Centre awaits instruction. If it is a marine animal, then the Nova Scotia Department of Oceans and Fisheries are contacted.

5. If other hazards are found, 911 is called and the staff await response by the appropriate emergency organizations who in turn may call out other emergency organization as warranted. The first responder to the site will become incident commander.

12) Forms

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Section E

Reponses to Non-visitor Related Emergency Situations

Non-Visitor Related Emergency Procedures

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13) Building/Utilities - Water

Incident: Roof leak, water line break etc.

In the event of an excess of water within the Centre, the following procedures will be applied:

Response:

1. Upon discovery of an excess of water, contact the Supervisor of the Day and the Maintenance Manger.

2. The Supervisor of the Day working with the Maintenance Manger will determine if there is a potential danger from the electrical hazards or structural damage.

3. The area will be secured with hazard tape and appropriate "warning signage."

4. If there is or might be an electrical hazard, shut off power if it is safe to do so. If it is not safe, or if there is any doubt, contact the power utility company to have the power shut off.

5. If there is a danger due to structural damage, follow the instructions located in the *Structural Damage, Collapse*.

6. If there is no danger due to structural damage, identify source(s) of water and stop or channel the flow by shutting off valves, catching the leak, or otherwise directing it.

7. Minimize damage by moving or covering exhibits, office equipment and or other Centre equipment.

8. Recovery of damaged exhibits, office equipment and or other Centre equipment will be coordinated through CREDA, the JFI, the Scientific Advisory Group and the designated insurance provider.

9. Complete *Joggins Fossil Centre Incident Review Form.*

13) Building/Utilities - Structural Damage, Collapse

Incident: Damage to the Centre's structure through wind, water, ice, snow, fire or man-made intervention.

In the event of structural damage within the Centre, the following procedures will be applied:

Response:

1. Upon discovery of some form of structural damage, contact the Supervisor of the Day and the Maintenance Manger.

2. The area will be evacuated and secured with hazard tape and appropriate "warning signage."

3. In the event of extensive damage, call the Joggins Volunteer Fire Department.

4. If injury has occurred, provide first aid and call 911.

5. Advise CREDA, the JFI, the Scientific Advisory Group and the designated insurance provider.

6. Complete the *Joggins Fossil Centre Incident Review Form.*

Note:

- Do not re-enter extensive damaged areas or building without permission of the concerned authorities. (RCMP, Fire Department, CREDA, JFI etc.)
- Do not remove exhibit material without the permission of CREDA, the JFI, Scientific Advisory Group unless some delay would cause further damage or loss.

13) Building/Utilities – Heating, Ventilation, Air-Conditioning Failure

Incident: Loss of heat, ventilation in the lab and or air-conditioning throughout the Centre.

In the event of Loss of heat, ventilation in the lab and or air-conditioning throughout the Centre, the following procedures will be applied:

Response:

1. Contact the Supervisor of the Day and the Maintenance Manger.

2. Contact systems repair company.
   Heating system: ______________________ Number: ____________________
   Ventilation System: ___________________ Number: ____________________
   Air-Conditioning:______________________ Number: ____________________

3. Try to determine how long the failure is likely to last.

4. Contact CREDA, the JFI and the Scientific Advisory Group to be advised.

5. Contact designated insurance provider if any of these situations causes damage.

6. Limit opening doors to retain residual heat.

7. Alternative heat sources may be used to reduce heat loss. Caution should be used as the fumes from some heaters (such as kerosene) may be toxic without proper ventilation.

8. Complete *Joggins Fossil Centre Incident Review Form.*

Note:

- Freezing conditions can cause damage to pipes and other waterlines. Discuss draining these with the Maintenance Manger.
- Exhibits that are more adversely affected by rapid changes in humidity and temperature should be warmed slowly. This should be discussed with CREDA, the JFI and the Scientific Advisory Group.

13) Building/Utilities – Loss of Power

Incident: Loss of power in sections or throughout the Centre.

In the event of loss of power, the following procedures will be applied:

Response:

1. Contact the Supervisor of the Day and the Maintenance Manger.

2. Evacuate visitors from affected areas or the entire Centre if necessary.

3. Ensure that all security, fire protection and detection systems have switched to battery power.

4. Contact power utility to inform them of the situation.

5. Try to determine how long the failure will last.

6. Disconnect any sensitive electronic equipment.

7. Disconnect or turn off any electrical equipment.

8. Advise CREDA, the JFI, and the designated insurance provider if the situation proves to cause damage.

9. Complete *Joggins Fossil Centre Incident Review Form*.

Note:

- Do not open freezers or refrigerators.

14) Theft

Incident: Theft of an exhibit item, Centre equipment, gift shop product, food product etc.

In the event of theft, the following procedures will be applied:

Response to Break and enter:

1. Do not enter the building.

2. Call 911.

3. Contact the Supervisor of the Day and the Maintenance Manger

4. Meet the RCMP.

Response to Robbery:

1. Call 911.

2. Contact the Supervisor of the Day and the Maintenance Manger

3. Advise CREDA and the JFI.

4. Ensure the scene is not disturbed.

5. Identify witnesses. Record any suspicious activity.

6. Complete Suspect Description Form (if appropriate).

7. Meet RCMP on arrival.
    - Provide police with as many details as possible.
    - Provide police with a description of items stolen.
    - Record details and police report numbers for future reference.

8. Re-secure building as soon as police gives approval.

9. Complete *Joggins Fossil Centre Incident Review Form.*

Note:

CREDA and the JFI will ensure that:

- Police are provided with detailed descriptions, photos, estimated value of stolen items, and any other information required to assist recovery efforts.

- Ensure that police are consulted before sending out a press release.
- Ensure that police progress is checked on periodically.
- Offer to provide or recommend safe environmental storage conditions, if police recover the object(s).

Joggins Fossil Cliffs Suspect Description Form (Theft and Vandalism)

Sex: ______________________________ Age: ______________________________
Height: ____________________________ Weight: ___________________________
Hair Colour: _________________________ Eye Colour: ________________________
Distinguishing Marks: (tattoos, scars, birthmarks, beard etc.)
____
Additional Details:
____
____
____

Clothing (colour, style, distinguishing features, etc.)
Hat: ____
Jacket: ____
Shirt: ____
Pants/Skirt: ____
Shoes/Boots: ____
Jewellery (Glasses, ring, watch, earrings, piercings etc.)
____
Additional Details:
____
____
____

Accent (English, French etc.) ____
Voice (loud, soft etc.) ____
Speech (fast, slow etc.) ____
Diction (good, nasal, lisp etc.) ____
Manner (calm, emotional, vulgar etc.) ____________________________________

Did the person seam familiar? (specify) ___________________________________
Was the person familiar with the area? ___________________________________
Additional Details:
____
____
____
____

Name: ____
Date: ____

X Signature: ______________________________________

15) Vandalism

Incident: Vandalism of Centre Property.

In the event of vandalism, the following procedures will be applied:

Response:

1. If vandalism is in progress, intervene only if appropriate and safe to do so.

2. Call 911. Give them location and circumstances.

3. Contact the Supervisor of the Day and the Maintenance Manger

4. Ensure the scene is not disturbed.

5. Identify witnesses, Record any suspicious activity.

6. Complete *Joggins Fossil Cliffs Suspect Description Form*. (above)

7. Meet police on arrival.
    - Record details and police report numbers for future reference.

8. Complete *Joggins Fossil Centre Incident Review Form*.

16) Collection and Exhibit Salvage

Undamaged Items:

If part of the Centre is secure, assemble undamaged objects there and try to maintain stable conditions (particularly temperature and humidity) as similar as possible to those that existed before the incident. Use whatever material available to protect and secure the area especially from water.

If no part of the building can be secured, protect damaged and undamaged objects alike "in situ" with whatever materials are available (e.g. plastic sheeting) until secure space can be found in another building, Then move the collections as quickly as possible, giving priority to undamaged objects.

Segregation:

When secure space is available, separate the damaged objects (particularly those that have been wet) from undamaged objects – and try to maintain the status quo for both groups.

- Try to keep undamaged objects as nearly as possible in the conditions that existed before the incident and keep damaged objects as they are now. If they are dry, keep them dry. If they are wet, keep them wet.

Wet Objects:

Wet or damp objects made of organic materials other than paper:

- Spray with unscented Lysol®, if available.
- Bag or lightly wrap in plastic sheeting.
- Place in a cool, well ventilated space away from undamaged objects
- Examine them daily for mold growth.
    - If any is found, spay again with Lysol® and open the bag to allow slow air drying. Never apply heat to wet organic materials.
- If in doubt, freeze them.

Wet Books or Documents:

- Freeze as soon as possible

Wet Metal, Glass or Ceramic Objects:

- Air dry quickly
- If necessary, mop gently with clean, soft dry lint-free cloths or paper towels.
- A warm air blower, hair dryer, may be used on metals with caution.

Objects that Have Dried After Being Wet:

- Keep in a cool, well ventilated place apart from those that have not been wet.
- Although it is not necessary to bag or wrap them, inspect them daily for mold.
    - If mold is found, spray with Lysol®.
    - Remove to the "wet" storage area and threat as wet objects

Smoke Damaged, Scorched, Charred or Dirt-Caked Objects

- Handle as little as possible.
- Do not try to clean.
- If they are dry, threat as dry objects; if they are wet, threat as wet objects.

Please note that these are strictly emergency first-aid measures to be used only when a conservator is not immediately available. (A conservator should be called as soon as possible.) They do not address all the problems that will arise, but they should minimize the damage that may occur until help arrives.

17) General List of Emergency & General Equipment and Supplies

Please check off what is available:

- Industrial wet/dry vacuum cleaner - *available*
- Sump pump with long tubing - *available*
- Mobile heater - *available*
- Emergency generator (gas powered) - *available*
- Fans - *available* *number:* _____
- De-humidifiers - *available* *number:* _____
- Transport Charts - *available* *number:* _____
- Heavy duty waterproof extension cords with ground fault interrupter - *available*
- Backup FRS Radios - *available* *number:* _____
- Heavy duty dusk mask - *available* *number:* _____
- Fire blankets - *available* *number:* _____
- Ladders - *available* *number:* _____
- Backup Flashlight (waterproof with batteries) - *available* *number:* _____
- Terry towelling - *available*
- Sponges - *available*
- Mops - *available* *number:* _____
- Pails - *available* *number:* _____
- Squeegees - *available* *number:* _____
- Blotting towel - *available* *number:* _____
- Plastic garbage bins - *available* *number:* _____
- Polyethylene sheeting - *available*
- Garbage bags - *available*
- Bubble Wrap - *available*
- Twist ties - *available*
- Clothes line and clothes pins - *available*
- Oilskins and sou'westers - *available* *number:* _____ *Sizes:* _______________
- JFC jackets- *available* *number:* _____ *Sizes:* _______________

Equipment continued

- Poly-gloves - *available* *number:* _____ *Sizes:* _______________
- Cotton Gloves - *available* *number:* _____ *Sizes:* _______________
- Rubber Gloves - *available* *number:* _____ *Sizes:* _______________
- Hard Hats - *available* *number:* _____
- Rubber Boots - *available* *number:* _____ *Sizes:* _______________
- Work Gloves - *available* *number:* _____ *Sizes:* _______________
- Masking Tape (plastic type) - *available*
- Waterproof markers - *available*
- Waterproof notepads - *available*
- Scissors - *available*
- String (twine) - *available*
- China Markers - *available*
- Tags, tie-on, waterproof - *available*
- Emergency area tape - *available*
- Emergency signs - *available* *number:* _____
- Lysol® disinfectant - *available*
- Heavy duty knifes - *available*
- Paper Hygrometers - *available*
- Pallets - *available* *number:* _____

Section F

Laboratory Safety Manual

The Joggins Fossil Centre Laboratory Safety Manual

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Introduction

The intent of a laboratory safety program is to provide guidance and training to all laboratory workers who use hazardous substances or engage in potentially hazardous laboratory operations. Experience in industry has shown that the laboratory can be a safe workplace; however, this achievement was accomplished ONLY by the implementation of vigorous safety planning and training sessions.

Educational activities shall be provided for all persons who may be exposed to potential hazards in connection with laboratory operations, lab supervisors, lab workers, maintenance workers, janitorial and storeroom personnel. If other non-lab related offices are nearby, consideration should be given to providing these workers with the necessary knowledge to protect them (which might be as simple as telling them which door to use in case of an emergency). This training process shall be part of new employee indoctrination or reassignment.

Institutional safety education programs shall be regular continuous activity and not once-a-year presentations provided for groups of new students or employees. The following sections are intended as resource documents for administrative benefit.

Section 1 – General Safety and Operation Rules

A. General Rules of Safety

- No running, jumping or horseplay in laboratory areas should be permitted.
- No employees should work alone in a laboratory or chemical storage area when performing a task that is considered unusually hazardously the laboratory supervisor or safety officer.
- Spills shall be cleaned immediately. Water spills can create a hazard because of the slip potential. And flooding of instruments (particularly on the floor below.) Small spills of liquids and solids on bench tops shall be cleaned immediately to prevent contact with skin or clothing.
- Ladders shall be in good condition and used in the matter for which they were designed. Wooden ladders shall not be covered in paint or other coating. (Structural defects may be hidden by the coating.)
- Lifting of heavy objects must be performed in the proper fashion, using the legs to lift, not the back.
- It is the responsibility of everyone working in the laboratory to make certain the laboratory is left clean after work is performed.
- Admittance to the non-staff members to the lab area is to be limited to visiting professionals or very special circumstances. The visitors are to be made aware that they are entering an area of increased hazard risk, and are not to be left unsupervised or to handle any equipment or materials. Any unacceptable behaviour will lead to removal from the lab area.

B. Personal Hygiene

- Wash promptly whenever a chemical has contacted the skin. Know what you are working with and have the necessary cleaning/neutralizing material on hand and readily available.
- No sandals, open toed shoes or clogs shall be worn by laboratory personnel.
- Clothing worn in the laboratory should offer protection from splashes and spills, should be easily removable in case of accident, and should be at least fire resistant. Lab jackets or coats should have snap fasteners rather than buttons so that they can be readily removed. These coats are to be fastened closed while working and removed prior to exit from the laboratory.
- Laboratory clothes should be kept clean and replaced when necessary. Clothing should be replaced or laundered using appropriate decontamination procedure whenever contamination is suspected.
- Lab coats are not to be worn outside the laboratory, especially in rest room or break facilities. Any lab coats, respirators, or other protective gear must be left in the lab areas. Employees must, as a matter of routine, be responsible for washing, cleaning, and any other decontamination required when passing between the lab and the other areas. Washing should be done with soap and water; do not wash with solvent.

- Inhalation is one of the four modes of entry for chemical exposure. “Sniff-testing” should not be done.
- Never pipette by mouth. Always use a bulb to pipette.
- Do not drink, eat, smoke or apply cosmetics in the laboratory or chemical storage areas.
- No food, beverage, tobacco, or cosmetics products are allowed in the laboratory or chemical storage areas at any time. Cross contamination between these items and chemicals or samples is an obvious hazard and should be avoided.

C. Housekeeping

As in many general safety procedures, the following listings of good housekeeping practices indicate common sense activities which should be implemented as a matter of course in the laboratory. These recommendations are designed for accident prevention.

- THE AREA MUST BE KEPT AS CLEAN AS THE WORK ALLOWS.
- Each laboratory employee shall be responsible for maintaining the cleanliness of his/her area.
- Reagents and equipment items should be returned to their proper place after use. This also applies to samples in progress. Contaminated or dirty glassware should be placed in specific cleaning areas and not allowed to accumulate.
- Chemicals, especially liquids, should never be stored on the floor, except in closed door cabinets suitable for the material to be stored. Nor should large bottles (2,5L or larger) be stored above the bench top.
- Reagents, solutions, glassware. Or other apparatus shall not be in hoods. Besides reducing the available work space, they may interfere with the proper air flow pattern and reduce the effectiveness of the hood as a safety device.
- Counter tops should be kept neat and clean. Bench tops and fume hoods shall not be used for chemical storage.
- Stored items, equipment, and glass tubing shall not project beyond the front of shelf or counter limits.
- Stored items or equipment shall not block access to fire extinguisher(s), safety equipment, or other emergency items.
- Stairways, hallways, passageways/aisles and access to emergency equipment and/or exits must be kept dry and not be obstructed in any fashion, including storage, equipment, phone or other wiring.
- No combustible material such as paper, wooden boxes, palettes, etc., shall be stored under stairwells or in hallways. Hallways shall be kept free of boxes and materials so that exits or normal paths of travel will not be blocked.
- Materials stored by aisles shall be restrained to prevent their falling.
- Mats and carpeting shall be kept in good condition.
- All working surfaces and floors should be cleaned regularly.

- All containers must be labelled with at least the identity of the contents and the hazards those chemicals present to users. If the contents of all containers are known we will no longer have an unknown waste disposal problem.

D. Electrical

The typical laboratory requires a large quantity of electrical power. This increases the likelihood of electrically-related problems and hazards. One must address both the electrical shock hazard to the facility occupants and the fire hazard potential. The following recommendations are basic to a sound electrical safety program in the laboratory.

- All electrical equipment shall be properly grounded.
- All electrical equipment shall be C.S.A approved.
- Sufficient room for work must be present in the area of breaker boxes. All the circuit breakers and the fuses shall be labelled to indicate whether they are in the "on" or "off" position, and what appliance or room area is served. . Fuses must be properly rated.
- Equipment, appliance and extension cords shall be in good condition.
- Extension cords shall not be used as a substitute for permanent wiring.
- Electrical cords or other lines shall not be suspended unsupported across rooms or passageways. Do not route cords over metal objects such as emergency showers, overhead pipes or frames, metal racks, etc. Do not run cords through holes in walls or ceilings, doorways or windows. DO not place under carpets, rugs, or heavy objects. Do not place cords on pathways or other areas where repeated abuse can cause deterioration of insulation.
- Multi-outlet plugs shall not be used unless they have a built in circuit breaker. This causes overloading on electrical wiring, which will cause damage and possible overheating.
- Most of the portable multiple outlets are rated at 15 amps. Employees shall check when all connections are made, to determine that the total input average will never exceed 15 amps. (The amperage on electrical equipment is usually stamped on the manufacturer's plate.)
- All building electrical repairs, splices and wiring shall be performed by licensed Electricians.

E. Vacuum Operations

In an evacuated system, the higher pressure is on the outside, rather than the inside, so that a break causes an implosion rather than an explosion. The resulting hazard consist of flying glass, spattered chemicals, and possibly fire.

A moderate vacuum, such as 10 mm Hg, which can be achieved by a water aspirator, often seems safe compared with a high vacuum, such as 10-5 mm Hg. These numbers are deceptive, however, because the pressure differences between the outside and inside are comparable. Therefore any evacuated container must be regarded as an implosion hazard.

- When working with a vacuum be aware of implosion hazards. Apply vacuum only to glassware specifically designed for this purpose, i.e., heavy wall filter flasks, desiccators, etc.
- Never evacuate scratched, cracked, or etched glassware. Always check for stars or cracks before use.
- Vacuum glassware which has been cooled to liquid nitrogen temperature or below should be annealed prior to reuse under vacuum.
- When a vacuum is supplied by a compressor or vacuum pump to distil volatile solvents, a cold trap should be used to contain solvent vapours. Cold traps should be of sufficient size and low enough temperatures to collect all condensable vapours present in a vacuum system. If such a trap is not used, the pump or compression exhaust must be vented to the outside using explosion proof methods.
- After completion of an operation in which a cold trap has been used the system should be vented. This venting is important because volatile substances that have been collected in a trap may vaporize when the coolant has evaporated and cause a pressure build-up that could blow the apparatus apart.
- After vacuum distillations, the pot residue must be cooled to room temperature before air is admitted to the apparatus.

F. Handling Glassware

- Glass breakage is a common cause of injuries in laboratories. Only glass in good condition should be used.
- Discard or send for repair all broken, chipped, starred or badly scratched glassware. Hand protection should be used when picking up broken glass.
- Clean all glassware before sending for repair.
- When using glass tubing, all ends should be fire polished. Lubricate tubing with glycerine or water before inserting into rubber stoppers or rubber tubing.
- Do not store glassware near the edge of shelves. Store large or heavier glassware on lower shelves.
- Use glassware of the proper size. Allow at least 20% free space. Grasp a three neck flask by the middle neck, not a side neck.
- Do not attempt to catch glassware if it is dropped or knocked over.
- Conventional laboratory glassware must never be pressured.

Section 2 – General Safety Equipment

Workers in a laboratory environment are surrounded by physical and chemical hazards, and the potential for accident and injury is always present. Adequate safety equipment in good working order shall be provided to prevent accident and injury.

A. Fire Extinguishers

- _________________________________ is responsible for the procurement, placement, inspection, and maintenance of all fire extinguishers at the museum.
- Laboratory personnel should be adequately trained regarding pertinent fire hazards associated with their work.
- Fire extinguishers must be clearly labelled to indicate the types of fire they are designed to extinguish. The following codes are presented in NFPA 10 "Portable Fire Extinguishers" are:
    - Class A- Fires in ordinary combustible materials such as wood, cloth, paper rubber and many plastics.
    - Class B- fires in flammable liquids, oils, greases, tars, oil-base paints, lacquers and flammable gases.
    - Class C- fires that involve energized electrical equipment where the electrical conductivity of the extinguishing medium is of importance; when electrical equipment is de-energized, extinguishers for class A or B can be safely used.
    - Class D- Fires of combustible metals such as magnesium, titanium, zirconium, sodium, lithium and potassium.
- Fire extinguishers of the "Halon" type are specifically designed so they leave no residue that could damage instruments or computers. (However, the area should be thoroughly ventilated before being reoccupied,)
- Fire extinguishers should never be concealed from normal view or blocked from access.
- Once a fire extinguisher has been installed, _________________________will Inspect and maintain the device.
- If an employee notices a fire extinguisher discharged or not fully charged, an extinguisher with the pin pulled out, an extinguisher obstructed from view, or not hanging in its proper location, please notify your supervisor and make sure that ______________________________is notified.

B. Safety Showers

If all protective measures fail and an employee receives a chemical splash to their body, then safety showers should be provided throughout the laboratory for immediate and thorough washing of the body.

- Employees should familiarize themselves with the location of the nearest safety shower.

- Employees should be familiar with the operation of the safety showers. Safety showers are designed to flood the entire body in the event of a clothing fire or a major spill of a chemical. In either case, an employee should simply stand under the shower and activate the shower. Flood the affected area for a minimum of 15 to 30 minutes.
- In the case of a corrosive liquid spill, the employee should remove the affected portion of clothing to reduce potential contact. Removal of clothing should be done while the individual is under the activated shower.
- The direct supervisor and the OHS committee are to be notified if an employee required the use of the safety shower.
- Safety showers are tested annually by the lab manager.

C. Eyewash Fountains

If all protective measures fail and an employee a chemical splash to their eyes, then eye wash fountains should be provided throughout the laboratory for immediate and thorough washing of eyes.

- Employees should familiarize themselves with the location and operation of the nearest eyewash fountain. Note: Contact lenses are not to be worn in the lab area.
- Always flood eyes for at least 15 to 30 minutes to be sure there is no residue of the corrosive liquid. Flush from eye outward.
- After thorough washing, the proper authorities must be notified and subsequent medical care for the employee should be seriously considered. This is because serious damage may have already occurred before the eye was thoroughly rinsed and/or the damage may not be immediately apparent.
- Eyewash fountains should be tested weekly by laboratories for proper operation and to prevent formation of bacteria.
- Eyewash fountains are checked annually, by the lab manager, for proper location and operational status.

D. First Aid Kits

First aid kits, which should be located in conspicuous places (with location clearly marked) in the laboratory, are to be used for the immediate response to minor injuries, such as cuts or burns. All injury victims have the option of obtaining medical treatment or consultation.

- Minor injuries requiring first aid shall always be reported to a supervisor.
  - A minor injury may indicate a hazardous situation which should be corrected to prevent a more serious injury.
  - It is important to document a minor injury as having been “work related” for the purpose of obtaining Worker’s Compensation, should the injury lead to later, more serious, complications.
  -

- The location and phone number of emergency services and Poison Control Center (1-800-565-8161) should be clearly posted.
- A designated party should be responsible for monitoring and maintaining the first aid kit(s). There should be a log attached to the kit indicating the last inspection date and by whom the kit was inspected by.
- First aid kit contents should include items such as Band-aids®, sterile gauze pads, bandages, scissors, antiseptic wipes or ointments. All kits should also contain examination gloves for response to emergencies in which blood is present. Pocket masks for CPR procedures are also recommended.
- The following items are not recommended for use in first aid kit.
    - Iodine – Tissue damage can be caused by improper use.
    - Ammonia Inhalants – If an individual is unconscious, obtain help – do not use ammonia.
    - Tourniquet – Not required for minor injuries; use the pressure technique until assistance is available.
- Laboratories where high voltage equipment is in use should have available an emergency electrical response board. This will contain an instruction card and a non conductive stick to turn off the equipment and remove the shock victim from contact with the source.

E. Ventilation Hoods

Work that involves hazards and noxious materials which are toxic, odoriferous, volatile or harmful shall be conducted within a laboratory hood.

The primary purpose of a laboratory hood is to keep toxic or irritating vapours and fumes out of the general laboratory working area. A secondary purpose is to serve as a shield between the worker and equipment being used when there is the possibility of an explosive reaction. This is done by lowering the sash of the hood.

- Hood ventilation systems are best designed to have an airflow of not less than 60 ft/min.[linear] and not more than 120 ft/min [linear] across the face of the hood. Flow rates of higher than 125ft\min can cause turbulence problems and are not recommended. If possible, a mark will have been placed on the hood so the sash can be drawn to a point where 100 linear ft/min can be achieved.
- Avoid creation of strong cross drafts (100fpm) caused by open doors and windows, air conditioning and/or heating vents, or personnel movement. Drafts will pull contaminants from the hood and into the lab.
- DO NOT ADJUST BAFFLES unless you have been instructed to do so by your departmental CHO. Do not remove baffles. If ventilation problems develop, contact the maintenance department.
- When not in use, the sash of the hood should be kept closed. While performing work in the hood, the sliding sash should be kept at the height designated to provide the minimum face velocity required (usually 100 Ifm).

This will ensure maximum velocity of air flow into the hood and out of the laboratory.

- Work should be performed as deeply within the fumr hood as possible. Equipment, reagents, and glassware should be placed as far back in the hood as is practical without blocking the rear baffle. Solid objects place at the face of the hood cause turbulence in the air flow.
- ONLY ITEMS NESSECARY TO PERFORM THE PRESENT EXPIEREMENT SHOULD BE IN THE HOOD. The more equipment in the hood, the greater the air turbulence and the chance for gaseous escape into the lab.
- When instrumentation is utilized for a process inside a hood, all instruments should be elevated a minimum of two inches from the hood base to facilitate proper air movement.
- The purpose and function of a hood is NOT to store chemicals or unused Items. The fume hood is not a storage cabinet.
- Hoods shall not be used as a means of disposing of toxic or irritating Chemicals, but only as a means of removing small quantities of vapour which might escape during laboratory operations. If vaporization of large quantities of such materials is a necessary part of the operation, a means of collecting the vapour by distillation or scrubbing should be considered, rather than allowing it to escape through the hood vent. The collected liquid can be disposed of as a liquid waste.
- Some hoods are constructed of stainless steel. These are usually “perchloric acid hoods” or “radioisotope hoods.” Never use perchloric acid in a hood not designed for that use. Perchloric acid hoods have a wash down feature which should be used after each use of the hood and at least every two weeks when the hood is not in use. Date of wash down should be recorded by the laboratory.
- Always look to assure fan motor power switch is in the “on” position before initiating experiment. Note: Some hoods do not have individual “on/off” switches and remain “on” continuously.
- Do not use infectious material in a chemical fume hood.
- Exhaust fans should be spark-proof if exhausting flammable vapours and corrosive resistant if handling corrosive fumes.
- Controls for all services (i.e., vacuum, gas, electric, water) should be located at the front of the hood and should be operable when the hood door is closed.
- An emergency plan should be prepared in the event of ventilation failure or other unexpected occurrence such as fire or explosion in the hood.
- ALWAYS ASSURE THE HOOD IS OPERATIONAL BEFORE INITIATING AN EXPERIMENT.

F. Flammable-Liquid Storage Cabinets

Cabinets designed for the storage of flammable liquids should be properly used and maintained. Read and follow the manufacturer’s information and also follow these safety practices:

- Store only compatible materials inside a cabinet.
- Do not store paper or cardboard or other combustible packaging in a flammable liquid cabinet.
- The manufacturer establishes quantity limits for various sizes of flammable-liquid storage cabinets; do not overload a cabinet.

G. Safety Shields

Safety shields should be used for protection against possible explosions, implosions or splash hazards. Laboratory equipment should be shielded on all sides so that there is no line-of-site exposure of personnel. Provided its opening is covered by closed doors, the conventional laboratory exhaust hood is readily available built-in shield. However, a portable shield should also be used when manipulation are performed, particularly with hoods that have vertical-rising doors rather than horizontal-sliding sashes.

Portable shields can be used to protect against hazards of limited severity, e.g., small splashes, heat, and fires. A portable shield, however, provides no protection at the sides or back of the equipment and many such shields are not sufficiently weighted and may topple toward the worker when there is a blast (permitting exposure to flying objects.) A fixed shield that completely surrounds the experimental apparatus can afford protection against minor blast damage.

Section 3 – Personal Protective Equipment

A. Eye Protection

Eye protection is mandatory in all areas where there is potential for injury. This applies not only to persons who work continuously in these areas, but also to persons who work continuously in these areas, but also to persons who may be in the area only temporarily, such as maintenance or clerical personnel. All eye protective equipment shall comply with the requirements set fourth in the American National Standard for Occupational and Educational Eye and Face Protection, Z 87.1-1968, and the Oklahoma Eyeglass Protection Law of 1916.

The type of eye protection required depends on the hazard. For most situations, safety glasses with side shields are adequate. Where there is a danger of splashing chemicals, goggles are required. More hazardous operations include conducting reactions which have potential for explosion and using or mixing strong caustics or acids. In these situations, a face shield or a combination of face shield or a combination of face shield and safety goggles or glasses should be used.

- Plastic safety glasses should be issued to employees who do not require corrective lenses.
- For persons requiring corrective lenses, safety glasses ground to their prescription are available in a safety frame. Please note that the wearing of safety glasses does not excuse the employee from the requirement of wearing safety goggles.
- It is recommended that contact lenses not be permitted in the laboratory. The reasons for this prohibition are is if a corrosive liquid should splash in the eye, the natural reflex to clamp the eyelids shut makes it very difficult, if not impossible, to remove the contact lens before damage is done.
- The plastic used in contact lenses is permeable to some of the vapours found in the laboratory. These vapours can be trapped behind the lenses and can cause extensive irritation.
- The lenses can prevent tears from removing the irritant.
- Although safety glasses are adequate protection for the majority of laboratory operations, they are not sufficient for certain specific operations where there is danger from splashes of corrosive liquids or flying particles. Examples are: washing glassware in chromic acid solution, grinding materials, or laboratory operations using glassware where there is significant hazard of explosion or breakage (i.e., in reduced or excess pressure or temperature). In such cases, goggles or face shields shall be worn if there is need for protection of the entire face and throat.
- If, despite all precautions, an employee should experience a splash of Corrosive liquid in the eye, the employee is to proceed (with the assistance of a co-worker, if possible) to the nearest eyewash fountain and flush the eyes with water for at least 15 to 30 minutes. Flush from the eye outward. During this time, a co-worker should notify the proper authorities.

- Visitors shall follow the same eye protection policies as employees. If they do not provide their own eye protection, it is the laboratory's responsibility to provide adequate protection. It should be the responsibility of the employee conducting the tour to enforce this policy. After use safety glasses/goggles used by visitors should be cleaned prior to reuse.

B. Clothing

THE FOLLOWING GUIDELINES FOR LABORATORY CLOTHING ARE OFFERED STRICTLY FROM A SAFETY STANDPOINT.

- Due to the potential for ignition, absorption, and entanglement in machinery, loose or torn clothing should be avoided unless wearing a lab coat.
- Dangling jewellery and excessively long hair pose the same type of safety hazard.
- Finger rings or other tight jewellery which is not easily removed should be avoided because of the danger of corrosive or irritating liquids getting underneath the piece and producing irritation.
- Lab coats should be provided for protection and convenience. They should be worn at all times in the lab areas. Due to the possible absorption or accumulation of chemicals in the material, lab coats should not be worn in the lunchroom or else where outside the laboratory.
- Shoes shall be worn at all times in the laboratories. Sandals, open-toed shoes, and shoes with woven upper, shall not be worn because of the danger of spillage of corrosive or irritating chemicals.
- Care should be exercised in protective clothing selection; some protective clothing has very limited resistance to selected chemicals or fire.
- Consult the MSDS for a chemical to find out the recommended clothing or PPE for a particular chemical. (Examples are latex, nitrile, or PVC gloves, or aprons.)

C. Aprons – Rubber or Plastic

Some operations in the laboratory, like washing glassware, require the handling of relatively large quantities of corrosive liquids in open containers. To protect clothing in such operations, plastic or rubber aprons may be supplied. A high-necked, calf or ankle-length, rubberized laboratory apron, or a long sleeved calf or ankle-length, chemical and fire resistant laboratory coat should be worn anytime laboratory manipulation or experimentation is being conducted. Always wear long sleeved and long legged clothing; do not wear short sleeve shirts, short trousers or short skirts.

D. Gloves

When handling chemicals, it's recommended that the correct gloves be used to protect the worker from accidental spills or contamination. If the gloves become contaminated they should be removed and discarded as soon as possible. There is no glove currently available that will protect a worker against all chemicals.

- Protection of hands while working with solvents, detergents, or any hazardous material is essential in the defence of the body against contamination. Exposure of the hands to a potentially hazardous chemical could result in burns, chafing of the skin do to extraction of essential oils ("De-fatting"), or dermatitis. The skin could also become sensitized to the chemical and once sensitized, could react to lesser quantities of chemicals than other wise would have any effect. It is well documented that primary skin irritations and sensitizations account for significantly greater numbers of lost time incidents on the job than any other single type of industrial injury.
- Proper selection of the glove material is essential to the performance of the glove as a barrier to chemicals. Several properties of both the glove material and the chemical wit which it is to be used should influence the choice of the glove. Some of these properties include: Permeability of the glove material, break through time of the chemical, temperature of the chemical, thickness of the glove material, and the amount of the chemical that can be absorbed by the glove material (solubility effect). Glove materials very widely in respect to these properties; for instance, neoprene, is good for protection against most common oils, aliphatic hydrocarbons, and certain other solvents, but is unsatisfactory for use against aromatic hydrocarbons, halogenated hydrocarbons, ketones, and many other solvents.
- Gloves of various types are available and should be chosen for each specific job for compatibility and breakthrough characteristics. An excellent source of information is Guide lines for the Selection of Chemical Protective Clothing. Published by the American Conference of Governmental Industrial Hygienists (ACGIH) or information provided by glove manufactures.
  - Selection - For concentrated acids and alkalis, and organic solvents, natural rubber, neoprene, or nitrili gloves are recommended. For handling hot objects, gloves made of heat-resistant materials (Leather or Nomex) should be available and kept near the vicinity of ovens or muffle furnaces. A hot object should never be picked up with rubber or plastic gloves. Special insulated gloves should be worn when handling very cold objects such as liquid N2 or CO2. Do not use asbestos containing gloves.
  - Inspection - Before each use, gloves should be inspected for discoloration, punctures and tears. Rubber and plastic gloves may be checked by inflating with air and submersing them in water to check for air bubbles.
  - Usage - Gloves should always be rinsed with compatible solvent, soap and water prior to handling. Wash bottles or other laboratory fixtures.
  - Cleaning - Before removal, gloves should be thoroughly washed, either with tap water or soap and water.
  - Removal - Employees shall remove gloves before leaving the immediate work site to prevent contamination of door knobs, light

switches, telephones, etc. When gloves are removed, pull the cuff over the hand.

E. Respirators

Respirator use should be avoided if at all possible (and is usually not required if adequate precautions are taken). Where possible, engineering controls (fume hoods, etc.) should be utilized to minimize exposure. If respirators are worn because OSHAPELs are being exceeded or other reasons, a respirator program must be established in accordance with OSHA 29 CFR 1910.134. Your Department Chemical Hygiene Officer should be consulted for additional information in guidance.

Section 4 – Safety Practices for Disposal of Broken Glass

Inspect all glassware before use. Do not use broken, chipped, starred or badly scratched glassware. If it cannot be repaired, discard it in containers specifically designated for broken glass. All broken glass requires special handling and disposal procedure to prevent injury not only to lab personnel, but members of the janitorial staff as well.

All broken glass shall be disposed in rigid, puncture proof containers such as a cardboard box with taped seams, or a plastic bucket or metal can with sealing lid. All broken glass disposal containers shall be clearly marked “DANGER – BROKEN GLASS”. Limit quantities to no more than approximately 15 to 20 pounds so that lifting of the container will not create a situation that could cause back injury.

- Food, beverage, and uncontaminated glassware: Disposed in a rigid, puncture proof container such as a box with sealed or taped edges or a metal or thick plastic can or bucket with a sealing lid. Label container “DANGER – BROKEN GLASS”.
- Glassware with biological contamination: Glassware that has been in contact with infectious agents may include: Used slides, cover slips, test tubes, beakers, pipettes, etc. Contaminated glassware shall be disinfected before disposal. Disposal in a rigid, puncture proof container such as a box with sealed or taped edges or a metal or thick plastic can or bucket with a sealing lid. Label container “DANGER – BROKEN GLASS”.
- Glassware with chemical contamination: Empty the contents of the glassware into a suitable container if safe to do so.

Section 5 – Chemical Safety

Working with potentially hazardous chemicals is an everyday occurrence in a laboratory setting. Hazardous situations can occur if employees are not educated in general chemical safety, toxicological information, and procedure for handling and storage for the chemicals they are using. This section of the laboratory manual addresses these educational components and spells out specific protocols to minimize hazardous chemical exposures.

A. Modes of Entry

There are four major modes of entry to chemicals: Inhalation, skin absorption, injection, and ingestion. Inhalation and skin absorption are the predominant occupational exposures you may inspect to encounter in the laboratory and will be discussed in some detail. Accidental injection of chemicals can be eliminated by good laboratory safety practices. Accidental ingestion of chemicals can be eliminated by a combination of good laboratory and hygienic practices such as washing hands and prohibiting foods, drinks, cosmetics and tobacco products in the laboratory work place. All potential exposures, i.e., inhalation, skin absorption, injection, and ingestion, are discussed in the Material safety Data Sheets available for each chemical or product. The hundreds of chemicals which employees are routinely exposed to during the course of their work in the laboratory can be divided into three main types: volatile solvents, corrosives, and toxic solids. The particular hazards associated with exposure to these materials, and ways to avoid them, are discussed in detail below.

B. Basic Chemical Classifications

Volatile Solvents

Organic solvents are perhaps the most ubiquitous chemicals found in the laboratory setting. The potential chronic health effects of some of these materials warrant special attention as one is likely to be exposed to more solvents than any other type of chemical. For safety purposes, these chemicals are generally subdivided into two categories: chlorinated and non-chlorinated. This is done mainly because the chlorinated solvents are, in general, not flammable while non-chlorinated solvents do decompose when burned. This results in high concentrations of toxic vapours, such as phosgene and hydrogen chloride.

Keeping in mind the difference in flammability between these two classes of solvents, we can discuss the health effects common to both classes. The primary route of exposure to these materials is through inhalation. In general, high concentrations of the vapour, when inhaled, produce drowsiness, dizziness, and headaches. This can occur quite quickly, since chemical vapours are rapidly absorbed. Most of the solvents will also act as upper respiration and/or eye irritants. One physical property common to most solvents is odour. Unfortunately, the odour of a solvent offers little in the way of determining whether or not the environment is immediately hazardous. Solvent odour thresholds vary widely and acclimation or odour fatigue is often rapid. Odour is also not generally indicative of the degree of hazard that the material presents. Butyl mercaptan has such an extremely disagreeable odour that one cannot tolerate a concentration necessary to be injurious. Chloroform, however, has a sweet odour to many people and tolerance levels can far exceed safe levels.

Chronic effects of solvent exposure vary widely. Of most concern is the potential for lung, liver, and kidney damage posed by some solvents. This, in general, applies to solvents which are not water soluble. Examples of these solvents would be benzene, toluene, xylene, chloroform, carbon tetrachloride, and trichloroethylene. Instances of chronic disease caused by occupational exposure to these solvents have been documented. However, it must be kept in mind that everyone reacts differently and individual susceptibilities are quite variable.

Skin absorption is an additional mode of entry for which an exposure to a solvent may occur. Most commonly, solvents act to de-fat the skin. This will cause drying and cracking of the skin, and may lead to chronic dermatitis with prolonged and repeated exposure. Some solvents can also act as corrosives. Most amines and phenols act in this manner.

In addition, many of the solvents (dimet, sulfoxide dimethyl formamide, for example) will penetrate the skin and be absorbed into the body; in this case the effects of exposure will be analogous to inhalation exposure. Carbon disulfide , n-butyl alcohol, and phenol, are common solvents which can penetrate intact skin. For those solvents, there will be a notation of skin exposure noted on the Material Safety Data Sheet. Most skin contact with solvents can be avoided by wearing gloves suitable for that chemical. It is important that the glove be resistant to the material being handled. Using the wrong glove can give a false sense of security and over exposure via the skin may result. If a solvent penetrates the glove, a prolonged contact will result do to a slowed evaporation rates. Rubber and neoprene gloves can be classed as good general purpose gloves, but a chemical resistance cghart in the MSDS should always be consulted.

Direct liquid contact by solvents in the eyes can be very serious. The victim could easily panic. Get them to the eye wash immediately and flush the eyes for at least 15 to 30 minutes. Medical assistance should also be summoned.

In summary, volatile solvents can pose inhalation, skin, and ingestion hazards. Some of the solvents may also be flammable, which could cause fire and/or explosion hazards. Whenever possible, use volatile solvents in a properly operating fume hood to eliminate inhalation hazards. Use correct skin and eye protection and use good laboratory and hygienic technique to eliminate any possible ingestion of volatile solvents.

Acids and Bases

Common to all acids and bases is their corrosive action on human tissue. Minor exposures are generally reversible, although often painful for a short period of time. The reversibility of the effects of acid and base exposure will depend on 3 factors: the duration of exposure, concentration of material, and the first aid methods used.

Exposure can occur through skin absorption or inhalation. With inhalation exposure, remove the victim form the area (Try to keep the victim from breathing to deeply, as this may accelerate the effects) and summon medical help.

Skin contact is the most common route of exposure. Here the concentration and type of acid are the most important factors. In concentrated forms, all types of corrosives may cause severe penetrating burns. Dilute solutions do not have the same warning properties as concentrated forms, so guard against exposure. One should be particularly careful with hydrofluoric acid (See Section 1.2 – 3).

Neoprene gloves provide the best protection from skin exposures to both acids and bases, but in all cases, follow the recommendations in the MSDS. When using or dispensing concentrated acids or bases, a lab coat or apron and a full face shield is required (See Section 1.3- "Personal Protective Equipment").

If there is skin or eye contact with acids or bases, make sure to flush the area with water for 15 to 30 minutes and summon medical assistance.

Toxic Solids

Many of the chemicals used in the laboratory that are solid and toxic are used in solution, so skin absorption can be of concern. This is particularly true when a substance is dissolved in a solvent which can penetrate the skin. Also, an oxidizing material dissolved in water can act directly on the skin causing irritation where the solid alone would be relatively less irritating. It is therefore important that proper personal protective equipment be worn (see Section 1.3 – "Personal Protective Equipment").

In the solid form, the greatest risk of exposure is through inhalation. This risk can be lessened by wearing the appropriate respirator and/or working in a fume hood.

C. Incompatible Chemicals

Certain hazardous chemicals cannot be mixed or stored safely with other chemicals due to potentially severe or extremely toxic reactions taking place. For example, keep oxidizing agents separated from reducing agents separated from reducing agents, initiators separated from monomers, and acids separated from alkalis, etc.

The chemical lab and Material Safety Data Sheet will contain information on incompatibilities.

A list of incompatible chemicals is included in Lab Safety Appendix.

Chemical Stability

Stability refers to the susceptibility of the chemical to decomposition. Ethers, liquids paraffin's, and olefins can form peroxides on exposure to air and light. Since these chemicals are packaged in an air atmosphere, peroxides can form even though the containers have remained sealed. Some inorganic chemicals are also unstable.

Unless inhibitor was added by the manufacturer, closed containers of ethers shall be discarded after one year. See section 2.2 – "Chemical Waste" for disposal procedures. Appropriate use of peroxide inhibitors is suggested.

Examples of potential peroxide forming materials are included in Lab Safety Appendix.

E. Shock-Sensitive Chemicals

Shock-sensitive refers to the sensitivity of the chemical to decompose rapidly or explode when struck, vibrated, or otherwise agitated.

The label and Material Safety Data Sheet will indicate if a chemical is shock-sensitive.

Shock-sensitive chemicals should be procured as needed to minimize storage problems. Shock-sensitive materials should be considered individually and disposed of as soon as practical.

Many chemicals become increasingly shock-sensitive with age. The date received and date opened shall be clearly marked on all containers of shock-sensitive chemicals.

Inhibitors are not to be added to shock-sensitive materials unless specific instructions from the manufacturer are provided.

F. Material Safety Data Sheets

The Material Safety Data Sheets (MSDS) is a format for describing what chemical or product you are working with, potential chemical hazards, and ways of minimizing these hazards. These sheets shall be on hand in the laboratory for people who use these chemicals. Information that is contained in the Material Safety Data Sheets is also required by law to be conveyed to employees on a chemical-by-chemical basis.

MSDSs are generally written for chemicals that are used in the industrial setting and it will become apparent that some of the information provided on the MSDS may not be applicable to laboratory usage. The use of these chemicals in a laboratory is generally in a more controlled environment than in the industrial setting and much smaller quantities of the chemical are being used at any one time. Nevertheless, a great deal of information on hazards associated with laboratory chemicals can be obtained by reading the MSDS.

Procurement of Chemicals

The achievement of safe handling, use, and disposal of hazardous substances begins with the persons who requisition such substances and those who approve their purchase orders. These persons must be aware of the potential hazards of the substances being ordered, know whether or not adequate facilities and trained personnel are available to handle such substances, and should ensure that a safe disposal route exists.

Before a new substance is received, information concerning its proper handling methods, including proper disposal procedures, should be given to all those who will be working with it. It is the responsibility of the laboratory supervisor to ensure that the facilities are adequate and that those who will handle any material have received proper training and education to do so safely.

For most substances, Material Safety Data Sheet's, which give physical property data and toxicological information, can be obtained by request to the vendor. However, the quality and depth of information on these sheets vary widely.

Shippers should furnish and attach DOT prescribed labels on all shipment of hazardous substances. These labels indicate the nature of the hazard(s) of the substance(s) shipped and thus provide some indication to receiving personnel of the type of hazard received.

No container or cylinder should be accepted that does not have an identifying label. For chemicals, it is desirable that this label correspond to ANSI Z129.1, which requires, at a minimum, the following components:

- Identification of contents of container
- Signal word and summary description of any hazard(s)
- Precautionary information – what to do to minimize hazard or prevent an accident from happening;
- First aid in case of exposure;
- Spill and cleanup procedures; and
- If appropriate, special instructions to physicians.

Every effort should be made to ensure that this label remains on the container and legible.

H. Spill Prevention

A hazardous chemical spill means that an uncontrolled release of a hazardous chemical has occurred. The release may involve a gas, liquid, or solid, and usually requires some action be taken to control the point of release or the spread of the chemical. A chemical is hazardous if it possesses a physical or health threat to humans, the environment, or property. More specifically, a substance is considered hazardous when:

- It is flammable, explosive, or reactive;
- It generates harmful vapour or dust;

- It is a carcinogen;
- It is a corrosive and attacks skin, clothing, equipment, or facilities;
- It is poisonous by ingestion, inhalation or absorption.

Spills involving hazardous materials will require different tactics depending on the magnitude of the spill, the material's toxicity, reactivity, and flammability, routes of entry of the material into the body, and the promptness with which the spill can be safely managed.

Many spills can be prevented or controlled by careful planning, use of trays, and absorbent paper. (Remember, hoods don't prevent or control spills; they just relocate them!)

Proper techniques for transporting hazardous chemicals and proper storage techniques may help prevent spills.

I. Handling and Transporting of Chemicals

Many laboratory accidents occur through the simple operation of carrying chemicals from one place to another or transferring them from one container to another. The chemicals used in a laboratory are often corrosive, toxic, or flammable and any accident involving these has the potential for personal injury. Therefore, it is good practise to assume that all chemicals are potentially hazardous.

- When large bottles of acids, solvents, or other liquids are transported within the laboratory without a cart, only one bottle should be carried at a time. The bottle should be carried with both hands, one on the neck of the bottle and the other underneath. Avoid the temptation to hook a finger through the glass ring on top of the bottle, allowing it to dangle while being transported. Never carry or attempt to pick up a bottle by the cap.
- While transporting bottles within the laboratory, a wheeled cart may be used. Carts should be stable under load and have wheels large enough to negotiate uneven surfaces (such as expansion joints and floor drain depressions) without tipping or stopping suddenly. Do not place the bottle near the edge of the cart, nor should they be touching each other or other glassware during transport. Be cautious rolling the cart over door sills or other possible obstructions. Incompatible chemicals should not be transported on the same cart. A list of incompatible chemicals is included in Lab Safety Appendix.
- Freight-only elevators should be used, if possible, when transporting chemicals, to avoid exposure to persons on passenger elevators.
- Special padded or rubber bottle carriers, pails or carts should be used to prevent breakage by accidental striking against walls or floor, and to contain the material if breakage does occur.
- Large quantities of concentrated mineral acids, e.g., sulphuric, nitric and hydrochloric acids, shall be kept in storage rooms, in cabinets for corrosive

substances, or chemical transfer rooms. Bottles of concentrated acids must be carried from the aforementioned areas in an approved acid bottle carrier.
- Organic solvents shall also be stored in specialized flammable storage areas. These solvents shall be carried from storage areas in special rubber carriers. Organic solvents can present fire hazards as well as inhalation hazards.

J. Chemical Storage

The principle concerns in achieving proper storage are to maximize employee safety with regard to chemical compatibility, spill control, fire/explosion control, to provide security, identification, and provide a "user friendly" system with respect to point-of-use.

- Every chemical in the laboratory should have a definite storage place and should be returned to that location after each use.
- Storage must conform to compatibility restrictions as described in Lab Safety Appendix. Typically, solvents, acids, bases, reactives, oxidizers, and toxins will be stored separately. Separation basically refers to physical separation of containers and isolation of potential spills and releases with the goal of preventing chemical reactions. Ideally, separate cabinets or isolated areas within a central storage area should be utilized for segregated storage or incompatibles.
- Adequate containment for spills and accidental releases shall be provided.
- Hazardous chemicals should never be stored on the floor. Containers should be kept on low shelves or in cabinets. The shelves should have a lip on the forward edge to prevent bottles from slipping off. Chemicals tend to "creep" toward and over the edge of a shelf. Shelving units should be securely fastened to the wall or floors. Shelves should not be overloaded.
- Utilize a compatible/suitable container for experiments, stored chemicals and collected wastes. In instances of corrosive wastes or halogenated solvents, the use of metal containers is often unsuitable, even if the solvents were originally shipped in metal containers. In these instances, plastic carboys (high density polyethylene) or lined metal containers may be more suitable. See the MSDS for specific information.
- There shall be constant vigilance for any sign of chemical leakage. Containers storing chemical waste must be expected weekly for any sign of chemical leakage. Containers of all types should be free of rust or deformation.
- Caps and covers for containers shall be securely in place whenever the container is not in immediate use.
- Storage shall be physically secure.
- NFPA labelling shall appear on cabinets and room doors at approximately waste level or lower to allow adequate visualization in dense smoke conditions.
- All containers used for storage (even short term) shall be. At a minimum, all containers must be labelled with regard to content and general hazard. Flammable liquids in quantities greater than one litre should be kept in metal

safety cans designed for such storage. The cans should only be used as recommended by the manufacturer, including the following safety practises:

- Never disable the spring-loaded closure.
- Always keep flame-arrestor screen in place; replace if punctured or damaged.
- Metal drums used for storage and dispensing of flammable chemicals shall be properly grounded. Ground cables shall be available and utilized in any lab using metal storage containers for flammable liquid storage.
- Chemicals should be stored as close as feasible to the point of use in order to maximize efficiency and minimize transport distance. Chemical storage should be limited only to areas in which the particular chemical is used. Storage locations must be identified on an emergency floor plan posted in each work area and should be equipped wit ha fire extinguisher, spill kit, eye wash, first aid kit, and telephone or other communication system to allow for adequate emergency notification.
- Small quantities of chemicals can be held at individual work stations if this quantity is to be promptly used in a test and does not compromise acceptable ambient organic vapour levels or procedures for spill control and fire safety. These containers must be properly labelled.
- Only limited quantities of chemicals and solvents should be stored in the laboratory. Large drums or multiple bottles of chemicals should be stored in a centralized chemical storage area.
- Out-of-date chemicals shall be disposed of on a periodic basis to reduce overall hazard potential and minimize inventory tracking and updating.

K. Prior Approval

Employees must obtain prior approval to proceed with a laboratory task from their laboratory supervisor whenever:

- A new laboratory procedure or test is to be carried out.
- It is likely that toxic limit concentrations could be exceeded
- There is a change in a procedure or test, even if it is very similar to prior practises. “Change in procedure or test” means:
  - A 10% or greater increase or decrease in the amount of one or more chemicals used.
  - A substitution or deletion of any of the chemicals in the procedure.
  - Any change in other conditions under which the procedure is to be conducted. (Communication is crucial; ensure employees are well informed.)
  - There is a failure of any of the equipment used in the process, especially of safeguards such as fume hoods or clamped apparatus.
  - There are unexpected results.
  - Members of the laboratory staff become ill, suspect that they or others have been exposed, or otherwise suspect a failure of any safeguards.

Museum personnel shall not accept any chemical, hazardous substance, or item(s) containing hazardous substances as gifts or donations to the museum without informing the OHS committee of the transfer.

Under no circumstances is any person to dispose of a hazardous substance down the drain or in the refuse disposal system where the applicable regulations, procedures and policies regarding its disposal as described in this document or MSDS for the product prohibit this action or are unknown. Prior to disposal of hazardous substances (via sanitary sewer or as solid waste), the Lab Safety Manual, applicable local and federal regulations, or the MSDS for the product shall be consulted. If any of the aforementioned documents prohibit drain or trash disposal, the material or product must be handled as hazardous waste.

A. Basic Procedures

- Collect substances in original or other suitable primary container.
- Properly label containers as to contents and hazards.
- Properly store containers until ready for disposal.
- When accumulation exceeds the available storage limits within the laboratory area, arrange for the transfer of the substances with the disposal company.
- The generator shall prepare individual container number and create a document describing items to be discarded.
- Individual containers, except in prearranged situations, shall NOT be boxed together.

B. Containers

A container refers to any of the following that serves as a primary container; or as an outer or secondary packaging over one or more primary containers.

Any steel, plastic, or fiberboard drum
Metal cans and pails
Steel cylinders and tanks
Plastic-coated paper bags
Plastic baggies
Glass, and plastic bottles, jars, vials
Sturdy cardboard boxes
Mercury containers

C. Container Condition

- Where possible, materials should be kept in their original containers.
- Containers shall be in good condition; leaking or damaged containers are not acceptable. If leaking or damaged, either repackage or call the disposal company to determine the proper packaging for disposal.

- Containers shall be equipped with a proper fitting cap or other closure means. Properly secured means with the original device or method provided by the manufacturer, or when unavoidable, with a substitute means of equal or better quality that will prevent leakage or incidental exposure during routine handling or in the event of the container tipping or falling over. Makeshift covers such as tape to hold down a screw cap or a rag stuffed in the opening are unacceptable.
- Containers shall be compatible with substances contained therein.
- Plastic bags, where acceptable as containers (double bagging is preferred), shall be without punctures or tears and shall be tightly sealed. Ordinary garbage (2 mil or less) bags shall not be used as a primary or secondary container for hazardous chemical waste.
- Containers should be inspected weekly for signs of leaks or deterioration.
- Compressed gas cylinders shall not be handled or transported until the regulating device is removed and the safety cap installed. Every effort should be made to return compressed gas cylinders to the manufacturer or original supplier.

D. Container Volumes and Sizes

Glass containers shall not exceed one gallon (4 litres) in size and shall not filled into the neck of the fill/pour spout. Where containers have flat tops, the liquid level shall be at least 1 inch from the fill/pour opening. Glass carboys are unacceptable.

E. Labelling of Containers

- Each container shall bear the Hazardous Chemical Surplus Tag which clearly and neatly indicates the chemical or common name of each substance which is at least 1% by volume of the total contents or mixture. Carcinogens or highly toxic substances which are 0.1% or more by volume must also be listed. Any amount of a heavy metal (e.g. As, Ba, Cd, Cr, Hg, Ni, Se, Ag, Th) greater than 1 part per million (1 ppm) in the container must be listed.
- Indicate the strength or concentration of the substance where applicable. Example: Hydrochloric Acid may have strength of 10%, 28%, 38%.
- Do not use chemical formulas, chemical symbols, chemical equations or abbreviations.
- Indicate the physical and/or health hazards of the substance if known.
- Indicate the name of the building, room, and principal investigator or person responsible for generating the waste (or someone with direct knowledge of the process).
- In the instance of time sensitive substances such as ethers, the date of container opening or initial accumulation shall be included on the form.
- Remove or obliterate any other labels or wordings not related to the current substance.
- Do not allow the creation of “UNKNOWNS’ through lack of secure readable labelling.

F. Storage of Waste Chemicals

Waste Chemicals shall be stored in the same manner and using the same procedure as other chemicals. It may be advantageous to further segregate chemical waste. A typical segregation of waste chemicals would be:

a. Acids
b. Caustics
c. Chlorinated Solvents
d. Non-Chlorinated Solvents
e. Mercury Wastes
f. Oxidizing Agents
g. PCB Wastes
h. Reactive Chemicals
i. Waste Oil
j. Waste with Heavy Metal Contamination

These chemicals shall be accumulated in separate containers and need to be isolated from one another to some degree, at least to the extent that spills or leaks would remain isolated from other containers. This is particularly true of acids, bases, and solvents.

Lab Safety Appendix

Incompatible Chemicals

Chemical:	Keep out of Contact with:
Acetic Acid	Nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali Metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, the halogens
Ammonia, Anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrite	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely organic or combustible material
Aniline	Nitric acid, hydrogen peroxide
Bromine	Same as chlorine: ammonia, acetylene, butadiene, butane, methane, propane(or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Butyl lithium	Water
Chlorates	Calcium hypochlorite, all oxidizing agents
Chromic Acid	Ammonium salts, acids, metal powders, sulfur, finely divided organic or combustible materials
Chlorine	Naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids in general Same as bromine: ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided
Metals:	**Keep out of Contact with:**
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Cumene hydro peroxide	acids, organic or inorganic
Cyanides (Na, K)	Acids

Flammable liquids	Ammonium nitrate, chronic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens, other oxidizing agents
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid	Ammonia, aqueous or anhydrous
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidizing gases
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitric acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases
Oxalic acid	Silver, mercury
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, sulfuric acid, organics
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, sulfuric acid
Silver	Acetylene, oxalic acid, tartaric acid, ammonium
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, furfural
Sulfuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium etc.)

Laboratory Notes -

Section G

Maps

Section H

Staff Positions and Responsibilities in an Emergency Situation

17) General Staff Positions

Director

Reporting directly to the Joggins Fossil Institute Board of Directors, the Director is responsible for overseeing all aspects of the Joggins Fossil Centre and property operations. The Director recommends policies and plans to the Board, implements policies and plans approved by the board and reports on the outcome of these plans and policies. The Director has overall responsibility for human resources management, occupational health and safety and management of the operations of the centre and property through the staff. The Director is responsible for financial management and seeking out sources of ongoing funding, including both private and public sources. The Director serves as the liaison with all levels of government and the local community, and develops strategies to promote the property locally, nationally and internationally.

Scientist

The scientist is responsible for the security, preservation, documentation and interpretation of Joggins' fossil resources. The scientist carries out property-specific research, makes that research available to the public and liaises with other researchers and institutions in the scientific community. The scientist provides curatorial input into the development of exhibitions and educational programs and is partially responsible for the training of interpretive and collections staff. The scientist leads tours and other educational programs for post-secondary and professional groups. To enhance the visibility of the property with the larger scientific community and to further scientific research, the scientist publishes scientific papers, attends conferences and conducts lectures on a regular basis.

Manager of Programming

The Manager of Programming is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the Joggins Fossil Centre and Cliffs, as well as outreach programs and extension programs. The Manager of Programming develops educational materials to accompany exhibitions and provides input into the development of new and/or temporary exhibitions.

Interpreters

Interpreters are responsible for advancing the educational goals of the Joggins Fossil Institute and enhancing the visitor experience by conducting guided tours of the Cliffs and Centre. Interpreters will lead workshops and facilitate other educational programs for visitors and groups. Interpreters will help to advance the scientific and research mission of the JFI by assisting in the preliminary identification, cataloguing and preparation of fossil specimens. Interpreters will have a role to play in ensuring safe and regulated beach visitation.

Manager of Visitor Services and Marketing

The Manager of Visitor Services and Marketing is responsible for the overall quality of the services offered at the Centre and for ensuring that high standards of customer care are met. The Manager of Visitor Services and Marketing recruits and manages customer service staff (admissions and retail), develops and implements the strategic marketing plan for the Joggins Fossil Cliffs and Centre in conjunction with the director and ensures that the Joggins Fossil Institute responds to multiple markets and changing visitors demands. The Manager designs and implements visitor use monitoring and social science research related to visitor satisfaction, expectations and trends. The Manager of Visitor Services and Marketing is responsible for overseeing revenue-generation centres including the gift shop, food-service concession, internet café and rentals.

Customer Service Associates

Customer Service Associates greet visitors, answer general visitor enquiries and introduce visitors to the menu of activities and experiences that can be enjoyed at the centre and property. Customer Service Associates process admissions, gift shop transactions and fossil exploration permit purchases, as well as ensuring that gift shop and information displays are well-stocked.

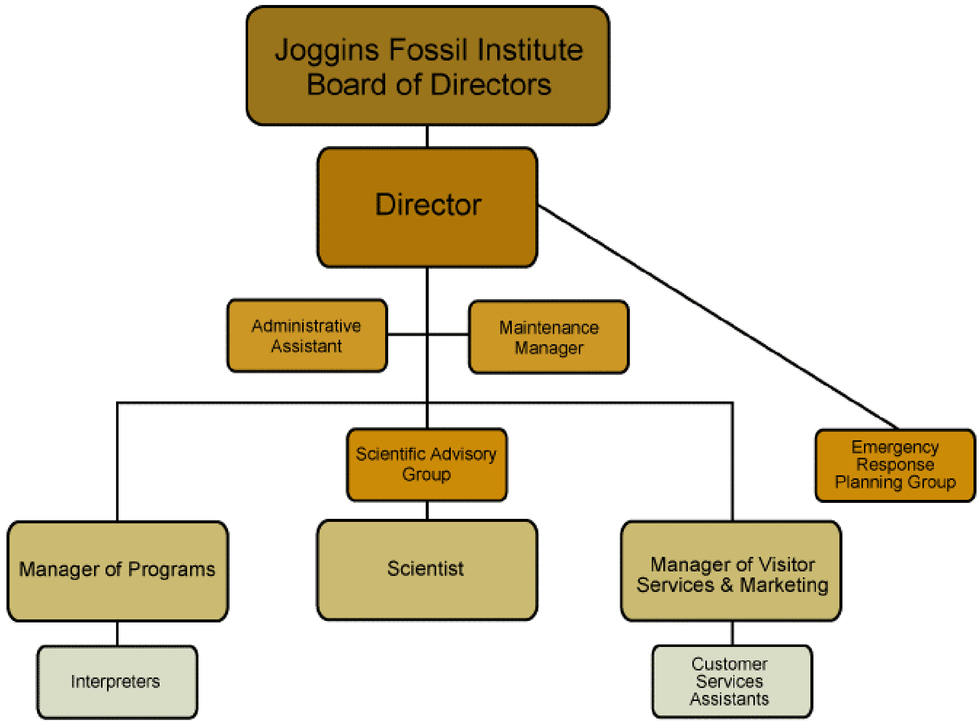
Administrative Assistant

The Administrative Assistant will provide support services for the centre and property operations. Responsibilities include: bookkeeping; clerical and filing duties; processing payment for workshops and programs; maintaining a database mailing list; program administration including course registration.

Maintenance Manager

The Maintenance Manger is responsible for overseeing all aspects of facility/ and property maintenance and housekeeping of the physical plant and grounds of the centre. Through an ongoing system, the Maintenance Manager will determine the need for repairs and preventative maintenance and will carry out necessary maintenance and repairs or will oversee the procurement and delivery of contracted services as necessary.

Organizational Chart for the Joggins Fossil Institute



18) Responsibilities of Staff in Emergency Situations

Section J

Review and Recovery from Emergency Situations

19) Review and Recovery form Emergency Situations Procedures

20) Forms for Review and Recovery from Emergency Situations

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Section K

Occupational Health and Safety
Workers Compensation

Occupational Health and Safety

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1. Legal and Public Policy Framework

a) The Joggins Fossil Institute requires as a matter of Board Policy that the Joggins Fossil Centre provide employees and visitors with a safe and healthy environment in which to work and enjoy the Joggins Fossil Cliffs. They will require all employees to use appropriate health and practices in the exercise of their duties.

b) In the interpretation and implementation of this Board Policy, the Joggins Fossil Institute Board of Directors requires that all Centre occupational health and safety practices be in compliance with relevant provincial and federal legislation, and all other accepted standards of prudence in health and safety matters affecting employees and visitors at all Joggins Fossil Institute developments. As such, this Administrative Regulation, and any procedures developed pursuant to its provisions, form part of Joggins Fossil Institute policy with respect to Occupational Health and Safety, as policy is defined in the Occupational Health and Safety Act, and the program included in these documents is a safety program as statutorily defined.

c) It is public policy in Nova Scotia to promote, create and maintain working environments that protect the health and safety of individuals in these environments. The Nova Scotia Occupational Health and Safety Act. 1996, c. 7, s. 1., and the Regulations under the Act are concerned with occupational health and safety and the maintenance of reasonable standards for the protection of the health and safety of employees in Nova Scotia workplaces.

2. Interpretation

a) In this Administrative Regulation, other individuals refer to those persons who are not employees or visitors of the Joggins Fossil Centre, but who are on Joggins Fossil Institute premises for authorized purposes. Other individuals include, but are not limited to, constructors and contractors (as defined in the Occupational Health and Safety Act) and members of the general public.

b) Other terms used in this Administrative Regulation for which there is a statutory definition in the Occupational Health and Safety Act shall be interpreted in accordance with those statutory definitions. Defined terms include:

1) "committee" means a joint health and safety committee established under the Act;
2) "employee" means (i) a person employed in a workplace (ii) a person in a workplace for any purpose in connection therewith;
3) "employer" means a person who employs one or more employees or contracts for the services of one or more employees, and includes a constructor or contractor;
4) "representative" means a health and safety representative selected pursuant to the Act;
5) "workplace" means any place where an employee is or is likely to be engaged in any occupation and includes any vehicle, fishing vessel or mobile equipment used or likely to be used by an employee in an occupation;
6) "owner" a trustee, receiver, mortgagee in possession, tenant, lessee or occupier of any lands or premises used or to be used as a place of employment;

3. Statement of Commitment

a) Joggins Fossil Institute values the health and safety of all employees, visitors and other individuals on Joggins Fossil Institute premises. It is, therefore the policy of the Joggins Fossil Institute to protect and promote the health and safety of all, employees, visitors and other individuals and to take every precaution, reasonable in the circumstances, to ensure that Joggins Fossil Institute premises are safe and healthy for all who come into contact with the Joggins Fossil Centre.

b) Furthermore, the Joggins Fossil Institute shall incorporate the principles and practices of occupational health and safety in all aspects of its interpretation and developments for the visitor to the Joggins Fossil Cliffs.

c) The Occupational Health and Safety Act and accompanying Regulations of the Province of Nova Scotia, along with acceptable occupational practices, shall constitute the minimum standard expected for health and safety in the Joggins Fossil Centre. Where it is in the interest of occupational health and safety, the Joggins Fossil Institute may exceed the requirements prescribed by legislation.

d) Joggins Fossil Institute shall promote an interpretation and workplace culture where visitors and employees are supported and encouraged to contribute to health and safety programs. The Joggins Fossil Centre commits to working in partnership with employees, visitors and their representatives to develop and implement measures to eliminate and minimize risk of injury and illness.

e) Joggins Fossil Institute holds all levels of Program and Administrative management responsible for implementing this policy, for developing and implementing an occupational health and safety program specific to each workplace, and for ensuring that each workplace is in compliance with the Occupational Health and Safety Act and Regulations. All Joggins Fossil Centre employees, including management, are responsible to comply with the duties set out in this policy, to follow campus health and safety programs and to cooperate with the Joint Occupational Health and Safety Committees and Representatives.

f) Outside contractors and constructors are to be informed of the sections of this Administrative Regulation that apply to them and they will be held responsible to comply with those sections.

4. Objectives

a) The objectives of this Administrative Regulation are to ensure that the Joggins Fossil Centre is in compliance with the Occupational Health and Safety Act and Regulations and that every precaution, reasonable in the circumstances, is taken to provide for a healthy and safe working environment in accordance with Board Policy.

b) Implementation of this Administrative Regulation, through the incorporation of the principles and practices of occupational health and safety in Joggins Fossil Centre programs and the establishment of an occupational health and safety program specific to each workplace based on the concepts of internal responsibility, will assure that management and employees work together to promote healthy environments and prevent accidents and illnesses to themselves, visitors and other individuals.

5. Guiding Principles

a) Health and safety is a shared responsibility involving employer, employees, visitors and other individuals. All are responsible and accountable for their safely at all times, to identify and report hazards and to take whatever measures, necessary and reasonable in the circumstances, to protect and promote a healthy and safe environment.

b) The Joggins Fossil Centre shall prepare employees for workplace health and safety by providing instruction, relevant to the chosen occupational area, in the principles and practices of occupational health and safety.

c) Each workplace is responsible for implementing and complying with this Administrative Regulation in all areas of Joggins Fossil Centre operations and each level of Joggins Fossil Centre management is responsible for the provision of a safe and healthy environment and the achievement of the objectives of this Administrative Regulation.

d) Departmental Supervisors are responsible to maintain a safe and healthy work environment and to instruct their employees in safe work practices and procedures.

e) Without limiting the responsibility of other levels of Joggins Fossil Centre management, policy implementation, compliance and the provision of a safe and healthy working environment are part of the Director's general responsibility for management and operations, including administration o policies applicable to the Joggins Fossil Centre.

f) The Director Joggins Fossil Centre will delegate responsibility for overseeing this regulation and any related procedures to the levels of management.

g) The Director will designate an individual to be responsible for health and safety at each workplace who must ensure that the workplace environment is safe and healthy, that employees, visitors and other individuals are advised of actual or potential hazards, and are instructed in and follow safe procedures.

h) Active employee involvement and full cooperation in health and safety are key ingredients in effective health and safety programs.

i) The Workplace Joint Occupational Health and Safety Committees are key mechanisms for the collaborative, cooperative initiation, maintenance and support of health and safety programs.

j) Occupational Health and Safety Programs will be coordinated and consistent with this Administrative Regulation and with any Joggins Fossil Institute policies and regulations regarding safety and security.

k) Safety rules and practices shall be enforced, shall be reasonable and consistent, and shall be in compliance with the Occupational Health and Safety Act and Regulations.

6. Revisions to the Administrative Regulation

This Administrative Regulation shall be reviewed and, where applicable, updated annually through a consultative process coordinated by the Director of the Joggins Fossil Centre and involving participation of all Joint Occupational Health and Safety Committees and Representatives.

7. Implementation Process

a) The Joint Occupational Health and Safety Committee and Representatives will govern themselves in accordance with provisions of the attached Terms of Reference (Appendixes A & B), this Administrative Regulation and the Occupational Health and Safety Act & Regulations. Each Committee and Representative shall be provided with a copies of the following:

1) The Nova Scotia Occupational Health and Safety Act.
2) WCB - Employer Information Guide
3) WCB - Prevention Workplace Injuries: A Resource Manual
4) WCB - Worker's Handbook
5) WCB - Accident Report: User's Guide

WCB Handbooks and Guides are found at: http://www.wcb.ns.ca/new/index.php?id=46

b) A Register of Committee membership and Representatives shall be maintained by the Director of the Joggins Fossil Centre.

c) The Director will maintain a centralized repository of all Committee and Representative Records.

d) The Director will support and facilitate the activities of the Committees and Representatives.

e) The Director will coordinate a monitoring and evaluation function to supervise and coordinate the activities of the Committee and Representatives.

Appendix A: Terms of Reference for Joint Occupational Health and Safety Committee

a) The Joint Occupational Health and Safety Committee shall consist of the number of at least four persons agreed to by the employees and the Joggins Fossil Institute.

b) The employees on the Committee shall be selected by the employees they represent.

c) At least one-half of the members of a Committee shall be employees at the workplace who do not exercise managerial functions and Joggins Fossil Institute may choose up to one-half of the members of the committee.

d) The Committee shall:

1) cooperate to identify hazards to health and safety in the workplace and effective systems to respond to the hazards;
2) receive, investigate and promptly dispose of matters and complaints with respect to workplace health and safety;
3) participate in inspections, inquiries and investigations with respect to the occupational health and safety of the employees in the workplace;
4) advise the employer on individual protective devices, equipment and clothing that, in accordance with the Act and the regulations, are best adapted to the needs of the employees;
5) advise the employer regarding a policy or program required pursuant to the Act;
6) make recommendations to the employer, the employees and any other person for the improvement of the health and safety of persons at the workplace;
7) maintain records and minutes of committee meetings in a form and manner approved by the Director of Occupational Health and Safety and provide an officer with a copy of these records or minutes on request.

e) The Committee will meet at least once each month unless the Committee alters the required frequency of meetings in its rules of procedure.

f) Every employee who is a member of a Committee is be entitled to take the time off from work that is necessary to attend meetings of the Committee, to take any training prescribed by the regulations and to carry out the employee’s functions as a member of the Committee.

Appendix B: Terms of Reference for Joint Occupational Health and Safety Representative

a) An employee who is a Representative is entitled to such reasonable time off from work as is necessary to carry out the employee's functions as a Representative.

b) Every representative shall be involved on behalf of the employees, together with the employer, in occupational health and safety in the workplace and shall:

   1) cooperate by identifying hazards to health and safety and effective systems to respond to the hazards;
   2) cooperate by monitoring compliance with health and safety requirements in the workplace;
   3) cooperate with the employer in the investigation and prompt disposition of matters and complaints with respect to workplace health and safety;
   4) participate in inspections, inquiries and investigations with respect to the occupational health and safety of the employees in the workplace;
   5) advise the employer on individual protective devices, equipment and clothing which, in accordance with the Act and the regulations, are best adapted to the needs of the employees;
   6) advise the employer with respect to a policy or program required by the Act; and
   7) make recommendations to the employer, the employees and any other person for the improvement of the health and safety of persons at the workplace.

Appendix C: Nova Scotia Occupational Health and Safety Act.

Occupational Health and Safety Act

CHAPTER 7

OF THE

ACTS OF 1996

amended 2000, c. 28, ss. 86, 87; 2004, c. 6, s. 24

An Act Respecting Occupational Health and Safety

Short title

1 This Act may be cited as the Occupational Health and Safety Act. *1996, c. 7, s. 1.*

Internal Responsibility System

2 The foundation of this Act is the Internal Responsibility System which

(a) is based on the principle that

(i) employers, contractors, constructors, employees and self-employed persons at a workplace, and

(ii) the owner of a workplace, a supplier of goods or provider of an occupational health or safety service to a workplace or an architect or professional engineer, all of whom can affect the health and safety of persons at the workplace,

share the responsibility for the health and safety of persons at the workplace;

(b) assumes that the primary responsibility for creating and maintaining a safe and healthy workplace should be that of each of these parties, to the extent of each party's authority and ability to do so;

(c) includes a framework for participation, transfer of information and refusal of unsafe work, all of which are necessary for the parties to carry out their responsibilities pursuant to this Act and the regulations; and

(d) is supplemented by the role of the Occupational Health and Safety Division of the Department of Labour, which is not to assume responsibility for creating and maintaining safe and healthy workplaces, but to establish and clarify the responsibilities of the parties under the law, to support them in carrying out their responsibilities and to intervene appropriately when those responsibilities are not carried out. *1996, c. 7, s. 2.*

Interpretation

3 In this Act,

(a) "aggrieved person" means an employer, constructor, contractor, employee, self-employed person, owner, supplier, provider of an occupational health or safety service, architect, engineer or union at a workplace who is directly affected by an order or decision;

(b) "analyst" means a person appointed as an analyst by the Minister pursuant to this Act;

(c) "appeal panel" means an appeal panel designated pursuant to this Act;

(d) "committee" means a joint occupational health and safety committee established pursuant to this Act;

(e) "compliance notice" means a response, in writing, to an order of an officer, describing the extent to which the person against whom the order was made has complied with each item identified in the order;

(f) "constructor" means a person who contracts for work on a project or who undertakes work on a project himself or herself;

(g) "contractor" means a person who contracts for work to be performed at the premises of the person contracting to have the work performed, but does not include a dependent contractor or a constructor;

(h) "contracts for work" includes contracting to perform work and contracting to have work performed;

(i) "Council" means the Occupational Health and Safety Advisory Council established pursuant to this Act;

(j) "dependent contractor" means a person, whether or not employed under a contract of employment and whether or not furnishing the person's own tools, vehicles, equipment, machinery, material or any other thing, who performs work or services for another on such terms and conditions that the person is

(i) in a position of economic dependence upon the other,

(ii) under an obligation to perform duties mainly for the other, and

(iii) in a relationship with the other more closely resembling that of an employee than an independent contractor;

(k) "Deputy Minister of Labour" includes a person designated by the Deputy Minister of Labour to act in the stead of the Deputy Minister;

(l) "Director" means the Director of Occupational Health and Safety or any person designated by the Director pursuant to this Act to act on behalf of the Director;

(m) "Director of Labour Standards" means the Director of Labour Standards under the Labour Standards Code;

(n) "Division" means the Occupational Health and Safety Division of the Department of Labour;

(o) "employee" means a person who is employed to do work and includes a dependent contractor;

(p) "employer" means a person who employs one or more employees or contracts for the services of one or more employees, and includes a constructor, contractor or subcontractor;

(q) "former Act" means Chapter 320 of the Revised Statutes, 1989, the Occupational Health and Safety Act;

(r) "Labour Standards Tribunal" means the Labour Standards Tribunal under the Labour Standards Code;

(s) "Minister" means the Minister of Labour;

(t) "occupation" means any employment, business, calling or pursuit;

(u) "officer" means an occupational health and safety officer appointed pursuant to this Act and includes the Director;

(v) "owner" includes a trustee, receiver, mortgagee in possession, tenant, lessee or occupier of lands or premises used as a workplace and a person who acts for, or on behalf of, an owner as an agent or delegate;

(w) "police officer" means

(i) a member of the Royal Canadian Mounted Police, or

(ii) a member or chief officer of a police force appointed pursuant to Section 14 or 17 of the Police Act;

(x) "policy" means an occupational health and safety policy made pursuant to this Act;

(y) "practicable" means possible, given current knowledge, technology and invention;

(z) "program" means an occupational health and safety program required pursuant to this Act, unless the context otherwise requires;

(aa) "project" means a construction project, and includes

(i) the construction, erection, excavation, renovation, repair, alteration or demolition of any structure, building, tunnel or work and the preparatory work of land clearing or earth moving, and

(ii) work of any nature or kind designated by the Director as a project;

(ab) "reasonably practicable" means practicable unless the person on whom a duty is placed can show that there is a gross disproportion between the benefit of the duty and the cost, in time, trouble and money, of the measures to secure the duty;

(ac) "regularly employed" includes seasonal employment with a predictably recurring period of employment that exceeds four weeks, unless otherwise established by regulation or ordered by an officer;

(ad) "representative" means a health and safety representative selected pursuant to this Act;

(ae) "self-employed person" means a person who is engaged in an occupation on that person’s own behalf but does not include a dependent contractor;

(af) "supplier" means a person who manufactures, supplies, sells, leases, distributes or installs any tool, equipment, machine or device or any biological, chemical or physical agent to be used by an employee;

(ag) "union" includes a trade union as defined in the Trade Union Act that has the status of bargaining agent under that Act in respect of any bargaining unit at a workplace, and includes an organization representing employees where the organization has exclusive bargaining rights under any other Act in respect of the employees;

(ah) "workplace" means any place where an employee is or is likely to be engaged in any occupation and includes any vehicle or mobile equipment used or likely to be used by an employee in an occupation. *1996, c. 7, s. 3; 2000, c. 28, s. 86.*

APPLICATION AND ADMINISTRATION

Application of Act

4 (1) This Act binds Her Majesty in right of the Province.

(2) This Act applies to

(a) every agency of the Government of the Province; and

(b) all matters within the legislative jurisdiction of the Province.

(3) To the extent that Her Majesty in right of Canada submits, this Act binds Her Majesty in right of Canada, every agency of the Government of Canada and every other person whose workplace health and safety standards are ordinarily within the legislative jurisdiction of the Parliament of Canada. *1996, c. 7, s. 4.*

Conflict with other enactments

5 Notwithstanding any general or special Act, where there is a conflict between this Act and the regulations and any other enactment, this Act and the regulations prevail. *1996, c. 7, s. 5.*

Supervision and management of Act

6 The Minister has the general supervision and management of this Act and the regulations. *1996, c. 7, s. 6.*

Research, programs and activities

7 The Minister may undertake research, programs and activities to promote occupational health and safety and may undertake such programs in co-operation with the Government of Canada or of any other province of Canada or with any person or organization undertaking similar programs. *1996, c. 7, s. 7.*

Continuation of Division

8 The Occupational Health and Safety Division of the Department of Labour, established by the former Act, is hereby continued. *1996, c. 7, s. 8.*

Functions of Division

9 The Division shall

(a) be concerned with occupational health and safety and the maintenance of reasonable standards for the protection of the health and safety of employees and self-employed persons;

(b) either alone or in conjunction with the Workers' Compensation Board, the Department of Health or other departments and agencies, prepare and maintain statistics and information relating to employees and self-employed persons;

(c) provide assistance to persons concerned with occupational health and safety and provide services to assist joint occupational health and safety committees, health and safety representatives, employers, employees and self-employed persons in maintaining reasonable standards for the protection of the health and safety of employees and self-employed persons;

(d) promote or conduct studies and research projects in the field of occupational health and safety;

(e) encourage and conduct educational programs to promote occupational health and safety;

(f) annually, submit to the Advisory Council a report on a review of this Act; and

(g) perform such other functions as the Minister or the Governor in Council may direct. *1996, c. 7, s. 9.*

Payment from Accident Fund

10 Part of the costs of the Division pursuant to this Act and the regulations and costs of education and research related to occupational health and safety shall be paid out of the Accident Fund by the Workers' Compensation Board as determined by the Governor in Council. *1996, c. 7, s. 10.*

Director and other personnel

11 (1) There shall be appointed in accordance with the Civil Service Act ~~an~~ [a] Director of Occupational Health and Safety and such officers and employees as are necessary for the administration and enforcement of this Act and the regulations.

(2) Notwithstanding subsection (1), the Minister may appoint officers, to administer and enforce this Act and the regulations, who are employees of

(a) the Government of Canada or an agency thereof;

(b) the government of another province of Canada or an agency thereof;

(c) another department or an agency of the Government;

(d) a municipality within the meaning of the Municipal Affairs Act or an agency thereof; or

(e) an agency created by any combination of the governments of this Province, other provinces of Canada or the Government of Canada,

and who work in the field of occupational health and safety.

(3) The Director may, in writing, delegate to any person any of the Director's powers, duties or functions pursuant to this Act and shall, when so delegating, specify the powers, duties or functions to be exercised by the person to whom the Director delegates.

(4) Notwithstanding anything contained in this Act, an officer appointed pursuant to subsection (2) shall not exercise the powers, duties and functions the officer has pursuant to this Act in relation to the agency, department or municipality, as the case may be, that employs the officer. *1996, c. 7, s. 11; 2000, c. 28, s. 87.*

Designation of inspectors

12 The Minister may designate certain officers as inspectors or chief inspectors for the purpose of this Act or any other Act or part thereof that is administered by the Division. *1996, c. 7, s. 12.*

DUTIES AND PRECAUTIONS

Employers' precautions and duties

13 (1) Every employer shall take every precaution that is reasonable in the circumstances to

(a) ensure the health and safety of persons at or near the workplace;

(b) provide and maintain equipment, machines, materials or things that are properly equipped with safety devices;

(c) provide such information, instruction, training, supervision and facilities as are necessary to the health or safety of the employees;

(d) ensure that the employees, and particularly the supervisors and foremen, are made familiar with any health or safety hazards that may be met by them at the workplace;

(e) ensure that the employees are made familiar with the proper use of all devices, equipment and clothing required for their protection; and

(f) conduct the employer's undertaking so that employees are not exposed to health or safety hazards as a result of the undertaking.

(2) Every employer shall

(a) consult and co-operate with the joint occupational health and safety committee, where such a committee has been established at the workplace, or the health and safety representative, where one has been selected at the workplace;

(b) co-operate with any person performing a duty imposed or exercising a power conferred by this Act or the regulations;

(c) provide such additional training of committee members as may be prescribed by the regulations;

(d) comply with this Act and the regulations and ensure that employees at the workplace comply with this Act and the regulations; and

(e) where an occupational health and safety policy or occupational health and safety program is required pursuant to this Act or the regulations, establish the policy or program. *1996, c. 7, s. 13.*

Precautions to be taken by contractors

14 Every contractor shall take every precaution that is reasonable in the circumstances to ensure

(a) the health and safety of persons at or near a workplace;

(b) that the activities of the employers and self-employed persons at the workplace are co-ordinated;

(c) communication between the employers and self-employed persons at the workplace of information necessary to the health and safety of persons at the workplace;

(d) that the measures and procedures prescribed pursuant to this Act and the regulations are carried out at the workplace; and

(e) that every employee, self-employed person and employer performing work at the workplace complies with this Act and the regulations. *1996, c. 7, s. 14.*

Precautions to be taken by constructors

15 Every constructor shall take every precaution that is reasonable in the circumstances to ensure

(a) the health and safety of persons at or near a project;

(b) that the activities of the employers and self-employed persons at the project are co-ordinated;

(c) communication between the employers and self-employed persons at the project of information necessary to the health and safety of persons at the project, and facilitate communication with any committee or representative required for the project pursuant to this Act or the regulations;

(d) that the measures and procedures prescribed under this Act and the regulations are carried out on the project; and

(e) that every employee, self-employed person and employer performing work in respect of the project complies with this Act and the regulations. *1996, c. 7, s. 15.*

Precautions to be taken by suppliers

16 Every supplier shall take every precaution that is reasonable in the circumstances to

(a) ensure that any device, equipment, machine, material or thing supplied by the supplier is in safe condition, and in compliance with this Act and the regulations when it is supplied;

(b) where it is the supplier’s responsibility under a leasing agreement to maintain it, maintain any device, equipment, machine, material or thing in safe condition and in compliance with this Act and the regulations; and

(c) ensure that any biological, chemical or physical agent supplied by the supplier is labelled in accordance with the applicable federal and Provincial regulations. *1996, c. 7, s. 16.*

Employees’ precautions and duties

17 (1) Every employee, while at work, shall

(a) take every reasonable precaution in the circumstances to protect the employee’s own health and safety and that of other persons at or near the workplace;

(b) co-operate with the employer and with the employee’s fellow employees to protect the employee’s own health and safety and that of other persons at or near the workplace;

(c) take every reasonable precaution in the circumstances to ensure that protective devices, equipment or clothing required by the employer, this Act or the regulations are used or worn;

(d) consult and co-operate with the joint occupational health and safety committee, where such a committee has been established at the workplace, or the health and safety representative, where one has been selected at the workplace;

(e) co-operate with any person performing a duty or exercising a power conferred by this Act or the regulations; and

(f) comply with this Act and the regulations.

(2) Where an employee believes that any condition, device, equipment, machine, material or thing or any aspect of the workplace is or may be dangerous to the employee's health or safety or that of any other person at the workplace, the employee shall

(a) immediately report it to a supervisor;

(b) where the matter is not remedied to the employee's satisfaction, report it to the committee or the representative, if any; and

(c) where the matter is not remedied to the employee's satisfaction after the employee reports in accordance with clauses (a) and (b), report it to the Division. *1996, c. 7, s. 17.*

Self-employed persons' precautions and duties

18 Every self-employed person shall

(a) take every reasonable precaution in the circumstances to protect the self-employed person's own health and safety and that of other persons who may be affected by the self-employed person's undertaking;

(b) co-operate with any employer, joint occupational health and safety committee or health and safety representative that may be found at a place at which the self-employed person conducts an undertaking, to protect the self-employed person's own health and safety and that of other persons who may be affected by the undertaking;

(c) co-operate with any person performing a duty or exercising a power conferred by this Act or the regulations; and

(d) comply with this Act and the regulations. *1996, c. 7, s. 18.*

Owners' precautions and duties

19 Every owner shall

(a) take every precaution that is reasonable in the circumstances to provide and maintain the owner's land or premises being or to be used as a workplace

(i) in a manner that ensures the health and safety of persons at or near the workplace, and

(ii) in compliance with this Act and the regulations; and

(b) give to the employer at the workplace the information that is

(i) known to the owner or that the owner could reasonably be expected to know, and

(ii) necessary to identify and eliminate or control hazards to the health or safety of persons at the workplace. *1996, c. 7, s. 19.*

Precautions to be taken by providers of service

20 Every person or body who, for gain, is a provider of an occupational health or safety service shall take every precaution that is reasonable in the circumstances to

(a) ensure that no person at a workplace is endangered as a result of the provider's activity; and

(b) ensure, where the service involves providing information, that the information provided, at the time that it is provided, is accurate and sufficiently complete to enable the recipient to make a competent judgement on the basis of the information. *1996, c. 7, s. 20.*

Precautions to be taken by architects and offence

21 (1) An architect, as defined in the Architects Act, who gives advice or affixes the architect's seal to documents or a professional engineer, as defined in the Engineering Profession Act, who gives advice or stamps documents shall take every precaution that is reasonable in the circumstances to ensure that a person who is likely to rely on the advice, seal or stamp will not be in contravention of this Act or the regulations as a result of such reliance.

(2) Where

(a) an architect, as defined in the Architects Act, gives advice or affixes the architect's seal to documents; or

(b) a professional engineer, as defined in the Engineering Profession Act, gives advice or stamps documents, negligently or incompetently and a person at a workplace is endangered thereby, the architect or professional engineer contravenes this Act. *1996, c. 7, s. 21.*

Required instruction in principles

22 The curricula of

(a) a trade school or home study course within the meaning of the Trade Schools Regulation Act;

(b) a program of instruction within the meaning of the Community Colleges Act; and

(c) any other educational institution or class of educational institution designated pursuant to the regulations,

shall include instruction in the principles of occupational health and safety contained in this Act. *1996, c. 7, s. 22.*

Nature and extent of duties and requirements

23 (1) A specific duty or requirement imposed by this Act or the regulations does not limit the generality of any other duty or requirement imposed by this Act or the regulations.

(2) Where a provision of this Act or the regulations imposes a duty or requirement on more than one person, the duty or requirement is meant to be imposed primarily on the person with the greatest degree of control over the matters that are the subject of the duty or requirement.

(3) Notwithstanding subsection (2), but subject to subsection (5), where the person with the greatest degree of control fails to comply with a duty or requirement referred to in subsection (2), the other person or persons on whom the duty or requirement lies shall, where possible, comply with the provision.

(4) Where the person with the greatest degree of control complies with a provision described in subsection (2), the other persons are relieved of the obligation to comply with the provision only

(a) for the time during which the person with the greatest degree of control is in compliance with the provision;

(b) where simultaneous compliance by more than one person would result in unnecessary duplication of effort and expense; and

(c) where the health and safety of persons at the workplace is not put at risk by compliance by only one person.

(5) Where the person with the greatest degree of control fails to comply with a provision described in subsection (2) but one of the other persons on whom the duty or requirement is imposed complies with the provision, the other persons, if any, to whom the provision applies are relieved of the obligation to comply with the provision in the circumstances set out in clauses 4(a) to (c) with the necessary modifications. *1996, c. 7, s. 23.*

OCCUPATIONAL HEALTH AND SAFETY
ADVISORY COUNCIL

Continuation of Council

24 (1) The Occupational Health and Safety Advisory Council, established by the former Act, is hereby continued.

(2) The Minister shall appoint to the Council persons who have a particular knowledge and experience relating to the protection and promotion of occupational health and safety generally. *1996, c. 7, s. 24.*

Membership of Council and subcommittees

25 (1) The membership of the Council shall include equal representation from employers and employees.

(2) In addition, the Director and the Chair of the Workers' Compensation Board, or a person designated to represent the Chair, and a representative of any group or groups selected by the Minister are members of the Council.

(3) The Minister may appoint one or more alternate members of the Council.

(4) An alternate member of the Council shall act in place of a member of the Council.

(5) A member or alternate member of the Council holds office during the term prescribed in that person's appointment and may be re-appointed.

(6) The Council may, with the approval of the Minister, appoint one or more subcommittees of the Council and a subcommittee shall perform any of the functions described in Section 26, as determined by the Council.

(7) For greater certainty, a person who is not a member of the Council may be a member of a subcommittee of the Council.

(8) The Minister may designate one employer representative and one employee representative as co-chairs of the Council.

(9) Persons appointed to the Council or a subcommittee of the Council shall be paid the reasonable expenses incurred by them in the course of carrying out their duties for the

Council or subcommittee of the Council, plus such remuneration as is determined by the Minister. *1996, c. 7, s. 25; 2004, c. 6, s. 24.*

Functions of Council

26 The Council may advise the Minister on

(a) the administration of this Act and the regulations;

(b) occupational health and safety including, but not limited to, providing recommendations, giving advice and monitoring and reporting on occupational health and safety throughout the Province;

(c) the exclusion of any profession, employee, employer, workplace, project, owner, occupation, industry, self-employed person or dependent contractor from all or part of the application of this Act or the regulations;

(d) any other matter relating to occupational health and safety. *1996, c. 7, s. 26.*

OCCUPATIONAL HEALTH AND SAFETY POLICY

Requirement for policy

27 (1) Where

(a) five or more employees are regularly employed by an employer other than a constructor or contractor;

(b) five or more employees are regularly employed directly by a constructor or contractor, not including employees for whose services the constructor or contractor has contracted;

(c) the regulations require an occupational health and safety policy; or

(d) an officer so orders,

the employer shall prepare and review, at least annually, a written occupational health and safety policy, in consultation with the committee or representative, if any.

(2) Where this Act or the regulations do not require there to be a committee at a workplace, consultation on the development of the policy shall be carried out by the employer and shall include discussion of the proposed policy at one or more workplace health and safety meetings involving the employees.

(3) The policy shall express the employer's commitment to occupational health and safety and shall include

(a) the reasons for the employer's commitment to health and safety;

(b) the commitment of the employer to co-operate with the employees in pursuing occupational health and safety; and

(c) the responsibilities of the employer, supervisors and other employees in fulfilling the commitment required pursuant to clause (b). *1996, c. 7, s. 27.*

OCCUPATIONAL HEALTH AND SAFETY PROGRAM

Requirement for program

28 (1) Where

(a) twenty or more employees are regularly employed by an employer other than a constructor or contractor;

(b) twenty or more employees are regularly employed directly by a constructor or contractor, not including employees for whose services the constructor or contractor has contracted; or

(c) the regulations require an occupational health and safety program,

the employer shall establish and maintain a written occupational health and safety program, in consultation with the committee or representative, if any, that is adapted to the circumstances of the organization for the purpose of implementing the employer's policy, this Act and the regulations.

(2) The program shall include

(a) provision for the training and supervision of employees in matters necessary to their health and safety and the health and safety of other persons at the workplace;

(b) provision for the preparation of written work procedures required to implement safe and healthy work practices, including those required pursuant to this Act, the regulations or by order of an officer, and identification of the types of work for which the procedures are required at the employer's workplace;

(c) provision for the establishment and continued operation of a committee required pursuant to this Act, including maintenance of records of membership, rules of procedure, access to a level of management with authority to resolve health and safety matters and any information required under this Act or the regulations to be maintained in relation to a committee;

(d) provision for the selection and functions of a representative where required pursuant to this Act, including provision for access by the representative to a level of management with authority to resolve health and safety matters;

(e) a hazard identification system that includes

(i) evaluation of the workplace to identify potential hazards,

(ii) procedures and schedules for regular inspections,

(iii) procedures for ensuring the reporting of hazards and the accountability of persons responsible for the correction of hazards, and

(iv) identification of the circumstances where hazards must be reported by the employer to the committee or representative, if any, and the procedures for doing so;

(f) a system for workplace occupational health and safety monitoring, prompt follow-up and control of identified hazards;

(g) a system for the prompt investigation of hazardous occurrences to determine their causes and the actions needed to prevent recurrences;

(h) maintenance of records and statistics, including reports of occupational health and safety inspections and occupational health and safety investigations, with provision for making them available to persons entitled to receive them pursuant to this Act; and

(i) provision for monitoring the implementation and effectiveness of the program.

(3) The employer shall make available a copy of the program

(a) to the committee or representative, if any; and

(b) on request, to an employee at the workplace. *1996, c. 7, s. 28.*

JOINT OCCUPATIONAL HEALTH
AND SAFETY COMMITTEES

Requirement for committees

29 (1) At every workplace where twenty or more persons are regularly employed, the employer shall establish and maintain one joint occupational health and safety committee or, at the discretion of the employer, more than one such committee and, where twenty or more persons are regularly employed by one or more constructors at a project, a constructor shall establish and maintain a joint occupational health and safety committee for the project.

(2) At a workplace where fewer than twenty persons are regularly employed, the Director may

(a) consult with the employer and employees at the workplace regarding whether a committee should be formed at the workplace; and

(b) order that a committee be established.

(3) Where an order respecting establishment of a committee is given pursuant to subsection (2), the employer shall ensure that the committee is chosen and functioning in accordance with this Act within fifteen days of receipt of the order. *1996, c. 7, s. 29.*

Composition and procedure of committee

30 (1) A committee shall consist of such number of persons as may be agreed to by the employer and the employees or their union or unions.

(2) At least half of the members of a committee shall be employees at the workplace who are not connected with the management of the workplace and the employer may choose up to one half of the members of the committee if the employer wishes to do so.

(3) The employees on the committee are to be determined by the employees they represent, or designated by the union that represents the employees.

(4) A committee shall meet at least once each month unless

(a) a different frequency is prescribed by the regulations; or

(b) the committee alters the required frequency of meetings in its rules of procedure.

(5) Where a committee alters the required frequency of meetings by its rules of procedure and the Director is not satisfied that the frequency of meetings is sufficient to enable the committee to effectively perform its functions, the frequency of meetings shall be as determined by the Director.

(6) An employee who is a member of a committee is entitled to such time off from work as is necessary to attend meetings of the committee, to take any training prescribed by the regulations and to carry out the employee's functions as a member of the committee, and such time off is deemed to be work time for which the employee shall be paid by the employer at the applicable rate.

(7) A committee shall establish its own rules of procedure and shall adhere to the applicable regulations.

(8) Unless a committee determines another arrangement for chairing the committee in its rules of procedure, two of the members of the committee shall co-chair the committee,

one of whom shall be selected by the members who represent employees and the other of whom shall be selected by the other members.

(9) The rules of procedure established pursuant to subsection (7) shall include an annual determination of the method of selecting the person or persons who shall

(a) chair the committee; and

(b) hold the position of chair for the coming year.

(10) Where agreement is not reached on

(a) the size of the committee;

(b) the designation of employees to be members; or

(c) rules of procedure,

the Director shall determine the matter. *1996, c. 7, s. 30.*

Functions of committees

31 (1) It is the function of the committee to involve employers and employees together in occupational health and safety in the workplace and, without restricting the generality of the foregoing, includes

(a) the co-operative identification of hazards to health and safety and effective systems to respond to the hazards;

(b) the co-operative auditing of compliance with health and safety requirements in the workplace;

(c) receipt, investigation and prompt disposition of matters and complaints with respect to workplace health and safety;

(d) participation in inspections, inquiries and investigations concerning the occupational health and safety of the employees and, in particular, participation in an inspection referred to in Section 50;

(e) advising on individual protective devices, equipment and clothing that, complying with this Act and the regulations, are best adapted to the needs of the employees;

(f) advising the employer regarding a policy or program required pursuant to this Act or the regulations and making recommendations to the employer, the employees and any person for the improvement of the health and safety of persons at the workplace;

(g) maintaining records and minutes of committee meetings in a form and manner approved by the Director and providing an officer with a copy of these records or minutes on request; and

(h) performing any other duties assigned to it

(i) by the Director,

(ii) by agreement between the employer and the employees or the union, or

(iii) as are established by the regulations. *1996, c. 7, s. 31.*

Deemed establishment of committee

32 Where a committee was established prior to January 1, 1986, and has been maintained, pursuant to a collective agreement or other arrangement in a workplace, and the Director is satisfied that such committee or arrangement provides benefits for the health and safety of employees equal to or greater than the benefits to be derived under a committee established pursuant to this Act, the committee or arrangement is deemed to have been established in compliance with this Act. *1996, c. 7, s. 32.*

HEALTH AND SAFETY REPRESENTATIVES

Requirement for and functions of representatives

33 (1) At a workplace where no committee is required pursuant to Section 29 and where the number of persons employed is five or more, the employer shall cause the employees to select at least one health and safety representative from among the employees at the workplace who are not connected with the management of the workplace.

(2) At a project where no committee is required pursuant to Section 29 and where the number of persons employed is five or more, a constructor shall cause the employees to select at least one health and safety representative for the purposes of the project from among the employees at the project who are not connected with the management at the project.

(3) At a workplace where fewer than five persons are employed, the Director may

(a) consult with the employer and employees at the workplace regarding whether a representative should be selected at the workplace; and

(b) order that a representative be selected by the employees from among the employees at the workplace who are not connected with the management of the workplace.

(4) Where an order respecting the selection of a representative is given pursuant to subsection (3), the employer shall ensure that the representative is selected and functioning in accordance with this Act within fifteen days of receipt of the order.

(5) An employee who is a representative is entitled to such reasonable time off from work as is necessary to carry out the employee's functions as a representative, and such time off is deemed to be work time for which the employee shall be paid by the employer at the applicable rate.

(6) It is the function of the representative to be involved, on behalf of the employees together with the employer, in occupational health and safety in the workplace and, without restricting the generality of the foregoing, includes

(a) the co-operative identification of hazards to health and safety and effective systems to respond to the hazards;

(b) the co-operative auditing of compliance with health and safety requirements in the workplace;

Section L

Terms and Definitions

Section M

Appendix

24) JFC Emergency Response Planning Group, Minutes & Documents

PUBLIC RELATIONS LIMITED

Cumberland Regional Economic Development Association

Communications Plan for Joggins Fossil Cliffs and Cape Chignecto Provincial Park

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INTRODUCTION

MT&L Public Relations has been asked to consider inputs, including new and available research and develop a joint marketing communications plan for the Joggins Fossil Cliffs and Cape Chignecto Provincial Park. Through primary and secondary research, current perceptions of both sites have been assessed and the best course of action for marketing and communication.

Communications occur in a highly dynamic, external environment. Therefore it is important to gain an understanding of external perceptions, assumptions, and influences before launching a communications plan or initiative. Moreover, perceptions do not always reflect reality, and external perceptions are often slow to change. However, information about perceptions that exist among stakeholders is important to the Cumberland Regional Economic Development Association (CREDA), the Joggins Fossil Institute, Cape Chignecto Provincial Park, and the region. This is particularly true when considering marketing and communications initiatives for both the Joggins Fossil Cliffs and Cape Chignecto Provincial Park as CREDA seeks ways to attract visitors to these natural sites.

In developing this plan, both qualitative and quantitative research was undertaken. Research included a visit to both sites to meet with local staff and others in the community. Design and interpretive elements being developed by D+C, the design firm for the Joggins Fossil Cliffs and Centre were reviewed in addition to a wide range of background information provided by staff of the CREDA, Cape Chignecto Provincial Park, and other stakeholders. Media and profile articles, websites and other materials were also reviewed. The qualitative research consisted of a communications audit involving 25 key stakeholders to identify the perceptions and the main issues and/or opportunities for future marketing and communications initiatives for the Joggins Fossil Cliffs and Cape Chignecto Provincial Park.

Solid strategy and sustained communications are critical in creating a greater awareness of both sites, attracting visitors, and ultimately increasing socio-economic development in the area. The following strategy and tactical plan supports this overall objective.

In the competitive tourism market, good plans can be established over a short time, but perceptions, awareness and understanding can only be changed over an extended implementation period. As this plan is implemented, it will be important to have continual assessments through benchmark research and to involve and mobilize specific individuals or organizations for their support, but more importantly, for the influence these partners can bring to promoting the objectives, and ultimately, the brand of the Joggins Fossil Cliffs and Cape Chignecto Provincial Park.

SITUATION ANALYSIS

The Joggins Fossil Cliffs are recognized worldwide as possessing an unrivalled fossil record of the Coal Age tropical ecosystem preserved in its truest environmental context.

2006 marks both the beginning of construction of a new centre at the Joggins Fossil Cliffs, as well as the potential inscription as a UNESCO Natural World Heritage Site. In preparing for these significant milestones, it is an objective of the Joggins Fossil Institute to raise awareness of, provide for the advancement of scientific research, and increase appreciation for the site's natural heritage. CREDA is working with key partners and stakeholders to ensure that the Joggins Fossil Cliffs property is developed into a world-class sustainable tourism, scientific and educational product, which will, in turn, foster lasting economic benefits for the Cumberland County region, Nova Scotia, and the Maritimes as a whole. This new site is also intended to act as an "anchor" for the region to attract visitors, who will then visit other sites and destinations in the area. 2006 is also a pivotal year for Cape Chignecto Provincial Park as the Park has been operating for over ten years and has initiated further enhancements with construction of a new visitor centre and opening the west side for day use for a wider audience. Cape Chignecto Provincial Park continues to offer exceptional hiking and camping in a scenic, natural setting, and also the opportunity for cross-promotional activities to attract visitors to both sites.

The new centre at the Joggins Fossil Cliffs will provide research facilities for scientists and provide educational and interpretive areas for the general public, visitors, and local community member groups. The approximately 13,000 square foot centre will provide opportunities for visitors to interpret the Coal Age period of geological time and the fossil cliffs, access food, and shop for souvenirs. Amenities will include a café, a multipurpose room (for meetings and education), a dry and wet lab, a gift shop, office space for the RCMP, and interpretive space. Administration functions for the management of the site will be housed at the centre as well. The design of the centre will minimize the ecological footprint and has been created to conserve energy and reflect respect and stewardship of the natural world.

The three essential aspects of the visitor experience at the Joggins Fossil Cliffs and new centre will be: (1) The fossils - the scientific and human importance of the Coal Age life and the stewardship of these resources; (2) The community of Joggins - its cultural, historic and geological dimensions and; (3) The cliffs - Joggins' position within the Bay of Fundy ecosystems and the forces that created and shaped the cliffs.

Although Joggins has an established profile among geologists and individuals engaged in the areas of natural sciences, it is relatively unknown as a visitor destination. Therefore, there is a need to create a greater overall awareness of: (1) The site(s) as a destination to visit; and (2) What the fossil cliffs represent; a more thorough understanding of the story of the fossils in the context of natural history.

Up to now, the experience offered by the Joggins Fossil Cliffs has not been positioned and marketed as a destination for visitors, families, adventure seekers, and other audiences. While Cape Chignecto has engaged in marketing activities over the years, the visitor experience at Cape Chignecto has been enhanced with the completion of Phase Two, and now offers day-use trails and new view points, in addition to the hiking and camping experience. Until now, focus or effort has not been put into developing either site as a comprehensive visitor experience and many potential visitor markets have not been explored. The Joggins site attracts approximately 25,000 visitors annually (Andrea Arbic Report) despite its few amenities and limited interpretive material. The establishment of the Joggins Fossil Institute, construction of the new centre and its supporting programs will significantly enhance the visitor experience, allowing everyone to discover the “power of the cliffs”.

The Joggins Fossil Institute submitted the nomination dossier to UNESCO in September 2006 and the potential distinction of the fossil cliffs as a site of international scientific importance will be a very positive marketing communications factor for implementing the communication plan. Inscription on the UNESCO World Natural Heritage list would make Joggins an even more appealing destination for residents, visitors, and educational markets. Cumberland County is home to a diverse range of attractions. Many of these attractions are smaller than the property and centre at Joggins, most attractions in the region operate on a seasonal basis and there is an opportunity to increase overall visitation beyond its current level. There will be opportunities to work with many of the other destinations in the area, and the centre at Joggins will be complimentary to not only other attractions in the county, but also other provincial and regional attractions and popular areas of destination or travel. There will be an opportunity to work with the Fundy Geological Museum, which is open year round.

The success of Hopewell Rocks, for example, in attracting visitors demonstrates the potential for a high quality visitor centre at a geological site to attract significant visitor numbers. In 2005, Hopewell Rocks attracted over 180,000 paid visitors to the site, the second highest visitor numbers among all attractions in New Brunswick (Andrea Arbic Report). New Brunswick has positioned Hopewell Rocks as a lead attraction for the province and, has invested heavily in marketing the site. Hopewell Rocks has benefited from aggressive marketing and this has been critical in creating the high profile needed to attract significant numbers of visitors.

The nature and quality of the visitor experience will have the greatest impact on attendance levels. Other international heritage sites dedicated to the conservation and interpretation of the sites’ geological and paleontological importance have developed an international reputation for excellence. Marketing and site promotion has been driven by their world-class interpretive centres and programming. The key elements that have influenced their attendance has been educational programming and hands-on interpretive elements. Once the centre at Joggins is open and programming is developed, the intention is that the visitor experience at Joggins will be interactive and high quality, therefore, sufficient to generate positive word-of-mouth and repeat visits.

The resident market for Joggins is small, meaning that the site and the centre must attract a high proportion of visitors from greater distances. While Joggins' proximity to the busiest provincial gateway is an opportunity - only a thirty minute drive from the Nova Scotia/New Brunswick border – few motor vehicles actually stop in Amherst. Going forward, those visitors who do stop at the Amherst visitor centre should be provided with information to encourage them to visit both sites. Additionally, Joggins is located on a secondary highway that does not currently attract high levels of traffic. Therefore, the centre and the site will not benefit from the type of "drive-by" traffic that it would if it were located on a major travel route.

There are limited visitor services and amenities in the immediate area around the community of Joggins, such as service stations, restaurants and accommodations. It is reasonable to expect, however, that the local tourism infrastructure will develop over time as more visitors are drawn to the Joggins area with the opening of the centre. Significant effort has been made to date in including the community of Joggins and it will be a priority going forward to continue to ensure opportunities are sought to further engage local residents.

The focus of this plan's marketing and promotional efforts will be to attract visitors to the new centre at Joggins. Opportunities will be identified to also promote Cape Chignecto Provincial Park. Visitors to one site, by virtue of their interest in geology, natural sciences or nature, would likely also be inclined to visit other area destinations, which would complement their visitor experience. Therefore, it is expected that an increase in visitors to Joggins will provide an opportunity to attract visitors to Cape Chignecto Provincial Park. In the future, both the centre at Joggins and Cape Chignecto Provincial Park will benefit from plans to market the Fundy shore as a tourism destination area. The region itself and other attractions along the shore will in turn benefit from a higher profile as a result of the World Natural Heritage Site designation at Joggins.

REVIEW OF RESEARCH

An important component in the development of the communications plan is the preliminary research. The research conducted has helped determine directions, develop the strategy, and identify the tactical approaches outlined in the plan.

MT&L visited both the Joggins Fossil Cliffs site as well as Cape Chignecto Provincial Park to meet with local staff and others in the community. It gave us the opportunity to view the sites first-hand, ask questions and get a sense of the visitor experience. In addition to this, we met on several occasions with CREDA and were briefed on the development of the sites and overall vision. We also had the opportunity to review the design and interpretive elements being developed by the design firm, D+C. MT&L reviewed a wide range of background information provided by staff of CREDA, Cape Chignecto staff and other stakeholders, including back issues of *Cliff Notes*, *CREDA Newsletter,* relevant media and profile articles and material. We also reviewed the websites of both attractions as well as all relevant promotional material for both Cape Chignecto Provincial Park and the Joggins Fossil Cliffs.

We also undertook a review of regional and provincial tourism information, including promotional videos, pamphlets, websites, guides and other tourism related material.

Our research included a review and analysis of the Andrea Arbic report, *Operating Revenues & Expense Projections*. In addition to this, MT&L reviewed the Atlantic Canada Opportunities Agency funding proposal, as well as a number of other submissions and proposals made to various government organizations and funding agencies.

In addition, MT&L conducted a qualitative assessment in the form of a communications stakeholder audit. One-on-one interviews were conducted with 25 stakeholders in an effort to gauge their perceptions and seek input on future marketing and communications initiatives for Joggins and Cape Chignecto.

Based on this research, a SWOT (strengths, weaknesses, opportunities, threats) analysis was conducted. Below is a summary of the key findings.

Areas of Strength

- **The story of Joggins as an educational experience**. The geological story of the cliffs and the historical significance of the fossil cliffs is its key strength. The story of Joggins and the cliffs represent a place in time that visitors can discover. It is unique to the region and to the world. Through interpretation, visitors can be guided back through time.

- **The experience of self-adventure.** The prospect of exploring for and discovering a fossil or evidence of past life and participating in stewardship is a key element to the experience offered at Joggins. Finding a fossil can be a special experience and, through interpretation, visitors can be left to explore and learn about the cliffs and beach on their own or with their families.

- **Strong awareness and profile of Joggins among enthusiasts.** There is currently a strong degree of awareness of the fossil cliffs among those individuals who have an interest in geology and natural history. These individuals are aware of the site because of its reputation and they tend to find out about the site through their own research and have some degree of knowledge of its historical and geological significance.

- **Distinctive coastal/tidal experience.** The experience at Joggins is special because it is unlike any other destination in the region. Visitors have direct access to the beach and will be provided with world-class interpretation of the geological and natural historical significance of the fossils. During the timeframe projected for the opening of the centre, there will be no other attractions with a comparable focus developed in the Fundy region. A visit to the shores is not a 24 hour a day experience like Peggy's Cove because beach access is limited due to the tides. The tides, on the other hand, do allow the visitor to experience the beach first-hand. Tidal erosion continually changes the nature of each visit.

- **Appeal to wide variety of audiences.** Beyond the dedicated enthusiasts, both sites have the opportunity to appeal to a broad range of potential visitors, including school groups, outdoor hiking enthusiasts, and elder hostels, among others. This broad appeal is a strength in attracting potential visitors to both the Joggins Fossil Cliffs and to the new interpretive centre.

- **International recognition**. The UNESCO Natural World Heritage Site designation would enhance the reputation of the Joggins Fossil Cliffs, as well as that of the entire region. The geological and historical significance of the fossil cliffs are internationally recognized, which offers an opportunity to reflect this in marketing and communications efforts. The UNESCO designation would significantly elevate international recognition.

- **The "total coastal" experience of Cape Chignecto.** Visitors to the park can experience accessible and backcountry trails, as well as remote trails. Given the varying degree of difficulty of the trails, the park can be accessed not only by the serious hiker, but also the casual visitor. The park offers a "total coastal" experience with large cliffs, deep valleys, sheltered coves and scenic and wilderness trails. The hiking, camping and trails are situated along the coast. Its location on the Fundy shoreline makes it different from any other park in the province.

- **Natural complementary attributes of both sites as a destination.** The type of visitors who would be attracted to one site would naturally be inclined to visit the other. Both sites offer extreme outdoors as an experience not typical of others in the region.

- **"Green" Building and Operations**. The new centre at Joggins is a state-of-the-art facility that is being built with the environment in mind. The use of renewable energy, LEED, pursuing ISO certification, interpretation of coal age relative to climate change, recycling, choice of products (paper vs plastics) will appeal to the "eco-tourist" and project funders. As well, CCPP's new visitor centre has also been designated an LEED architect and will operate under the same ISO registration as Joggins. At Cape Chignecto, Phase Two is completely powered by renewable energy.

Areas of Weakness

- **Lack of general awareness and understanding of the sites**. Among the general public, there is only a very basic level of knowledge about the fossil cliffs. Even among the general public who are aware of the site, there is not a high degree of understanding of its outstanding universal value or geological importance. People who know about it do not necessarily know what is there. There is also a lack of awareness of what Cape Chignecto has to offer - current experiences and also expanded opportunities for day use.

- **Lack of amenities.** There are a lack of amenities within the proximity of Joggins and Cape Chignecto required to support an increased number of visitors (such as adequate restaurants, hotels, service stations and other support infrastructure).

- **Poor road signage.** Lack of sufficient road signage to direct visitors to both the Joggins Fossil Cliffs and Cape Chignecto Provincial Park is a challenge for current and prospective visitors.

- **Readiness of the community of Joggins**. Generally speaking, awareness of the significance of what the development will bring and means to Joggins is limited. The readiness of the community to welcome additional visitors presents communications challenges. It is understood that Cape Chignecto faced a similar challenge but that the community has largely begun to embrace the park.

- **Perception that Joggins and Cape Chignecto Provincial Park are out of the way relative to major centres.** There is a perception that both sites are hard to get to—that they are not close to anything and are "off the beaten track." Although many will be attracted to places they consider remote or out of the way, the perception that the sites are not easy to access could impact on visitation.

- **Perception that there is a critical mass of things to do in the region**. The region faces the challenge of keeping visitors in the area, once attracting them, due to a perception that there are a limited number of alternative places to visit in the region. Other area visitor attractions are not high profile and not necessarily directly linked to either Cape Chignecto or the Joggins Fossil Cliffs.

- **A general lack of appreciation or understanding of natural heritage** The average person may not find the fossil cliffs interesting, and would not be able to fully appreciate the geological and historical significance of the fossils. This holds true for the natural history/heritage at Cape Chignecto as well.

- **Outdated marketing material for Cape Chignecto**. The opening of the day use trails and new view points have elevated the quality of the visitor experience currently offered at the Park. Therefore, some marketing material for the area is now outdated; it does not reflect the current enhanced visitor experience.

Opportunities

- **Branding Joggins**. Since the general public is largely unaware of what the property and centre has to offer or knowledgeable about the fossils, there is an opportunity to brand Joggins without having to overcome pre-conceived ideas or perceptions about the site among most prospective visitors.

- **Expanding the visitor volume beyond the core visitor.** Currently, the visitor core to the site is largely history and geologist enthusiasts, and those who discover the site by word-of-mouth. The experience can be many things to many people, and a wide range of people would be interested in visiting both sites. As well, because of the changing nature of the cliffs (due to the tides), an opportunity also exists to encourage repeat or return visitors - because the experience is different each time.

- **UNESCO World Natural Heritage Site designation**. Potential inscription will present an opportunity to reach a target market of those individuals or groups who seek out such sites as destinations. The site should be branded as a “must see” for this group. There are a number of opportunities related to UNESCO, such as UNESCO mailing lists, clubs and societies, scientific meetings, guidebooks and maps, and profile articles in target publications such as *Canadian Geographic.* Other sites dedicated to the conservation and interpretation of the sites’ geological/palaeontological importance have developed international reputations for excellence. Marketing and site promotion has been driven by their world-class interpretive centres and programming.

- **Further local community engagement**. There is an opportunity to further develop civic pride and a sense of stewardship of the property and new centre within the community of Joggins. Also, opportunities exist related to the development of Joggins for economic renewal. Development, management and conservation of the fossil cliffs site and potential inscription on the World Natural Heritage List will provide much-needed economic vibrancy to the community that will spin growth, employment, investment opportunities, entrepreneurship, and both community pride and vision for the future.

- **Engaging the student market.** Like most heritage attractions, primary and secondary school groups will represent an important resource of visitors for Joggins. The potential primary and secondary school market in the region is approximately 25,000. With over 200 geology schools or colleges with geology departments in the United States, and 20 Canadian universities offering geology degrees, there is also potential for Joggins to attract visitors from a broader number of post secondary schools.

- **Plugging into existing tourism networks.** These would include Tourism Nova Scotia, Fundy Shore Tourism Destination Area, TIANS, NSATA, CNTA, among others. An opportunity exists, particularly for Cape Chignecto, to plug into the network of hiking and outdoor enthusiasts through targeted marketing, mailing lists, and membership targeted activities.

- **Developing educational material.** There is an opportunity to develop interpretive materials and marketing that speak to the natural and geological significance of the site. Materials can provide visitors with the tools they require to explore the beach and the fossils on their own and address the varying degree of understanding and interest of visitors.

- **Creating regional partnerships.** In order to encourage higher traffic to the region, an opportunity exists to work with other local businesses and attractions to develop a package geared towards "destination marketing".

- **Developing joint marketing initiatives.** The natural historic and geologic similarities of both sites, as well as the coastal experiences offered at both sites, presents an opportunity to develop joint marketing initiatives. Marketing initiatives could draw visitors who would be attracted to one site, and by virtue of their interests, also be interested in visiting the other site. Opportunities exist as well to promote area kayaking, birders, museums, antique shopping, dining, among others.

- **"Green" Building and Operations**. The new centre at Joggins is a state-of-the-art facility that is being built with the environment in mind. The use of renewable energy, LEED, pursuing ISO certification, interpretation of coal age relative to climate change, recycling, choice of products (paper vs plastics) presents an opportunity to appeal to the "eco-tourist" and project funders. The LEED and ISO certification of CCPP will also present the same opportunity. At Cape Chignecto, Phase Two is completely powered by renewable energy.

Threats

- **Poor visitor experience and word-of-mouth**. Visitors to date who have experienced both the Joggins Fossil Cliffs and Cape Chignecto Provincial Park have formed impressions based on the quality of their visits. Many of them chose to visit because they have heard from others of the distinctive features of the sites. Cleary, "word–of-mouth" and reputation have been key factors in forming lasting opinions and impressions. Going forward, it will be important to address the threat of a negative visitor experience. A negative visitor experience would undermine the branding of the sites and impact on return visitors and potential visitors who might have considered Joggins or Cape Chignecto as a place to visit. Threats could emerge from any of the following factors:
    - Visitors could go to the cliffs and be disappointed because they might mot be able to access the beach;
    - Lack of understanding of the fossils by the visitor, and then disappointment when they can not fully appreciate the fossils;
    - Visitors could search the beach at Joggins and not find any fossils. Without the necessary guidance and interpretation, visitors may be disappointed and not return, not refer others, or even discourage prospective visitors.

- **The lack of capacity of the community of Joggins to accommodate visitors.** This could lead to a poor visitor experience. This is especially a factor as it relates to road access, lack of visitor amenities, as well as the perceived poor condition of the community of Joggins.

- **The perception that Joggins and Cape Chignecto are out of the way relative to major centres**. Although the location of both sites can be attractive to some potential visitors, this perception could also prevent some visitors from seriously considering a trip to the area.

- **Relying on the UNESCO designation**. Although the historical and geological significance of the fossil cliffs are internationally recognized, the UNESCO World Natural Heritage Site designation has yet to be achieved. Should marketing and promotion efforts portray the site as a UNESCO site, and designation is not secured, it could negatively impact the reputation.

- **Perception of Joggins as unsafe.** Some potential visitors might not consider the Joggins Fossil Cliffs as a destination because they perceive the site as unsafe and uncontrolled.

- **Perception that visitors must be experienced.** The perception that the hiking and camping experience offered at Cape Chignecto is for the "extreme hiker" might prevent others, such as families with kids or older visitors from considering a visit to Cape Chignecto.

- **Lack of understanding of the fossil collecting policy.** There may be a lack of understanding among visitors as to the policy on viewing the fossils. Up to now, the general public has received mixed messages about the site and whether or not collecting fossils is permitted. To ensure visitors are not disappointed, efforts will be required to communicate the stewardship of the site.

DRAFT

Key Communications Considerations

Based on our research, we have identified key communications considerations that have guided the development of the marketing communications strategy.

Partnerships. The new interpretive centre at Joggins is being developed in partnership with a number of organizations, including CREDA, the provincial and federal governments, among others. In developing a marketing communications strategy, consideration will need to be given to engaging the various partners involved in the project—either currently involved or those that would be useful to engage. These partners, specifically government, may also be valuable to address issues which may impact visitor experience, such as road signage, infrastructure, road access and other challenges. Therefore, stakeholder and government relations are a key communications consideration.

Location. The Joggins Fossil Cliffs site and Cape Chignecto are currently as well positioned as visitor destinations relative to others in the province, so most visitors will be required to make a deliberate effort to visit. Targeted efforts will be required to raise awareness of Cape Chignecto Provincial Park and the Joggins Fossil Cliffs and their location relative to Halifax, the New Brunswick/Nova Scotia border and the New Brunswick/PEI border.

Unique Visitor Experience. The Joggins Fossil Cliffs and the new centre offers a distinct educational experience, coupled with self-exploration and adventure. It is the only place in the world that will offer the opportunity to, in a sea coast setting, discover fossils from the Coal Age, along with world-class interpretation and programming.

Importance of interpretation. While the science and history of the area is highly significant and of outstanding universal value, it is relatively "academic" and not easily accessible as an educational and recreational experience. Without interpretive materials and programs, a visit to Joggins could seem like an unfulfilling effort that may not meet visitor expectations. It will be important, therefore, to create an experience that will help the visitor better understand the site. With this in mind, on site programming and interpretive material will guide and educate the visitor. Marketing efforts will need to reflect the actual experience of visiting the site and set realistic expectations about what the visit will offer through these programs and interpretive materials.

Motivated audience. There are clusters of individuals, or target audiences, who will be more likely predisposed to visiting Joggins because of their interest in natural history or geology. Those working or teaching geosciences, as well as serious "rock hounds" represent a relatively small but important potential market for Joggins. This audience includes geologists, university researchers, naturalists and scientists, among others. This audience will naturally have a greater awareness and higher level of engagement with respect to the "story of Joggins." This market is highly motivated to visit sites like Joggins and is likely to spend more time at the site than casual visitors. Focussing on attracting the more "engaged" visitor in initial marketing efforts would also likely yield a higher visitor rate than other audiences.

Understanding audiences. We recognize that the complete audience for communications encompasses a broad spectrum. The experience offered by the Joggins Fossil Cliffs has not been positioned as a destination for visitors, families, adventure seekers, and other audiences. With the new interpretive centre, it will be important to identify and understand the various audiences. While different audience groups may be interested in the new centre, their level and focus of interest will be varied. Understanding audience segments and their specific interests will be key. Consideration should be given to how best to reach, motivate and guide these potential visitors, and to ensure that once recruited they have a positive experience.

Destination marketing. Cumberland County hosts a number of other attractions and points of interest. Visitors to the region could enjoy a number of area experiences within the vicinity of Joggins and, although the attraction and value of a new interpretive centre at Joggins is worthwhile, it will be important to highlight (or offer) to visitors other attractions in order to create an enhanced visitor experience. Where possible, synergies between the marketing and communications efforts of other area destinations can be achieved.

Visitor services considerations. The lack of amenities and visitor services should be addressed in conjunction with promoting the area as a visitor destination. The capacity of the area to accommodate an increased number of visitors is an important consideration. Visitors may be disappointed if they arrive in Joggins and are unable to access services they expected. Until adequate lodging, dining, gas and other services are available in the immediate vicinity, communications efforts should consider ways to provide visitors with information about alternative service options currently offered in the area.

Engaging the community of Joggins. A key consideration in the marketing and promotion of Joggins will be to achieve a higher degree of engagement from the local community. Successfully seeking and securing buy-in from the community could instil a sense of pride among residents. If those living in the region recognize the value of sharing Joggins with visitors, it will encourage them to improve the condition of the community, be more likely to be receptive to those visitors once they arrive, and capitalize on the economic development opportunities. The perceived lack of engagement of the community of Joggins presents both challenges and opportunities in developing a marketing and communications strategy for the site and the region.

Accessing provincial tourism infrastructure. There are currently a number of organizations within the province and the region that work collectively to ensure that Nova Scotia and the region are positioned as a visitor destination and that the specific attributes of each destination are communicated to potential visitors. Marketing and communications opportunities to promote Joggins can be achieved by working with organizations such as the Province, Fundy Tourism Partnership, Central Nova Tourism Association, CREDA and others.

Addressing improvements to roads and signage. The need for improvements to roads leading to Joggins could be an impediment to attracting visitors. This is primarily a factor for family vehicles and motorcycles. It will also be important to develop new road signage to direct visitors to the sites. Although there is some signage already in place, current signage can be improved upon. As the sites develop, the nature of the visitor experience will need to be reflected in road signage.

Stewardship of the site and fossil collecting. The largest threat to the Joggins Fossil Cliffs is the illegal removal of fossils from the site. Excavation of fossils is limited to removal of exposed specimens under the authority of the a Heritage Research permit granted by the Province of Nova Scotia to qualified researchers only. It will be important, therefore, to communicate to visitors the policy for discovering fossils. Public education, through interpretive programs, on-site instruction and print media will be required to ensure that visitors understand and respect the fossil collecting policy and are not disappointed that they are not permitted to remove fossils from the beach.

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GOALS

Based on our review of research and key findings from the SWOT analysis, we have identified the following as the primary goals of the marketing communications plan for the Joggins Fossil Cliffs and Cape Chignecto Provincial Park.

- To enhance and create awareness of Joggins as a world-class sustainable tourism, scientific, and educational destination.
- To attract visitors to the Joggins Fossil Cliffs.
- To build a sustainable framework for the long-term Joggins experience for stakeholders.
- To seek opportunities to co- or cross-promote Cape Chignecto Provincial Park with Joggins Fossils Cliffs to targeted audiences.

OBJECTIVES

In support of the goals, below are the objectives that will guide the tactical elements identified in this plan.

- To create awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- To clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- To attract visitors to the Joggins Fossil Cliffs in support of the visitor projections of 38,400 in year one, 42,300 in year two, and 40,200 in year three (based on the Arabic Report).
- To support a positive and exceptional on-site visitor experience at the Joggins Fossil Cliffs centre.
- To encourage regional visitation and “cross pollination” among other area destinations by engaging in tourism partnerships.
- To encourage coordination with regional and community organizations.

TARGET AUDIENCES

The following list outlines audiences to whom staff at Joggins and Cape Chignecto should direct its communications efforts. The target audiences have been divided into two categories–primary audiences and secondary audiences. Within each, there are specific target groups. Short-term situations may require that certain groups are added or removed. However, the following groups will have the most ability to achieve the overall goals of this plan. With this in mind, we want these audiences to have as much information as possible about the visitor experiences offered at both sites.

Primary Audiences

Local Community

- Business owners
- Residents
- Chambers of Commerce
- Key community influencers

UNESCO Network

- Individuals and organizations who support world heritage values
- Conference attendees
- Nomination committee
- Other UNESCO World Heritage sites
- Targeted publications

Government

- Federal government
  - Parks Canada
  - Natural Resources Canada
  - Atlantic Canada Opportunity Agency
  - Department of Heritage
- Provincial government
  - Office of Economic Development
  - Department of Natural Resources
  - Department of Tourism, Culture and Heritage
  - Office of Health Promotion
  - Department of Education
  - Department of Environment and Labour
  - Communications Nova Scotia
- Local government
  - Municipality of the County of Cumberland
  - Town of Amherst
  - Town of Parrsboro

Potential Visitors and Visitors

- Nova Scotia residents
  - Halifax residents
  - Amherst
  - Families
- Atlantic Canada residents
  - Moncton residents

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  - Individuals and groups entering the province
  - Vehicle traffic
  - Hotel visitors
- Outdoor enthusiasts
  - Hikers
  - Campers
  - Nature seekers
- Residents of other Canadian provinces
  - Families
  - 55-64 year old travelers – “empty nesters”
- International visitors
  - Families
  - 55-64 year old travelers – “empty nesters”

Media

- Local
  - Print
  - Television
  - Radio
- Provincial
  - Print
  - Television
  - Radio
- Regional
  - Print
  - Television
  - Radio
- National
  - Print
  - Television
  - Radio
- Tourism and travel
  - Publications
  - Magazines
  - Guides
  - Online sites
- Scientific
  - Publications
  - Magazines
  - Online sites
- Recreation and sports
  - Publications
  - Magazines
  - Online sites

Geologists and Educational Community

- Geologists
- “Rock hounds”
- Educational institutions
- Research community

Travel Industry

- Tour operators
- Travel agents
- Travel publications
    - Guides
    - Publications
    - Magazines
    - Online sites

Secondary Audiences

Cumberland Regional Economic Development Agency

- Board of Directors
- Staff
- Action team
- Volunteers

Tourism Industry Organizations

- Regional tourism organizations (i.e., Fundy Shore Destination Tourism, Central Nova Tourism Association, Bay of Fundy Tourism Partnership)
- Provincial tourism organizations (TIANS, Atlantic Canada Tourism Partnership)

Educators/Students

- Universities
- Teachers
- Curriculum advisors
- Students
- Parents

KEY MESSAGES

Given the varied audiences identified in the development of marketing and communications initiatives, every effort should be made to consistently deliver concise messages to meet the needs of each audience. Each key message must be adaptable for the intended audience, while still maintaining its original intent. The underlying themes in the key messages must reinforce the underlying idea that both Joggins and Cape Chignecto offer the visitor a distinct and positive visitor experience. The following are the overall messages for Joggins, Cape Chignecto and the region, while specific key messages for other audiences are listed below.

Broad Key Messages - Joggins Fossil Cliffs

- The Joggins Fossil Cliffs represent the best example of the “Coal Age” terrestrial ecosystem in the world – it’s a trip through time and illustrates life 350 million years ago.
  - The quality, diversity and quantity of the fossils at Joggins are unrivalled.
  - The cliffs have yielded fossils that have given an unprecedented glimpse of life during the Coal Age. It is the world’s largest collection of fossils from this period.
  - The fossils at Joggins show the first evidence of animal life on land. They are referenced in Charles Darwin’s, *The Origin of Species.*

- The Joggins Fossil Cliffs are recognized worldwide and the site is a potential inscription on the UNESCO World Heritage List.
  - To develop, manage, and conserve the Joggins Fossil Cliffs site, natural heritage values are respected, valued and understood.
  - The Joggins Fossil Institute in partnership with the Province of Nova Scotia and the Municipality of the County of Cumberland will promote, conserve, and manage the property and the fossil resource.

- The new Joggins Fossil Centre will provide research facilities for scientists and provide educational and interpretive areas for the general public, visitors, and local community member groups.
  - The approximately 13,000 square foot centre will provide opportunities for visitors (visitors) to interpret the Coal Age period, purchase food, visitor information, shop for souvenirs, and access reference/educational material.

- Fossil discovery is about scientific, educational and awareness-building. Uncontrolled collecting of fossils on the property by persons not in possession of an approved permit is prohibited.

Broad Key Messages - Cape Chignecto Provincial Park

- The hiking trails and the varying degrees to which they challenge visitors, both campers and hikers alike, are unlike any others offered in Nova Scotia.

- The Park is easily accessible for the casual visitor. You don't have to be in top physical condition to enjoy the Park. The new day use trails, visitor walkways and view points offer the casual visitor a glimpse of the spectacular nature of the Park.

- The Park showcases unexploited beauty and sense of unspoiled nature. The trails can be remote, free of people and outside distractions.

- Cape Chignecto has built its reputation on its awareness and respect for the environmental, on its mission of embracing and involving the community in the operation of the park and on its desire to sustain a pristine wilderness environment.

- Cape Chignecto is about promoting healthy lifestyles, physical fitness and awareness for the environment.

- Phase Two of the Park is completely powered by renewable energy.

Broad Key Messages – The Region

- Joggins is located in Nova Scotia, Canada – which has a positive national and international reputation. The Joggins and Cape Chignecto sites are representative of Canada's and Nova Scotia's rugged, unspoiled nature and known as a safe place to visit.

- The Joggins Fossil Cliffs are located on a scenic coastal loop in Nova Scotia, which includes the Fundy Geological Museum, Cape d'Or and Cape Chignecto Provincial Park, among others.

- There is something in the region for the entire family. There are a number of complementary attractions and sites to visit.

- The area is largely unexplored – it's a hidden jewel.

- At the Bay of Fundy, visitors will encounter an amazing landscape steeped in history and shaped by the highest tides in the world.

- The Fundy shores offer some of the best outdoor experiences Nova Scotia has to offer, including tidal bore rafting, amazing coastal hiking, sea kayaking, and fossil and rock hounding.

- The area is renowned for its aboriginal heritage and geology, including distinctive landforms, fossils, dinosaur bones, and semi precious stones.

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- Other cultural heritage attributes in Cumberland County include, the age of sail, mining and railway history, four of the fathers of confederation came from this area, art, antiques, festivals, music etc.

The varied audiences will need to be considered in the development of marketing and communications initiatives, and efforts must consistently deliver concise messages to meet the needs of each audience. Specific key messages for each audience are noted below.

Audience	**Adapted Messages**
Local Community	• The community of Joggins has been consulted and involved throughout the development process for the Joggins Fossil Cliffs centre. o Regular meetings o Updates provided o Access to committee members • Working together with the Joggins Area Planning Advisory Committee, the economic and social needs of residents as well as visitors have been carefully considered. o Housing needs o Quality of life o Local development issues • The new Joggins Fossil Cliffs centre will ensure economic sustainability through tourism and infrastructure. o Increase marketing of area means more visitors o Growth in popularity will influence need for amenities, staff o The centre will provide the community with a facility that will be available for their use and enjoyment • The residents of Joggins will continue to act as stewards of the property, by assisting the managers in

	communicating the fossil collecting policy to visitors to the community.
UNESCO Network	• Joggins Fossil Cliffs are an unrivalled historical and cultural resource that should be preserved and internationally recognized. o Provide an unprecedented view of life during the Coal Age period o Demonstrate first evidence of animal life on land • The community of Joggins and province of Nova Scotia are honoured that the Joggins Fossil Cliffs are being considered for the UNESCO World Heritage list. • As part of the UNESCO World Heritage list, Joggins Fossil Cliffs would strive to exceed international standards for heritage management.
Government	• The property is currently protected by the Special Places Protection Act and the Beaches Act. • The province of Nova Scotia has been consulted throughout the development process for the Joggins Fossil Cliffs centre. o Regular meetings o Updates provided o Access to committee members • The Joggins Area Planning Advisory Committee will continue to partner with various members of government to explore mutually beneficial activities for the Joggins area, including: o Signage o Road development o Potential promotion of UNESCO World Heritage listing • The development of the

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	new Joggins Fossil Cliffs centre will contribute to several areas of growth in the province as well as nationally and internationally, including: o The economy o Tourism and Hospitality
Geologists/Research Community	• Joggins Fossil Cliffs is the richest, most representative and significant Coal Age fossil site in the world. • The new Joggins Fossil Cliffs centre will provide research facilities for scientists to explore the unprecedented quality, diversity and quantity of fossils at the site. • Further development and natural change in the Joggins Fossil Cliffs will ensure ongoing research and learning opportunities for the geology and research community. • The fossil collecting policy will be communicated directly to visitors to ensure the stewardship of the site.
Visitors	• Joggins Fossil Cliffs is a historical and cultural treasure that illustrates life 350 million years ago during the Coal Age. o The first evidence of animal life on land. o Unrivalled quality, diversity and quantity of fossils. • A visit to Joggins Fossil Cliffs will be an exciting, adventure-filled, educational discovery of life. o Fossil exploration and discovery o Bay of Fundy tides o Day trails, walkways, viewpoints, hiking, camping and trails • The Joggins Fossil Cliffs is an easily accessible site that appeals to a broad

	range of enthusiasts of all ages. o Low-intensity activities for children and seniors o Challenging trails and hiking for the hardy outdoor adventurers o Plenty of activities in between for everyone else
Travel Industry	• The Joggins Fossil Cliffs and Cape Chignicto Provincial Park offer travelers an unparalleled outdoor adventure. • At the Joggins Fossil Cliffs centre visitors can discover firsthand fossils from 350 million years ago and learn about the significance and importance of preservation of these treasures. • The Joggins Fossil Cliffs is an easily accessible site that appeals to a broad range of enthusiasts of all ages. o Located on a scenic coastal loop in Nova Scotia that includes Cape Chignicto Provincial Park, Cape d'Or and the Fundy Geological Museum o Low-intensity activities for children and seniors o Challenging trails and hiking for the hardy outdoor adventurers o Plenty of activities in between for everyone else
Educators	• Joggins Fossil Cliffs is a historical and cultural treasure that illustrates life 350 million years ago during the Coal Age. o The first evidence of animal life on land.

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	- Unrivalled quality, diversity and quantity of fossils. • A school trip to Joggins Fossil Cliffs will engage students and educators with a hands-on history and geology lesson in a world-renowned centre. • Educating students about this natural resource will promote positive attitudes towards conservation and preservation of resources.

STRATEGY

The strategy of this communications plan is to **proactively position with stakeholders and target audiences the Joggins Fossil Cliffs as a world-class scientific, educational and outdoor adventure destination**. Our primary focus is to introduce the new Joggins Fossil Cliffs site as a destination to visitors and stakeholders with proactive, aggressive and targeted communications. By proactively positioning Joggins, we will focus on raising awareness and communicating the opportunity to encourage support and visitation from targeted stakeholders. Our efforts will also seek to promote Cape Chignecto Provincial Park where there are synergies.

We propose to engage in communications and marketing efforts that will offer potential visitors substantive information about the site and the interpretive centre. Visitors to the site who are better informed in advance and have a degree of knowledge about what the site has to offer are more likely to plan a visit to the site. A visitor who is aware of the experience at Joggins is more likely to be more intimately engaged during their visit and therefore be more inclined to have a positive visitor experience. These visitors will be more likely to share their positive experiences with friends, families and others and be more inclined to provide positive word-of-mouth endorsement, which will help not only to increase repeat visitation, but also build a strong reputation for the site as a destination worth visiting.

Our strategy can be summarized as follows:

1. Introduce the new Joggins Fossil Cliff centre as a destination to target audiences.
2. Support an exceptional visitor experience, which will encourage repeat visits and ensure positive word-of-mouth endorsements.

Pillars to Support the Strategy

The tactical elements identified in this communications plan are based on the following strategic pillars; key strategies we have identified to guide communications planning.

1. Build on the Joggins brand. The brand will be more than just a visual identity. It should reflect the actual experience and that will resonate with audiences. Branding for Joggins should reflect the world-class nature. The visitor experience should be cultivated to ensure positive word-of-mouth repeat visitors.

2. Continue to engage the local community. Develop ways to continue with the efforts to keep the community of Joggins up to date on the project. the positive impact the development of site will offer to the community, both in terms of economic development opportunities but also in building a stronger local awareness of the international significance of the fossil cliffs. This will require continuing to engage the community on projects that focus on their interests and the opportunities it presents for them.

3. Plug into and collaborate with existing provincial tourism network. Work with other provincial organizations, regional businesses and attractions to develop marketing initiatives aimed at attracting and retaining visitors to the region.

4. Increase/enhance joint marketing initiatives for Joggins and Cape Chignecto. Where possible, joint marketing and communications initiatives should be sought which highlight the complementary nature of visiting both sites, focussing on the tides, geology and the coastal experience.

5. Proactive outreach and targeted communications. There are target audiences who will be predisposed to visiting Joggins because of their interest in natural history or geology. Those working or teaching geosciences, as well as serious “rock hounds” represent a relatively small but important potential market for Joggins. This audience includes geologists, university researchers, naturalists, and scientists. This audience will naturally have a greater awareness and higher level of engagement with respect to the “story of Joggins.” Focussing on attracting the more “engaged” visitor in initial marketing efforts would likely yield a higher visitor rate than other audiences.

6. Leverage UNESCO World Heritage Site designation. The potential UNESCO World Natural Heritage Site designation provides the opportunity to reach a target market of individuals or groups who seek out such sites. Marketing and promotion should communicate that Joggins is currently on Canada’s tentative list to be inscribed as a Natural World Natural Heritage site, and explain what the designation means in terms of the quality of their visit. Communications efforts should reflect the higher threshold of visitor experience for such a site.

Once the designation is confirmed, this would open up new opportunities to link Joggins to other similar sites. This would mean plugging into the network of people who know what the site means and search out such sites. Focus could be placed on tactics such as:

- UNESCO mailing list
- Clubs and societies
- Scientific meetings
- Guidebooks and maps
- Profile articles

TACTICAL PROGRAM

The following tactics are designed to support the overall goals of the communications plan. They are intended to provide a framework to guide communications over the short-term, and should be reviewed regularly to modify and evaluate the program as it unfolds. They also ensure that the vision for both sites is communicated to stakeholders. The tactics we have identified target the aforementioned audiences with a focus on the primary audiences.

In considering which tactics would be recommended in this plan, our approach was to develop those that would have the most impact with a focus on doing a few things well. The plan outlines several key areas rather than an extensive shopping list that could spread resources too thin. While implementation of all tactics within a communications plan is desirable, initiated activities must be based on available resources. CREDA can give the following plan broad consideration. Based on resources and commitments during the next year, CREDA would identify priorities. **Upon further development and determination of budget, timing, and resources, the order of the tactics can be reviewed and further expanded or revised.** There may also be the opportunity to partner with Cape Chignecto or others to execute specific elements within this plan.

Based on feedback we receive from the CREDA Action Team, MT&L will outline a timeline for each of the tactics identified. In addition, the final document will further refine priority tactics and outline execution recommendations. This document is intended to be a “living” plan that will be assessed and adjusted to meet deadlines.

Tactics in Support of the Strategic Pillars

Below is a summary of the strategic pillars identified in the communications strategy and the tactics that support these pillars. In some cases, the tactics we have identified will support one or more strategic pillars.

1. Build the Joggins brand
Tactics: • Ensure strategic placement of road signage • Develop a community relations program • Facilitate FAM Tours • Create a Joggins “road show” • Develop a tradeshow and conference participation strategy • Coordinate strategic display of promotional material • Develop a “Friends of the Cliffs” membership program • Develop a Joggins “Ambassador Program” • Create a dedicated website for the centre • Develop customer service guidelines and employee workshop • Develop an advertising program • Develop a promotional tool kit • Develop a media relations program

2. Continue to the engage local community
Tactics: • Develop a community relations program • Develop a "Friends of the Cliffs" membership program • Develop a media relation program

3. Plug into and collaborate with existing provincial tourism network
Tactics: • Facilitate FAM (familiarization) tours • Develop a media relations program • Create a dedicated website for the centre

Increase/enhance joint marketing efforts for Joggins and Cape Chignecto
Tactics: • Ensure strategic placement of promotional road signage • Develop a community relations program • Develop a tradeshow and conference participation strategy • Develop strategic partnerships • Develop a media relations program

5. Pro-active outreach and targeted communications
Tactics: • Develop a "Friends of the Cliffs" membership program • Develop a government relations program • Develop a Joggins "Ambassador Program" • Undertake education outreach for schools • Develop a Joggins "roadshow" • Develop an advertising program

6. Leverage UNESCO Natural World Heritage Site designation
Tactics: • Targeted outreach to UNESCO network

The following pages contain each of the above mentioned tactics in more detail, and in order of priority as identified by the CREDA action team.

Tactic – Develop a Media Relations Program

In support of strategic pillars:

- Build the brand.
- Increase/engage local support.
- Proactive outreach and targeted communications.
- Increase/enhance joint marketing initiatives for Joggins and Cape Chignecto.

Key Audiences:

- Local media
- Regional media
- National media
- Targeted scientific media
- Heritage focused media

Considerations:

One of the most effective ways to build brand reputation and general reputation is through the media. The media reaches a large audience in a relatively cost-effective manner. A timely and coordinated media relations program will help Joggins build a rapport with reporters and build on the foundation of media relations activities that have already occurred during the development phase of the new centre.

It is important that a proactive media relations approach be adopted where opportunities provided to the media are exploited to maximum advantage.

Implementation:

The media relations program should be developed so that it considers specific events, such as project milestones and groundbreaking, the opening of the centre, as well as ongoing media relations activities, such as news events. Incorporated as part of the media plan would be to seek out and identify opportunities to reach out to segmented media, such as scientific, geology, travel, tourist, health, and lifestyle media. Media relations activities initially should focus on the following:

1) Ongoing Media Relations Activities

- Develop a list of targeted regional media outlets and publications with a focus on Nova Scotia and New Brunswick.
- Create a list of reporters and key publications/contact list.
- Develop a comprehensive list of targeted media, including tourism, travel, scientific and adventure writers.
- Develop media relations guidelines for staff.
- Establish media relations best practices.
- Develop pitch points and key messages for potential story ideas. Targeted media could be approached to write specific stories.

- Individual contact could be made with specific writers to invite them to the sites.
- Develop a media kit template
- Create media kit folders.
- Develop a media advisory and press release template.
- Regular contact should be made with key media contacts to proactively generate newsworthy topics.
- Media monitoring for articles that refer to Joggins or Cape Chignecto.
- A "roster of experts" should be developed who are available to speak to the media, to a varying degree of detail, about the geological and historical significance of the sites.
- Media training could be considered for those individuals identified as spokespersons. This session could include all aspects of newspaper, radio, and television interviews and cover such topics as: how the media works; preparing for an interview; anticipating questions; keeping an interview on track and delivering key messages.

2) Media Relations – Ground Breaking

The official ground breaking at the site will be an important milestone for the project that would present opportunities to raise awareness of all major stakeholders. An event should be developed which would seek to secure coverage among all major Atlantic Canada media outlets. This event would also present an opportunity to pro-actively engage the local community.

- Develop a list of targeted regional media outlets and publications with a focus on Nova Scotia and New Brunswick.
- Develop pitch points and key messages.
- Develop a media kit, including backgrounder, brochures, FAQs and details of the new centre should be included.
- Develop and issue a media advisory and press release.
- Develop a comprehensive invitation list, including scientific, research, and other key sector stakeholders.
- Develop an e-invite for distribution.
- Personal invitations and a program around community awareness of the ground breaking should be developed. The event could be communicated to the local community through Eastlink.

3) Official Opening and Launch Event

- Develop a list of targeted regional media outlets and publications with a focus on Nova Scotia and New Brunswick.
- Develop pitch points and key messages.
- Direct contact could be made with key publications to secure a profile article prior to, or just after, the centre is officially open.
- Develop a comprehensive invitation list, including scientific, research, and other key sector stakeholders.
- Develop an e-invite for distribution.
- Develop an event scenario.
- Develop and issue a media release.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.

- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

Tactic – Develop Community Relations Program

In support of strategic pillars:

- Build the brand.
- Continue to engage the local community

Key Audiences:

- Residents of Joggins and surrounding area
- Area businesses
- Community organizations and associations

Considerations:

CREDA has actively engaged the community of Joggins during the development phase of the new centre through community workshops, meetings and representation on the action team. It has been a priority to share with the community the progress of the development and seek local opinions and input. Going forward, it will be important to identify ways to continue to keep the local community engaged and updated on issues that may have an impact on them.

The ground breaking will present an opportunity to directly engage the local community and to formally communicate that the project is under way. Special attention should be paid to extending personal invitations to the event and ensure that members of the community play a prominent role in the official ceremony. Personal invitations for the event should be extended on behalf of CREDA and a plan should be developed to generate “a buzz” in the community for this important milestone.

Implementation:

- Develop a groundbreaking event for multi-stakeholders and members of the community.
- Where possible, hire and train local residents to work at the site.
- Provide regular updates to the community through newsletters or public meetings.
- Host an event for the community in advance of the official opening of the centre.
- Make the centre as accessible as possible for members of the community by offering complimentary passes or membership in the “Friends of the Cliffs” program.
- Consideration should be given to establishing an annual event for the community.
- Actively seek to host community events, such as meetings and official functions.
- Host and promote events such as guest speakers and special exhibits.

- Work with CREDA to host sessions and workshops on economic development opportunities for area businesses and potential entrepreneurs.
- Develop a plan for ongoing community relations.
- Monitor issues and immediately act to mitigate community concerns and issues.
- Provide ongoing updates and feedback on milestones, developments and achievements.
- Recognize community support.
- Work with CREDA to recognize the success of community building, such as economic development and local infrastructure.

Results:

- Encourage coordination with regional and community organizations and individuals.
- Support a positive on-site visitor experience at the Joggins Fossil Cliffs centre.

<u>Tactic – Create a Dedicated Website for the Centre</u>

In support of strategic pillars:
- Build the brand.
- Plug into and collaborate with existing provincial tourism network.

A dedicated website will provide the centre with the opportunity to reach key audiences directly. The majority of people seeking information on the centre or making travel plans will use the Internet as a tool. The development of a dedicated website that is easy to find will generate awareness of the fossil centre, provide information, and attract visitors to the site. This is a flexible tool and as the new centre at Joggins opens and the visitor experience is enhanced by the on-site programming and interpretive materials, the website will need to reflect the updated brand of the site.

Key Audiences:

- Partners
- Potential visitors
- Researchers
- Students
- Educators
- Media

Considerations:

The website will be used by many different types of users, each with their own particular and important frame of reference. In order to build this website properly, research and planning are critical. There are obvious features, some noted below, that should be included on the website. Effective planning that will help develop tools that the users will find helpful and informative in promoting the centre. It will be important that the website works for all stakeholders and is based on an understanding of their specific frames of reference.

The website should reflect the brand of the centre and be expandable so that it can be built upon and updated information can be posted regularly. This means that the site will require ongoing maintenance. The site content should include the following:

- Information on the site and its universal value
- Information about the centre and its development
- Programming information and interpretive material (consistent with on-site material)
- Optimum visitation time (tide, sun rise, sun set, hours of operation)
- Tour bookings information
- Calendar of events
- Ticket prices
- On-line shopping for items in the gift shop
- Contact information, including a dedicated email address for inquiries
- “Friends of the Cliffs” membership program information
- Links to key partners (funding and community partners)
- Cliffs Newsletter
- Testimonials
- Newsroom which includes press releases and profile articles
- FAQs
- Information on where to find visitor services in the area, such as accommodations, restaurants and other amenities.
- Information on other area attractions and places of interest, such as Cape d’Or, Cape Chignecto, the Fundy Geological Museum, and others.
- Useful links – weather, regional and provincial tourism information links.

Once launched, the website will be viewed around the world. The site will need to be world-class and reflective of the actual experience of visiting Joggins. Include tracking and monitoring system – how many hits, where hits are from etc. Creative considerations should include the use of bright colours, vivid photos of the site, and people exploring the fossils to help draw people to the site.

Implementation:

- Develop a portal plan; develop a site map for content
- Write the content, making sure that the messaging is consistent with that of the interpretive material on-site.
- Get input from key stakeholders.
- Create and confirm (test) web portal.
- Designate a “web-master” to ensure that the site functions properly and updated information is posted on a regular basis.
- Develop a system for ongoing maintenance.
- Customize settings.
- Launch the website.
- The website address or link to the site should be available on all collateral material.
- Develop list of key words for inclusion in various Internet search engines.
- Website links should be created with all key stakeholders and partners.

- Identify other regional, national, and international organizations that could be approached about linking their websites to the Joggins and Cape Chignecto sites.
- Consideration should be given to online advertising.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.
- Support a positive on-site visitor experience at the Joggins Fossil Cliffs centre.
- Regional visitation and "cross pollination" among other area destinations by engaging in tourism partnerships.

Tactic – Facilitate FAM (Familiarization) Tours

In support of strategic pillars:

- Build the brand.
- Plug into and collaborate with existing provincial tourism network.

Key Audiences:

- Provincial visitor information centre staff
- Tour operators
- Travel agents (established booking agents)
- Regional special interests such as geology groups, outdoor/adventure related organizations

Considerations:

Many potential visitors from outside the province rely on visitor information centre staff, tour operators, or travel agents to provide them with the information they require to plan a visit to the region. Information they receive from these sources plays an important role in developing itineraries, tour plans, and determining where visitors choose to spend time. Since the Joggins Fossil Cliffs site and Cape Chignecto Provincial Park will be unfamiliar to most potential visitors, it will be important to ensure that those on the front-line are equipped to answer potential questions about both sites, explain what type of experience to expect, and even recommend the sites as destinations worth visiting. Not only will this raise awareness and attendance, but will help to ensure accurate information about the site is dispensed.

In order to ensure that visitor information centre staff, tour operators and travel agents are familiar with Joggins as a destination and are comfortable in their knowledge about the new visitor experience offered at Cape Chignecto, it will be important to identify opportunities to reach them directly.

The priority will be to ensure that the staff at visitor information centres are engaged directly. They are the front-line staff and present the biggest opportunity to direct visitors entering or traveling the province to Joggins and Cape Chignecto. They also provide for the greatest opportunity for immediate return. Given the high return rate of information centre staff, any efforts to share information with this group will offer value-added opportunities going forward. A number of ways to reach them is identified below.

Tour operators and travel agents are regularly asked to participate in FAM tours and it will be important to provide participants with a memorable experience and, most importantly, leave them with the impression that visitors would enjoy their visit. It provides the opportunity for those booking travel to familiarize themselves with the site, what it has to offer, amenities, and key attributes. Obviously, these initial FAM tours will provide CREDA with the opportunity to showcase the new interpretive centre and most will see the cliffs for the first time. That is why the FAM tours should be memorable. It will be during this visit that tour participants will form their lasting impression.
That is why the initial FAM tours should be:

- Fun
- Eventful
- Educational
- A quality experience
- Logistically sound
- Provide enough time to enjoy and understand the experience. Often, FAM tours are too short to provide participants with a thorough understanding of their experience.

Implementation:

- Identify key tour operators and travel agents currently operating in the region. Priority should be given to local tour operators, such as Ambassatours, Aquila, CanVac, and Scott Walking Tours.
- Develop a visitor experience model. Once the interpretive centre is complete, a tour itinerary should be developed for Joggins, including a full day of planned activities for visitors. A Cape Chignecto tour experience could be incorporated, which highlights the new day-use trails and view points.
- Develop a series of dry-run FAM tour visits, coordinated to ensure consistency and quality of visits for participants.
- Develop a letter and information package that would be sent prior to the official opening. It could include a “coming soon” letter that would introduce the site and offer some insight into the visitor experience. The package would indicate that they can expect to receive a call from the manager to answer any questions and discuss a site visit.
- The manager of centre should make personal calls to targeted tour operators and travel agents to seek participation in FAM tours.
- Work with the Department of Tourism to ensure that the Joggins experience is included in the annual training session for front-line staff at the visitor information centres. Coordination of this could be

facilitated with Peter Johnson from Tourism to ensure buy-in and request that the site is highlighted in training sessions.

- Request that Joggins and Cape Chignecto be included in information provided at spring orientation for staff.
- Select a launch date for three initial FAM tours, targeting established tour operators and booking agents.
- Participation at the annual Atlantic Canada Showcase, which is attended by Department of Tourism officials and approximately 40 key operators who have an interest in tourism in Atlantic Canada. An initial meeting with Michelle Borgois to determine opportunity for participation and profile should be arranged.
- Consideration could be given to setting up a “virtual” FAM tour for operators and booking agents who do not visit the site. Based on footage and photos, a narrated virtual tour could be provided by CD or available on the website.
- Follow-up with tour participants. Follow-up interviews will be useful to respond to questions, determine ways in which the tour can be improved, and to receive general feedback.

Results:

- Create awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly positioning the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

<u>Tactic – Develop an Advertising Program</u>

In support of the strategic pillars:

- Build the brand.
- Proactive outreach and targeted communications.
- Increase/enhance joint marketing initiatives for Joggins and Cape Chignecto Provincial Park.

Key Audiences:

- Potential visitors – general public
- Event organizers
- Event participants

Considerations:

Depending on budget and resources, consideration should be given to developing an advertising program; creative tools that promote the Joggins Fossil Cliffs and Cape Chignecto Provincial Park. A template advertisement would form the basis for placement in targeted publications and would be flexible enough so that key messages could be refined to meet the specific requirements of the key audience. The creative would be consistent and would help to support messages for the targeted audiences.

Implementation:

- Develop advertising concepts.

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- Develop advertisement template which incorporates the brand.
- Test advertising with stakeholders.
- Identify targeted publications and determine publication frequency and pricing.
- Consult with existing agencies and attractions regarding opportunities for cost sharing and cooperative advertising (i.e. CNTA)
- Print ads in trade publications.
- Identify publications which accept contributed articles.
- Develop a master list of targeted publications and submission deadlines.
- Research should be conducted to determine which regional, national and international publications present the best opportunities.
- Priority publications should include Doers and Dreamers, Coastal Discovery Guide, Atlantic Group Planner and Starting Line (a new publication with a focus on outdoor adventure and active living)

Results:

- Create an awareness of Joggins as a world-class sustainable tourism, scientific and educational destination.
- Attract visitors to the Joggins Fossil Cliffs.

Tactic – Develop Strategic Partnerships

In support of the strategic pillars:

- Build the brand.
- Increase/enhance joint marketing initiatives for Joggins and Cape Chignecto.

Key Audiences:

- Regional businesses
- Regional tourist attractions
- Regional business and tourism organizations
- Chambers of Commerce
- Enterprise Moncton

Considerations:

Cumberland County hosts a number of other attractions and points of interest. Visitors to the region could enjoy a number of area experiences within the vicinity of Joggins and, although the attraction and value of a new interpretive centre at Joggins is worthy in of itself, it will be important to highlight (or offer) to visitors other attractions in order to create an enhanced visitor experience. While the focus of marketing and communications activities will focus on Joggins and Cape Chignecto, there is an opportunity to cross-promote other destinations and amenities in the region by working with partners. Where possible, synergies between the marketing and communications efforts of other area destinations can be achieved.

Implementation:

- Identify and facilitate strategic alliances with other regional tourist attractions in year one. Identify what is already being done in the region to ensure efficiencies.
- Identify appropriate regional attractions which complement the Joggins experience.
- Liaise with potential partners to identify opportunities for joint promotion.
- Develop recommendations for priority partnerships.
- Create strategic alliances with other attractions so that visitors to the area can engage in/choose among many complementary experiences and visitor services. These could include: sea kayaking, Driftwood Park Retreat, Fundy Geological Museum, Parrsboro Rock and Mineral Museum, Ships Company Theatre, Spencer's Island and Springhill Mine Tours.
- In the longer term, look at participating in a destination marketing plan for the region.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.
- Regional visitation and "cross pollination" among other area destinations by engaging in tourism partnerships.
- Coordination with regional and community organizations.

<u>Tactic – Develop Tradeshow and Conference Participation Strategy</u>

In support of strategic pillars:

- Build the brand.
- Proactive outreach and communications.
- Increase/enhance joint marketing efforts for Joggins and Cape Chignecto.

Key Audiences:

- Potential partners
- Potential visitors
- Media

As part of the overall plan to market and promote the Joggins Fossil Cliffs centre and Cape Chignecto as visitor destinations, participation at various targeted tradeshows and conferences is recommended. Participation would include booth presence and/or opportunities to showcase the geological and natural historical importance of Joggins at tradeshow/conference related seminars and workshops. These forums will provide an opportunity to reach the public directly and to promote the visitor experience.

Considerations:

The strategy for a tradeshow program is to proactively inform targeted audiences about the significance of the fossil cliffs and relate to them why a visit to the site, including the new interpretive centre, would be a memorable experience. Tactics are designed to introduce Joggins and Cape Chignecto and build overall awareness of the sites as potential destinations for visitors from both within and outside the province.

It will be important to identify regional opportunities as well as others outside the province. In making recommendations for tradeshow/conference participation for year one, it will be important to collect as much information about the event as possible and apply the following criteria when considering the value of participation:

- Is the event an opportunity to reach visitors directly?
- Would the individuals attending be part of our targeted audience?
- Is there an opportunity to set up a booth and provide collateral material?
- Are there opportunities for booth partnership?
- Are there other provincial/regional exhibitors who would be willing to assist in the promotion of Joggins?
- Are there additional promotional or marketing opportunities, such as contests?
- Are there opportunities to participate in tradeshow seminars or information sessions?

The various tradeshows will each have a different focus and, therefore, each one will offer a different opportunity to promote Joggins and Cape Chignecto in a way that takes advantage of the distinctiveness of each opportunity. Participation at tradeshows will largely depend on resources available. Often, it will be useful and cost-effective to partner with other regional businesses and attractions.

Possible tradeshow options may include:

- Toronto Outdoor Adventure Show (February 2007)
- Moncton Kiwanis Family Show (April 2007)
- Saltscape Expo (April 2007)
- Atlantic Canada Showcase (October 2008)

Implementation:

The various tradeshows will all have a different focus and, therefore, each offers an opportunity to promote the Joggins Fossil Cliffs and Cape Chignecto as visitor destinations. Below are some tactical considerations for tradeshow participation and profile building.

- Identify tradeshow participation for year one and develop a calendar of opportunities to display booth and promotional materials.
- Secure booth presence at priority tradeshows and confirm attendance with event organizers.
- Assess current booth set-up and determine what, if any, enhancements need to be made to the actual booth structure or set-up.
- Contact could be made with potential partners to explore joint marketing and promotion opportunities and to optimize participation. Work with partners to share booth space or have a joint presence. Potential partners could include Cape Chignecto, the Fundy Geological Museum or other area destinations.

- Develop supporting collateral. Develop an audit of the collateral material that can be used at the booth, including pamphlets, brochures, photos and fossil samples. Determination will need to be made as to what collateral material would be the most appropriate for each show, and what material should be created for specific tradeshows.
- Seek opportunities to participate in on-site tradeshow sessions and seminars. Work with event organizers to identify secure opportunities for seminar participation and other public seminars.
- Work with partners to develop an on-site contest or give-away to encourage traffic to the booth. Depending on the resources available, it could include merchandise, free guided tours of the fossil cliffs or centre, complimentary meal at the café, or discounted admission.
- Arm the on-site Joggins representative with useful and relevant information so that they are well informed are better positioned to help to booth visitors. As part of their orientation package, background information might include the following: FAQs, tips for drawing visitors to the booth, event map, and list of other relevant partners, easily recognizable attire, information on contests or give-aways, and tracking sheet for questions–capturing this information will be useful for the next tradeshow as well as identifying the most common inquiries.
- Develop a targeted advertising campaign to promote the booth presence and on-site contest or give-away. Depending on the resources available, a simple ad could be created for the tradeshow program or in the local newspaper in advance of the tradeshow.

Results:

- Raise awareness among interested target audiences.
- Clear positioning of the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

<u>Tactic – Develop Government Relations Program</u>

In support of strategic pillars:

- Build the brand.
- Proactive outreach and targeted communications.

Key Audiences:

- Federal government
    - Parks Canada
    - Natural Resources Canada
    - Atlantic Canada Opportunity Agency
    - Regional Members of Parliament

- Provincial government
    - Department of Economic Development
    - Department of Natural Resources

  - Department of Tourism, Culture and Heritage
  - Department of Health Promotion
  - Department of Transportation – Roads and Signage
  - Department of Education
  - Regional Members of the Provincial Legislature

- Local government
  - Amherst Council
  - Municipality of the County of Cumberland

Considerations:

CREDA has partnered with all three levels of government in the development of the new centre at Joggins. These partnerships have been a key factor to date in ensuring the significant progress that has been made in making Joggins a world-class destination. It will be important to cultivate these relationships by ensuring these funding partners and others are engaged on a regular basis and are updated on any issues or events of interest at the centre. Cape Chignecto could also benefit from a government relations plan in terms of creating a greater awareness among key decision-makers about the park as a visitor destination, stewardship of Nova Scotia's natural heritage and of its contribution to regional economic development.

Implementation:

- Identify relevant elected and non-elected key decision-makers and influencers within government, including all specific departments.
- Provide consistent and timely updates to key government stakeholders on a regular basis.
- Ensure that invitations are extended for significant events, such as ground-breaking, opening, and other important events throughout the year.
- Ensure that all media releases and announcements are sent to key government officials.
- Provide regular updates to government officials, as well as including them on distribution lists for newsletters, mailings, and other promotion materials.
- Identify priority politicians and decision-makers. Ensure that invitations are extended to them to visit the site, meet staff, and tour the centre.
- Provide key government contacts with a "launch" package, which could include a cover letter thanking them for their partnership, promotional material, information on the economic benefits to the community, and promotional gifts such as shirts.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly positioning the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.

<u>Tactic – Align Visitor Experience With Brand</u>

In support of strategic pillar:

- Build the Joggins brand.

Key Audiences:

- Visitors to the Joggins centre

Considerations:

Just as the on-site signage, interpretive display materials, the café, and other elements of the centre will support the overall branding of the new centre at Joggins, so should the items available at the gift shop. The items available at the on-site gift shop should reinforce the overall brand of the centre and include items that support a positive visitor experience. Consideration should be given to offering visitors items which are reflective of a visit to the cliffs. Specifically, items chosen for the gift shop should:

- Be made in Canada, and more preferably, in Nova Scotia.
- Be environmentally friendly.
- Be affordable but not too "touristy" – not items that you can get at any other shop in Nova Scotia.
- Be reflective of the visitor experience at Joggins. Themed items such as those related to fossils and cliffs.
- Items which would be of use to visitors to the cliffs could be made available, such as warm apparel items, hot drink holders, umbrellas, and other "outdoor gear".
- Educational material, such as reference guides and books and posters which outline the timeframes in which the fossils exist.

Results:

- Support a positive and exceptional on-site visitor experience at the Joggins Fossil Cliffs centre.

<u>Tactic – Develop a Promotional Tool Kit</u>

In support of strategic pillar:

- Build the brand.

Key Audiences:

- Potential visitors
- Organizers and visitors to events
- Key stakeholders

Considerations:

Developing creative tools that highlight the Joggins Fossil Cliffs centre and Cape Chignecto Provincial Park would contribute to the recognition of the sites and help to generate a higher volume of visitors. Opportunities will arise to create an awareness of the new centre at Joggins and Cape Chignecto at various events and celebrations which attract large numbers of participants and visitors. These opportunities would include various festivals, fairs, and community events, to name a few. In order to take advantage of these opportunities to reach large audiences, profile could be gained through the development and placement of creative material, such as brochures, posters, and other promotional material.

Implementation:

- Develop promotional concepts.
- Develop an advertisement template which incorporates the brand.
- Test advertising with stakeholders.
- Identify opportunities to display promotional material.
- Contact event organizers to coordinate material display and logistics around placement during events

Results:

- Create awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.
- Support a positive on-site visitor experience at the Joggins Fossil Cliffs centre.

Tactic – Ensure Strategic Placement of Promotional Road Signage

In support of strategic pillar:

- Build the Joggins brand.

Key Audiences:

- Vehicle visitors entering the province
- Residents of New Brunswick and Nova Scotia

Considerations:

The branding of the new centre at Joggins will need to be reflected in the creation of promotional and way-finding signage on provincial roads. The placement of this road signage at key points in the province will be a factor in driving traffic to the centre. These points include Highway #104 in both directions, in Parrsboro, Springhill, and on Route 16 for people coming across the Confederation Bridge from PEI. Coordination of wayward signs should be coordinated with Bob Book from Nova Scotia Tourism and should begin as soon as possible after the official ground breaking at Joggins.

Implementation:

- This tactic should be a priority and consideration should begin now to ensure that the process is under way.
- Explore the possibility of developing temporary signage that could be erected immediately: “Coming in 2007”.
- Based on the new visual identity, road signage which reflects the new visitor experience at Joggins will need to be developed.
- Signage for Cape Chignecto Provincial Park will need to be developed; signage that reflects the enhanced visitor experiences offered through the day-use trails and view points.

- Determine what are the best strategic locations for promotional road signage.
- Determine the requirements and the process for road signage placement will need to be made in consultation with the provincial Departments of Tourism and Transportation.
- Coordinate the placement of road signage through the provincial Ministry of Tourism. Currently, the contact is Bob Book.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.
- Support a positive on-site visitor experience at the Joggins Fossil Cliffs centre.

Tactic – Create a Joggins "Road Show" / Promotional Exhibit

In support of strategic pillars:

- Build the brand.
- Pro-active outreach and communications.

Key Audiences:

- Schools in Nova Scotia and New Brunswick
- General public
- Media

Considerations:

Even among those who are currently aware that there are fossils located at Joggins, the new centre will be an attraction unfamiliar to most residents in the region. It will be important to find effective and creative ways to generate awareness of the site and its natural and geological significance and to pique their interest in visiting the centre. In an effort to raise awareness and attract visitors, many museums and galleries have effectively developed a "road show" to showcase their product. A display or booth which provides a snapshot of the Joggins Fossil Cliffs and description of the centre would bring part of the experience directly to potential visitors. The "road show" display would be staffed by an employee who is intimately familiar with the centre and able to effectively articulate the visitor experience. Promotional material could also showcase and reference other area destinations such as Cape Chignecto Provincial Park. Material such as brochures, tide times, and maps would also be available to distribute.

Implementation:

- May be an opportunity to seek funding partnership with CNTA and the region's annual allocation of Destination Opportunities Program marketing funds from the Province.
- Tailor the existing tradeshow booth and accompanying material and fossil samples. Create a traveling promotional exhibit (using existing material).

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- Develop a booth host kit, including best practices for attracting visitors, key messages and tips. Appropriate staff members would need to be identified and trained.
- Identify profile opportunities in year one for the exhibit (such as regional fairs, exhibits, malls, and other events which attract large numbers of visitors).
- During the peak season, the “road show” could be displayed at the visitor centre at the New Brunswick/Nova Scotia border and other tourism decisions spots.
- During the school year, the “road show” could visit various schools in the province. This will require working with the curriculum coordinators and school boards.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among target audiences.
- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

Tactic – Coordinate Strategic Display of Promotional Material

In support of strategic pillar:
- Build the brand.

Key Audiences:

- Visitors entering the province by air or vehicle
- Visitors at hotels, restaurants, other attractions
- Residents of Nova Scotia

Considerations:

Visitors to the province often use visitor information centres for guidance and assistance in planning their visit to Nova Scotia. Itineraries and travel plans are often based on the information they are able to collect in their search for interesting things to do in the province. These visitors will also be seeking information in their hotels or at brochure displays during their visits to other attractions in the region. It will be important to identify where best to reach visitors and to strategically display promotional material in areas where visitor traffic is high.

Implementation:

- Confirm with Department of Tourism opportunities for strategic placement of promotional materials.
- Develop a priority list of recommended strategic locations for promotional material (brochures) in year one.
- Secure placement of promotional display material at hotels, visitor information centers and other visitor destinations.
- Develop printed material to be displayed at visitor information centres, other regional attractions, and hotels.

- Ensure that current promotional information is placed at these locations and usage is monitored to ensure adequate supply at each location.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

Tactic – Develop a "Friends of the Cliffs" Membership Program

In support of strategic pillars:

- Build the brand.
- Pro-active outreach and targeted communications.

Key Audiences:

- Community of Joggins
- Geologists
- UNESCO network
- Scientists
- Researchers
- Universities
- Environmental organizations

Considerations:

Certain audiences will have a keen interest in the historical and geological significance of the Joggins Fossil Cliffs as well as the new centre. Their interests will range from how the development will impact on the community to the important natural heritage represented by the cliffs and the fossils. As opposed those visitors who will visit the site a limited number of times, there will be a small but important core group of people who will have an ongoing interest in the sustainability of the site. It will be useful from a profile as well as a fundraising perspective to find ways to engage this audience on an ongoing basis. The development of a "Friends of the Cliffs" program will offer these individuals benefits, such as receiving a newsletter, discounts at the gift shop, invitations to special events, and admission discounts. This program will aim to keep members informed of events and news related to the centre as well as provide a sense of ownership in the sustainability of the site.

Implementation:

- Guiding principles and scope of the program would need to be developed initially.
- Administration of the program will need to be determined.
- Any individual or organization would be eligible to join the program.
- Initially, free memberships could be offered to select stakeholders, such as funding partners, members of the community, and other individuals identified as key to the development of the project.

- Initial mail and email distribution lists would be developed for prospective members.
- A letter of invitation and pitch package would be drafted to explain the purpose and value of the program
- Potential members should be able to get program information and details on joining from the Joggins centre website. The program could have its own dedicated icon on the centre website.
- Determine membership benefits. Membership benefits could include free admission to the centre, complimentary beach permits, a discount at the gift shop, regular newsletter and invitation to events.

Results:

- Create awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Clearly position the assets of Joggins and Cape Chignecto Provincial Park among key stakeholders.

Tactic – Develop a Joggins "Ambassador Program"

In support of strategic pillars:

- Build the brand.
- Proactive outreach and targeted communications.

As part of the overall efforts to create an awareness and understanding of the new centre at Joggins, the "Ambassador Program" would supplement opportunities identified in the tradeshow and educational outreach elements outlined in this plan. This program would seek to create speaking and profile opportunities for key individuals who are intimately familiar with the Joggins Fossil Cliffs site and of its natural, geological and historical significant.

Key Audiences:

- Local community
- Potential visitors
- Geologists
- Scientists
- Researchers

Considerations:

Opportunities should be sought to share the story of Joggins with the world. There are many organizations and individuals who would welcome the opportunity to learn more about the historical and geological significance of the Joggins Fossil Cliffs and the visitor experience at the new centre. Specific opportunities may arise within the scientific, historical, geological and educational communities. There will be speaking opportunities both domestically and internationally at educational institutions, as part of various conferences and workshops.

Implementation:

- Work with CREDA to identify appropriate speakers who are able to effectively articulate the story of Joggins and offer insight and context.
- Develop a template presentation kit for speakers tailored to specific opportunities, including key messages and key speaking points.
- Identify opportunities for speakers to promote Joggins (such as at geological conferences, universities, tourism events in years one and two.
- Presentation training for the “ambassadors” to equip them with key messages to build confidence and share tips and tactics to engage audiences

Results:

- Raise awareness of the new centre at Joggins among target audiences.
- Clearly positioning the assets of Joggins among key stakeholders.

<u>Tactic – Undertake Education Outreach for Schools</u>

In support of strategic pillars:

- Build the brand.
- Proactive outreach and targeted communications.

Key Audiences:

- Department of Education
- School boards
- Educators
- Principals
- Primary schools in Nova Scotia
- Junior high school students in Nova Scotia
- Secondary schools in the region

Considerations:

The objective of this program is to attract school visits to the new centre at Joggins. Like most heritage attractions, primary and secondary school groups will represent an important source of visitors. For example, as noted in the Andrea Arbic report, the potential primary and secondary school market in the Chignecto-Central Regional School Board is close to 25,000.

In order to attract visits from the P-12 school market, consideration should be given to developing curriculum-based programs for a variety of age levels and promoting these programs to provincial schools. This program would highlight the learning opportunities offered at the centre.

Implementation:

- Identify schools in the region that should be approached about offering class trips to the new centre.
- Liaise with Department of Education curriculum coordinators to determine opportunities for on-site learning at the Joggins centre.
- Create a curriculum-based teachers’ guide and information package.

- Distribution of materials to key educators.
- Approach the Department of Education about including the site and its educational value on the agenda at the Department's professional development days for teachers.
- Develop an on-site learning program and itinerary for school site visit program.

Results:

- Raise awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.
- Support a positive on-site visitor experience at the Joggins Fossil Cliffs centre.

Tactic - Develop Customer Service Guidelines and Employee Workshop

In support of strategic pillar:

- Build the Joggins brand.

Key Audiences:

- Fossil centre staff

Considerations:

As a new attraction, it will be important that visitor experiences to the new centre be positive. These visitors will share their experiences with friends, families and others and provide positive word-of-mouth endorsement, which will help to increase repeat visitors and build a strong reputation for the site as a destination worth visiting. Staff at the centre will play a role in determining whether or not a visitor has a positive experience, from the reception they receive when they enter the centre, the level of engagement they receive, timely and accurate responses to inquiries, and how well the staff are equipped to offer value-added information about the fossil cliffs.

Implementation:

- Review of best practices.
- Develop guidelines for service excellence for the centre.
- Develop Joggins philosophy and guidelines.
- Develop an employee handbook.
- Facilitate an employee workshop to review guidelines.

Results:

- Support of a positive on-site visitor experience at the Joggins Fossil Cliffs centre.

Tactic – Targeted Outreach to UNESCO Network

In support of strategic pillars:

- Build the brand.

- Leverage World Heritage Site designation.

Key Audiences:

- People who seek out world heritage sites
- Geologists
- UNESCO world-wide network

Considerations:

UNESCO designation as a World Natural Heritage Site will provide world-renowned recognition for the Joggins Fossil Cliff site. UNESCO functions thanks to the synergy between diverse communities that together form an international community. Established UNESCO networks and partnerships are the core of these communities. Together, they give life to UNESCO's ideals and values around the world, at the local, national and international levels. The designation will present an opportunity to identify these communities and to take advantage of this network to promote the site. There will be an opportunity to reach out to this target market of those individuals or groups who seek out such sites as destinations by identifying communications vehicles, such as websites and newsletters, to name a few, and creating profile opportunities. Marketing and promotion efforts should communicate to potential visitors that Joggins could potentially be inscribed on the World List, but also to communicate what the inscription means in terms of the visitor experience; that the site is world-class and offers a higher threshold in terms of excellence.

Specifically, the UNESCO network includes:

- 192 national commissions composed of representatives of national educational, scientific and cultural communities.

- 100 consultative committees, international commissions, and intergovernmental councils have been set up to carry out specific tasks or for purposes of reflection.

- 3,600 UNESCO clubs, centres, and associations in over 90 countries promote the organization's ideals and efforts at the grassroots level.

- 7,900 associated schools help young people develop attitudes of tolerance and international understanding.

- 229 non-governmental organizations, which maintain official relations with UNESCO and others cooperate on an occasional basis with the organization's sectors.

- A group of 42 eminent personalities - the Goodwill Ambassadors- use their talent and status to help focus the world's attention on the work and mission of UNESCO.

- Over 300 firms and organizations in the business community.

- 174 Member States maintain permanent delegations to UNESCO.

Implementation:

This will require identifying the broad UNESCO network and those individuals who are familiar with the importance of the designation. Focus could be placed on ensuring that information about Joggins is shared with the UNECSO network though their communications outlets such as:

- UNESCO mailing list
- Clubs and societies
- Scientific meetings
- Guidebooks and maps
- Websites of organizations

Results:

- Create an awareness of the new centre at Joggins and Cape Chignecto Provincial Park among interested target audiences.
- Attract visitors to the Joggins Fossil Cliffs in support of visitor targets.

Joggins Fossil Cliffs

Comprehensive Site Development Plan

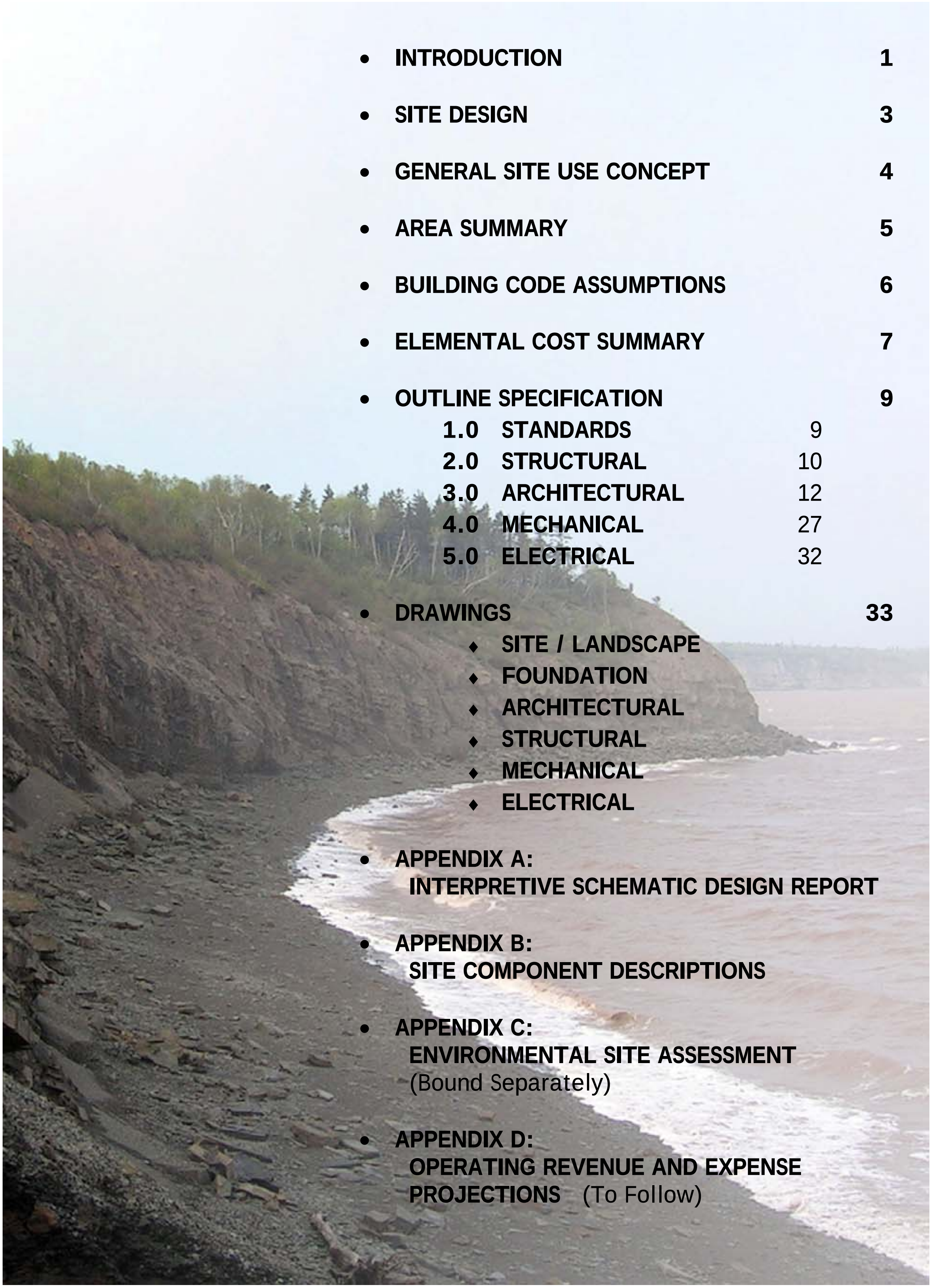
Design Development Submission

24 February 2006

whwarchitects

Joggins Fossil Cliffs
Comprehensive Site Development Plan
Design Development Submission

whwarchitects



This submission represents the Design Development stage for Site and Building Design and the Schematic stage of Interpretive Design for the Joggins Fossil Cliffs Comprehensive Site Development Plan. The Master Concept submitted in December of 2005 is still very much intact, both the physical site and building concept and the interpretive concept. That these concepts have proven resilient enough to accommodate the alterations and adjustments that have been made to the plan and program can be taken as evidence of their strength and "right-ness". As the project proceeds through its subsequent stages and further refinements are made to its parameters, the design team fully expects that this concept will continue to accommodate any further minor shifts and adjustments.

A more complete picture of the Centre's operation has led to an increase in overall building area of roughly 20% compared to the first concept drawings. The proposed staff complement is larger than first expected and this has necessitated an increase in the number of workstations to accommodate those staff. Extensive discussion regarding the size of the principal exhibit space has resulted in the net size of that component of the building being increased by 620 square feet or 22%. Although there is still some desire to increase this number even more, it must be remembered that interpretation will take place throughout the building and across the broader site. Capital and operating budgets are the principal constraint to a larger building. The next phase of the project will define the means for interpretation and theme throughout the building and site to ensure that every interpretive opportunity is being exploited.

While the December submission dealt almost exclusively with imagery and feeling, this document puts a solid framework around the visions and ideas of the concept stage. Construction details, materials and costs are more fully explored and have shaped the proposed design solution. The initial cost estimate, based on the concept design submitted in December, came within 9% of meeting the established budget, an amount that could have been addressed during the construction documents phase. Subsequent additions to the building's programmed area have exacerbated this problem, and more extensive measures were required to bring anticipated construction costs within the budget.

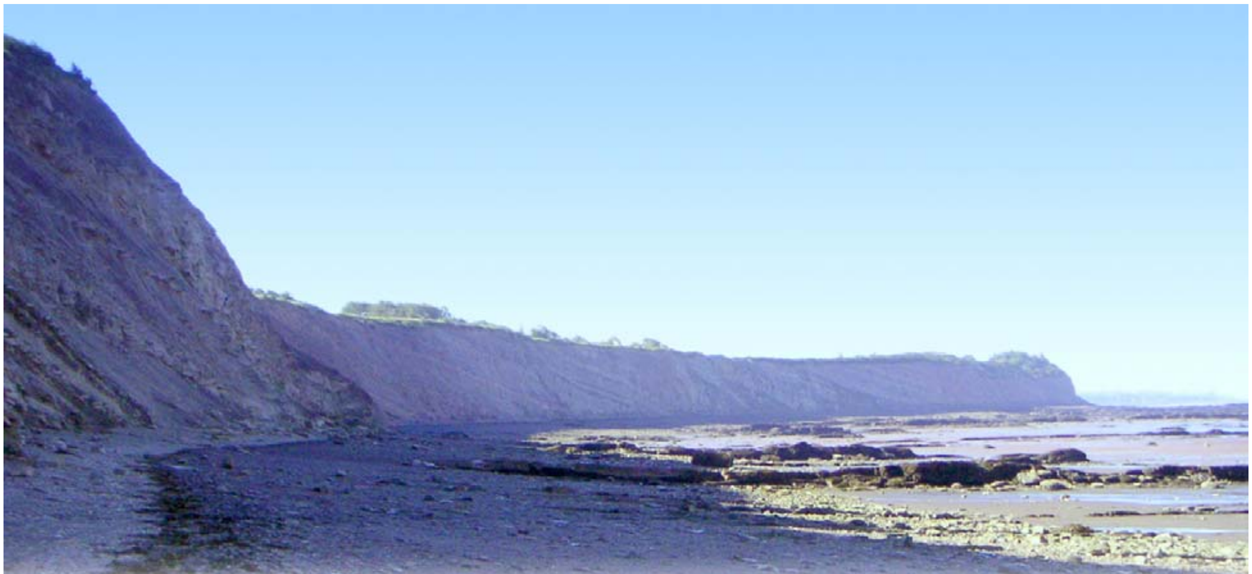
Reducing the building area was not felt to be an appropriate solution to the problem. Discussions to reallocate more funds from the total project budget to the building itself, combined with modifications to the design to achieve a more economical solution, have brought the amount of money needed more closely in line with the amount of money available. The most noticeable outward difference between the concept design and the present scheme is in the extent of Wallace sandstone cladding on the building. Both material and labour costs for stone cladding are high, so reducing the amount of stone will achieve substantial economies. The eastern or exhibit block of the building, which is the first face visitors will see when they arrive on the site, is still stone clad. The larger support block will be clad in a random exposure wood siding, coursed - like the stone - parallel to the roof line to maintain the dramatic, abstracted cliff-like character.

From the outset, it has been the intention that the interior finishes in the building would be kept to a minimum, bringing both cost savings and environmental advantages by using less material. Lest anyone should think that this means the building will look like a sterile warehouse on the inside, nothing could be further from the truth. Exposed wood decking above the steel structure will provide a warm, organic lining to the interior, contrasting with the exterior stone walls and polished concrete floors. Circular pits set into the floor of the lobby and topped with tempered glass will allow visitors to have something of the beach experience in the centre, as they learn to look between their feet to find evidence of 300-million-year-old life. Millwork in public and staff areas will add detail and interest to the spaces. Where appropriate, we will explore how these elements can be themed to extend the interpretive experience through the centre. Two seating benches in the lobby and coat areas are presently envisioned as upholstered Arthropleura, and the suspended acoustical elements in the public spaces are intended to suggest Hylonomous's view up through hollow tree stumps. Washrooms, the coat room, multi-purpose rooms, and the food service area will all be designed in the same spirit of discovery, humour and playfulness.

From an energy conservation standpoint, the design philosophy has first been to produce an efficient building to reduce demand, and only then to look to alternate energy sources. At this stage in the design, the working assumption for the electrical supply still involves the use of a wind turbine to supplement the supply from the utility. Based on projected demand and available technology, a 50kW generator has formed the basis of the design model. Wind data will be collected to establish the amount of power that can be generated on the site, pinpoint a location for the mast, and match the turbine to the specific site conditions. At least 12 months of data will be collected and reviewed prior to the installation of a turbine in May 2007.

Heating and mechanical ventilation for the centre will be provided by air-to-air heat pumps. The advantages that this system will provide compared to other possible systems include economy of operation, ready access to proven technology, simplicity of installation, and space efficiency. An additional benefit will be that the units can be used to provide cooling when conditions demand it.

The Multi-Purpose Room as well as the Exhibit Hall and the administrative areas include significant areas of Solera glazing, a Nova Scotia product that diffuses natural light in occupied spaces to provide a better quality of light and reduce reliance on artificial electric lighting. Solar collectors are being used to provide domestic hot water and an array of photovoltaic cells is under consideration as a source of renewable energy and to provide emergency back-up in the event of electrical grid failure. Green roofs will be employed to increase the insulation value, significantly extend roof lifespan, control storm drainage and support local flora and fauna. Green building strategies are employed for their practical and educational value in addition to helping reduce the long term operating costs of the facility. The strategies are seen as a good fit with the UNESCO educational objectives as well as the natural community instincts for earth stewardship.



The site facilities master concept seeks to resolve the relationship between the Fossil Centre building site proper in the Village of Joggins and the 16km extents of the proposed UNESCO designation area. To this end, the following will describe the respective roles of the Centre site and the broader site resources in delivering an integrated site visitor experience. In this regard, the word "site" will commonly refer to the whole UNESCO area or part thereof and the words "Centre site" will refer to the parcel of land in Joggins where the main Visitor Centre building will be located. This section will concentrate mainly upon the visitor experience primarily from the standpoint of accessibility, site facilities, services or amenities provided, and operational assumptions made. The stories to be told in the interpretive program will be described elsewhere as will the integration of the individual story and visitor experiential elements with specific site resources. This section will describe how the visitor will get to each area of the site, what facilities will be provided and some of the operational assumptions that the provision of these facilities entail. Recommendations divide into 3 broad categories:

- C1. Site facilities that work together in concept to form a complete set of user facilities contributing to an integrated visitor experience of the Centre and several selected areas of the site;
- C2. Site facilities that are not essential to delivery of an integrated visitor experience but provide additional 'value-added' amenities to the Fossil Cliffs project or to the local community;
- C3. Areas that are not recommended for general public access or program delivery but that are part of the UNESCO designation area and may fall under the general management of this project for resource security, scientific study or other purposes.

The following specific location descriptions will reference these categories to describe their function in context. All of the recommended site developments (C1 & C2) occur on publicly owned or publicly accessible lands. No development recommended by this report requires the acquisition of private lands.

For most visitors to the Joggins Fossil Cliffs site, the visitor experience will unfold as a sequential programmed tour of the Visitor Centre facility and of the site emphasizing a broad range of interpretive themes through exhibits, guided and self-guided tours and controlled access to site highlights balancing user enjoyment with safety, security and resource protection. This model provides a higher degree of management control over who uses the facilities and site and provides the opportunity to develop appropriate programs and revenues from an enhanced level of service. Various areas of the site can be hazardous at times due to the characteristics of the terrain or the effects of tidal action. A site development model that assumes a higher degree of staff supervision will assist in monitoring the safety of guests while on the site. It also provides numerous opportunities for interaction between visitors and staff to enhance the visitor experience.

In general, the areas of the site noted in Category 1 above will usually involve staff guided or monitored visitor experiences. Category 2 areas may fall more into the realm of self-guided, independent or casual recreation opportunities while Category 3 areas are not generally recommended for public access unless under special conditions. The site components by category are:

Category 1 (C1) Sites:
Joggins Fossil Cliffs Visitor Centre Site
Joggins Beach & Dugway Access
Grindstone Beach Access Park & Turnaround
Lower Cove Bridge and Beach Access – "The Bus Stop"
Main Fossil Cliffs, Lower Cove to Coal Mine Point

Category 2 (C2) Sites:
Bells Brook Access & Parking Area
McCarrons River to Joggins Beach
McCarrons River Point Pedestrian / Bicycle Access
North of Grindstone Beach / Boss Point / Downings Cove
Lands east of Joggins and Lower Cove / Former Rail ROW

Category 3 (C3) Sites:
Ragged Reef Point
Beach and uplands between Ragged Reef Point & McCarrons River Point
McCarrons River Point Vehicle Access
Coal mine site on Hardscrabble Road above Cliffs

Each site component is described in detail in the Appendix B.

Vestibule	90 sf
Lobby	1800 sf
Vestibule	90 sf
Admissions	130 sf
Visitor Information Centre	53 sf
Gift Shop	548 sf
(includes Stock 102 sf shared with VIC)	
Coats	374 sf
Men's WC	161 sf
Women's WC	275 sf
Exhibit	3455 sf
(includes Demonstration 230 sf)	
Laboratory	155 sf
Multi-Purpose Room A	609 sf
Multi-Purpose Room B	544 sf
Chair Storage	114 sf
Food Service	320 sf
(includes Storage 144 sf)	
Vestibule	61 sf
Janitor	58 sf
Corridor	671 sf
Collection Storage	150 sf
Executive Director	150 sf
Staff	187 sf
Visitor Services	100 sf
Curator	100 sf
Visiting Scientist/Swing	107 sf
Workstations (4)	245 sf
Program Storage	83 sf
Communications Closet	23 sf
Staff WR	84 sf
Files and Storage	154 sf
Electrical	92 sf
Mechanical	250 sf
Outside Storage	190 sf
RCMP Office	132 sf
RCMP Interview	86 sf
Sub-total	11641 sf
Walls and Partitions	1129 sf
GROSS AREA	12770 sf

Building Classification:
Group A, Division 2, Assembly Occupancy (includes Art Galleries, Museums, Exhibit Halls, Community Halls, Restaurants and Libraries)

Applicable Building Code Article:
3.2.2.25, Group A, Division 2, up to 2 Storeys
Building may be of combustible or non combustible construction. Sprinklers are not required. Area is limited to 1600m^2 (17,216 square feet) with the building facing 1 street (for fire truck access). Floor assemblies, mezzanines, roof assemblies, and load bearing components supporting an occupancy require a fire resistance rating of 45 minutes.

Building Area:
12,770 square feet gross

Occupant load:
Occupant Load had been calculated on the basis of area for the public spaces (using the figures in NBCC 1995, Table 3.1.16.1) and staff numbers for the "back of house" spaces.

The Lobby, Visitor Information Centre, Gift Shop, and Exhibit spaces are treated as Mercantile uses [3.7 m^2 (40 sf) per person]. With an area of 5856 sf, the occupant load for these spaces is 147 persons. The Multi-Purpose Rooms are treated as Assembly Use with non-fixed seats and tables [0.75 m^2 (10 sf) per person]. The combined area of these two rooms is 1153 sf, giving an occupant load of 113 persons. The building's peak staff complement is anticipated to be 16 including the RCMP office. With an assumption of an equal number of visitors doing business with the staff, the occupant load of the staff and administration areas is assumed to be 32. The total occupant load of the building is therefore 292 persons.

Exits:
Based on occupant numbers, the total width of exit doors required is 1781 mm or 70". The total width of exits provided is 180".

Washrooms:
In accordance with NBCC 1995, Article 3.7.4.2 and Table 3.7.4.2.A, numbers of water closets are determined based on equal numbers of male and female occupants. Using the figure of 146 occupants of each gender, 3 water closets are required for males and 6 for females. This number had been provided for visitors with an additional washroom for staff.

Project	: JOGGINS FOSSIL CLIFFS		Report date : 9 Feb 2006
	: INTERPRETATION CENTRE		Page No. : 1
Location	: Joggins, Nova Scotia	ELEMENTAL COST SUMMARY	Bldg Type : 770
Owner	:		C.T. Index : 0.0
Consultant	: WHW Architects		GFA : 12,900 sf

Element	Ratio to GFA	Elemental Cost Quantity	Elemental Cost Unit rate	Elemental Amount Sub-Total	Elemental Amount Total	Rate per sf Sub-Total	Rate per sf Total	%
A SHELL		12,900 sf			1,520,422		117.86	46.7
A1 SUBSTRUCTURE					274,254		21.26	8.4
A11 Foundations	1.000	12,900 sf	8.79	113,391		8.79		
A12 Basement Excavation				0		0.00		
A13 Special Conditions	1.000	12,900 sf	12.47	160,863		12.47		
A2 STRUCTURE					269,610		20.90	8.3
A21 Lowest Floor Construction	1.000	12,900 sf	5.98	77,142		5.98		
A22 Upper Floor Construction				0		0.00		
A23 Roof Construction	1.000	12,900 sf	14.92	192,468		14.92		
A3 EXTERIOR ENCLOSURE					976,558		75.70	30.0
A31 Walls Below Grade				0		0.00		
A32 Walls Above Grade	0.914	11,794 sf	41.63	490,984		38.06		
A33 Windows & Entrances	0.168	2,170 sf	53.11	115,250		8.93		
A34 Roof Coverings	1.009	13,015 sf	18.92	246,244		19.09		
A35 Projections	0.161	2,075 sf	59.80	124,080		9.62		
B INTERIORS		12,900 sf			363,142		28.15	11.2
B1 PARTITIONS & DOORS					163,737		12.69	5.0
B11 Partitions	1.116	14,397 sf	7.75	111,537		8.65		
B12 Doors	0.002	32 No	1,631.25	52,200		4.05		
B2 FINISHES					105,985		8.22	3.3
B21 Floor Finishes	1.000	12,900 sf	2.50	32,250		2.50		
B22 Ceiling Finishes	1.000	12,900 sf	3.25	41,925		3.25		
B23 Wall Finishes	2.441	31,495 sf	1.01	31,810		2.47		
B3 FITTINGS & EQUIPMENT					93,420		7.24	2.9
B31 Fittings & Fixtures	1.000	12,900 sf	7.24	93,420		7.24		
B32 Equipment	1.000	12,900 sf	0.00	0		0.00		
B33 Elevators				0		0.00		
C SERVICES		12,900 sf			645,356		50.03	19.8
C1 MECHANICAL					446,051		34.58	13.7
C11 Plumbing & Drainage	1.000	12,900 sf	5.00	64,500		5.00		
C12 Fire Protection	1.000	12,900 sf	0.08	1,000		0.08		
C13 HVAC	1.000	12,900 sf	26.00	335,400		26.00		
C14 Controls	1.000	12,900 sf	3.50	45,151		3.50		
C2 ELECTRICAL					199,305		15.45	6.1
C21 Service & Distribution	1.000	12,900 sf	4.10	52,890		4.10		
C22 Lighting, Devices & Heating	1.000	12,900 sf	7.45	96,105		7.45		
C23 Systems & Ancillaries	1.000	12,900 sf	3.90	50,310		3.90		
NET BUILDING COST - EXCLUDING SITE				$	**2,528,920**		196.04	77.6
D SITE & ANCILLARY WORK		12,900 sf			473,905		36.74	14.6
D1 SITE WORK					473,905		36.74	14.6
D11 Site Development	0.000	1 Sum	373,905.00	373,905		28.98		
D12 Mechanical Site Services	0.000	1 Sum	60,000.00	60,000		4.65		
D13 Electrical Site Services	0.000	1 Sum	40,000.00	40,000		3.10		
D2 ANCILLARY WORK					0		0.00	0.0
D21 Demolitions	0.000	1 Sum	0.00	0		0.00		
D22 Alterations	0.000	1 Sum	0.00	0		0.00		
NET BUILDING COST - INCLUDING SITE				$	**3,002,825**		232.78	92.2
Z1 GENERAL REQUIREMENTS & FEE					255,240		19.79	7.8
Z11 General Requirements		8.5 %		255,240		19.79		
Z12 Fee		0.0 %		0		0.00		
TOTAL CONSTRUCTION ESTIMATE - EXCLUDING CONTINGENCIES				$	**3,258,065**		252.56	100.0
Z2 ALLOWANCES					366,206		28.39	
Z21 Design & Pricing Allowance		8.0 %		260,645		20.21		
Z22 Escalation Allowance		0.0 %		0		0.00		
Z23 Construction Allowance		3.0 %		105,561		8.18		
TOTAL CONSTRUCTION ESTIMATE				$	**3,624,271**	$	**280.95**	

H2075 -D2 CLASS 'C' ESTIMATE

1.0 STANDARDS

.1 Codes, Standards and Guidelines:

.1 Codes – the following are applicable by law:

- .1 National Building Code of Canada.
- .2 Nova Scotia Building Code.
- .3 National Fire Code of Canada.

2.0 STRUCTURAL

2.1 FOUNDATIONS

.1 The foundations shall consist of piles, pile caps, grade beams and a structural slab. Piles type and capacity to be as specified by a qualified geotechnical engineer. Exterior grade beams of the building will have adequate soil cover for frost protection. All concrete foundations will be reinforced.

.2 The structural slab grade shall be cast in place concrete. The slab will be designed for not less than 4.8 kPa.

.3 The design of foundations and slab on grade construction are to be based on the geotechnical report prepared by a qualified geotechnical engineer for this project.

.4 Reinforcing steel shall be deformed bar manufactured in Canada to CAN/CSA - G30.18. The minimum yield strength shall be 400 MPa.

.5 Weld steel wire fabric for concrete reinforcement shall confirm to the requirements of CSA G30.3 and CSA G30.5.

.6 All concrete work shall be to CSA A23.1 with testing to CSA A23.2. Concrete shall have the 28 day compressive strength as follows:

Foundations and Footings	21 MPa
Structural Slab	27 MPa
Exterior sidewalks and flat work	32 MPa
Housekeeping and equipment pads	21 MPa

.7 All concrete shall meet the Classes of Exposure as defined in Table 7 of CSA A23.1.

.8 Concrete mix design will be adjusted to prevent alkali aggregate reactivity.

.9 Structural Slab construction shall be to CSA A23.1 Table 16 Slab and Floor Finish Classification Class C - moderately flat.

.10 A non-metallic floor hardener will be applied, as specified on the floor finish schedule, in accordance with the manufacturer's written instructions.

2.2 SUPERSTRUCTURE

.1 structural framing shall be constructed of structural steel columns, beams, open web steel joist and metal deck. Lateral bracing elements will be located in the exterior walls of the building and will consist of the steel diagonal bracing. The roof deck will provide a horizontal diaphragm to transfer lateral loads to the braced bays.

.2 The roof will be designed for a dead load of 2.5 kPa. The live load due to snow shall be to the National Building Code with a wind exposure factor of 1.0. Built up of snow around projections and due to sliding shall be according to the supplement to the National Building Code.

.3 The exterior walls will be framed with structural steel cold formed studs. The design, fabrication and erection will be in accordance with CSA S136.

.4 Structural steel shall be designed, fabricated and erected in accordance with CSA S16.1 and CSA S136. Welding shall be in accordance with CSA W59. All structural steel shall be prime painted in accordance with CSA S16.1 and CSA S136.

.5 Structural steel exposed to the exterior will be hot dip galvanized to CSA G164 with a minimum zinc coating of 600 g/sq. m.

.6 Open web steel joist shall be designed, fabricated and erected in accordance with CSA S16.1 and CSA S136. Welding shall be in accordance with CSA W59. All steel joist and bridging shall be prime painted in accordance with CSA S16.1 and CSA S136.

.7 Metal deck shall be designed, fabricated and erected in accordance with CSA S136 CSSBI 10M AND CSSBI 12M. Welding shall be in accordance with CSA W59. All metal deck will be fabricated from zinc-iron alloy coated steel sheet to ASTM A446M

.8 Seismic loads will be calculated in accordance with the National Building Code of Canada. The factors shall be as follows:

Zonal velocity ratio, v	as specified in the National Building Code
Seismic response factor, S	Table 4.1.9.A
Seismic importance factor, I	1.0
Foundation factor, F	1.0
Weight, W	as calculated

3.0 ARCHITECTURAL

3.1 EXTERIOR ENVELOPE

.1 Vertical Skin:

.1 Natural Stone on Laterally Load Bearing Stud Wall:

.1 Natural Stone:
  .1 Natural Sandstone from the Wallace Quarry.
    .1 3” to 8” Rise
    .2 50 % randomly dressed
    .3 Rock faced finish
    .4 Random courses of 2 ½”, 5 ½”, 8 ½”, 11 ½”
    .5 Anchoring devices as recommended by the Manufacturer.

.2 Air Space, 1”

.3 Rigid Insulation:
  .1 Standard of Acceptance
    .1 Extruded expanded Polystrene to CAN/CGSB 51.20-M87.
  .2 Thermal Value – RS1.2.64 (R-15) Insulation value thickness based on values listed in the latest edition of the NRC Evaluation Listing.
  .3 Insulation secured to wall with impaling clips.

.4 Air/Vapour Barrier:
  .1 Air/Vapour Membrane Description:
    .1 SBS modified bituminous membrane reinforced with proprietary glass scrim membrane self adhered to prepared substrate.
    .2 Conforms to CGSB 37-GP-56m
    .3 Standard of Acceptance:
      .1 Bakor
  .2 Air/vapour barrier applied over entire wall surface with minimum 8” overlaps in changes of substrate, all fenestration and entrance openings and roofing membrane systems.

.5 Sheathing Board:
  .1 Paperless sheathing panel engineered with a water-resistant treated core surfaced with a glass mat framings and a gold primer coat.
  .2 Product and installation to meet requirements for ASTM C 1177.
  .3 Standard of Acceptance:
    .1 Georgia Pacific – Dens-glas

.6 Laterally Load Bearing Steel Studs:
  .1 Roll formed of galvanized coated steel; thickness profile and spacing of members predicated by design.

.2 Laterally load bearing stud wall engineered for wind load conditions pertinent to place of construction.
.3 System to be designed and stamped by Professional Engineer registered to practice in Nova Scotia.

.7 Masonry Ties and Accessories:
.1 Reinforcing:
.1 Veneer Wall Tie:
.1 Standard of Acceptance:
.1 Dur-O-Wal bayonet tie system DA2201. As per requirements of CSA A370-M94.
.3 Corrosion protection: to S304-M84, hot dipped galvanized and / or stainless steel as per Structural Engineer's recommendation.
.2 Accessories:
.1 Control joint filler: purpose-made elastomer 80 durometer hardness to ASTM D 2240-91 of size and shape indictated.
.1 Standard of Acceptance:
.1 Dur-O-Wal, Rapid control joint.
.2 Weep & upper cell hole vents: purpose-made PVC
.1 Standard of Acceptance:
.1 Dur-O-Wal, model DA 1069.
.3 Soft joint: closed cell neoprene conforming to ASTM D 1056-91, class RE41
.1 Standard of Acceptance:
.1 Dur-O-Wal DA2010.
.4 Mortar control device: Mor-control by Duro-wall.
.5 Flashing:
.1 Self-adhering cold applied composite sheet membrane, 1/32" rubberized asphalt integrally bonded to 0.0075" high density cross laminated polyethylene for minimum thickness of 0.04"c/w primer as per manufacturer's recommendations.
.1 Standard of Acceptance:
.1 Bakor – Blueskin SA.

.8 Gypsum Board
.1 Regular & Type 'X' gypsum board to CAN/CSA-A82-27-M91 standards.

.2 Wood Siding Wall System:

.1 Cedar Siding
.1 Western Red Cedar
.2 Rough sawn texture
.3 Random exposed width (6" maximum)
.4 Butt edge all joints

.2 Strapping
  .1 Vertical Strapping 1" x 4" pressure treated material
  .2 Galvanized fasteners
  .3 Spacing @ 24" o.c.

.3 Horizontal Band
  .1 3 ½" x 3 ½" cedar banding perimeter area of Hardi Panel.
  .2 Finish cedar banding with coating to provide lasting finish.

.4 Rigid Insulation:
  .1 Standard of Acceptance:
    .1 Extruded expanded Polystrene to CAN/CGSB 51.20-M87.
  .2 Thermal Value – RS1.2.64 (R-15) Insulation value thickness per mm based on values listed in the latest edition of the NRC Evaluation Listing.
  .3 Insulation secured to wall with impaling clips.

.5 Air/Vapour Barrier:
  .1 Air/Vapour Membrane Description:
    .1 SBS modified bituminous membrane reinforced with proprietary glass scrim membrane is designed to be self adhered to prepared substrate.
    .2 Conforms to CGSB 37-GP-56m
    .3 Standard of Acceptance:
      .1 Bakor – Self Adhering Air/Vapour Barrier
  .2 Air/vapour barrier applied over entire wall surface with minimum 8" overlaps in changes of substrate, all fenestration and entrance openings and roof membrane system.

.6 Sheathing Board:
  .1 Paperless sheathing panel engineered with a water-resistant treated core surfaced with a glass mat framings and a gold primer coat.
  .2 Product and installation to meet requirements for ASTM C 1177.
  .3 Standard of Acceptance:
    .1 Georgia Pacific – Dens-glas

.7 Laterally Load Bearing Steel Studs:
  .1 Roll formed framing galvanized coated steel; thickness and profile and spacing of members predicated by design.
  .2 Laterally load bearing stud wall engineered for wind load conditions pertinent to place of construction.

.8 Gypsum Board
  .1 Standard & Type 'X' gypsum board to 5/8" thick to Standards CAN/CSA-A82-27-M91, taped and filled.

.3 Aluminum Curtainwall Framing Systems:

.1 Aluminum Curtainwall systems to be in compliance with Part 5 of the NBCC (1995) and shall be based on the 'rain screen principle'.

.2 Back Bar Assembly engineered for wind loading capabilities based on the place of construction.

.3 System to be designed and stamped by a Professional Engineer registered to practice in Nova Scotia.

.4 Curtainwall Framing System:
- .1 Aluminum extrusions – Aluminum Association alloy AA6063T5/T6.
- .2 Glazing gaskets – EPDM or Santoprene.
- .3 Thermal break – polyvinylchloride.
- .4 Fasteners – stainless steel, c/w extruded aluminum connector clips to compensate for any deflection of structural steel.
- .5 Finish: Clear anodized finish No.17 conforming to standards AA M12 C223 Class I finish.
- .6 Back bar dimensions – based on 2-1/2" frame width, depth of frame as per design requirements.
- .7 Exterior Face Cap/Silicone Glazing:
  - .1 Face cap – aluminum.
    - .1 Horizontal and perimeter wall application.
    - .2 Maximum depth cap approximately 3 ¾" deep.
  - .2 Silicone glazing butt c/w back bar.
    - .1 As per manufacturers recommendations.
- .8 Air/Vapour Barrier:
  - .1 Air/vapour barrier adhered to aluminum framing with 8" overlap. Ensure overlap material from adjacent substrate is married into same.
  - .2 Fill voids in frame and surrounding construction with injection foam.
- .9 Glazing:
  - .1 Insulating glass units:
    - .1 Hermetically sealed double glazing units. Unit fabricated to CAN/CGSB-12.8-M90 with ¼" tempered glass for the outer pane and inner panel of ¼" tempered. Air space ½". Approximately 1" thickness total, low 'E' glass and argon filled.
  - .2 Insulated translucent glazing system:
    - .1 ¼" tempered glazing (clear)
    - .2 Diffusing cloth
    - .3 Honeycomb transparent insulation
    - .4 ¼" float glazing (clear)
    - .5 System complete with sealant and spacers
    - .6 Standard of Acceptance:
      - .1 Solera Advanced Glazing Halo
  - .3 Glass Types:
    - .1 Clear glazing

.10 Light Shelf:
  .1 Extruded aluminum, same finish as curtainwall section.
  .2 Fascia cap.
  .3 Maximum projection from frame face 30".

.4 Aluminum Entrance System:

.1 Exterior Entrances & Screens:
  .1 Screens to CAN/CSA-A440-M90.
  .2 Main frame and sash: aluminum thermally broken, sized to accept 1" thick double glazed insulating glass units. Interior vestibule framing to match - for single glazing only.
  .3 Glazing: for exterior, double glazed, hermetically sealed, insulating glass units in accordance with CAN/CGSB-12.8-M90. Outer pane of ¼" tempered glass, inner pane of ¼" tempered glass, minimum ½" airspace, low 'E' glass and argon filled, 1" total thickness. Interior vestibules to be ¼" tempered glass.
  .4 Air/Vapour Barrier:
    .1 Air/vapour barrier adhered to aluminum framing with q 8" overlap.
    .2 Voids in frame filled with injection foam.
  .5 Aluminum Entrance Doors:
    .1 Doors of porthole extrusions (min. 3'-0" x 7'-0") with minimum wall thickness of 1/8".
      .1 Stiles: nominal 3 ½"
      .2 Top rail: nominal 3 ½"
      .3 Mid rail: nominal 3 ½"
      .4 Bottom rail: nominal 6 ½"
      .5 Reinforce mechanically-joined corners of doors.
      .6 Glazing stops: interlocking snap-in type for dry glazing. Exterior stops: tamperproof type.
  .6 Hardware:
    .1 Entrances shall be fitted with appropriate hardware suiting the functional and operating characteristics of the door and security requirements of the user.
    .2 Dedicated entrance door systems will be activated by:
      .1 Automatic Entrance Barrier Free systems
    .3 Keying:
      .1 Keying will be Grand Master Keyed to the Owner's specification.

.5 Exterior Metal Doors and Frames:

.1 Exterior hollow metal doors and pressed steel thermally broken frames.

.2 Doors and Frames in accordance with the Canadian Manufacturing Specification for Steel Doors and Frames 1990 (CSDMA).

.3 Exterior Door:
  .1 18 gauge material

.2 Stiffened: face sheets laminated, welded, insulated core.
.3 Polyurethane to CCGB 51-GP-21M rigid, modified poly-isocyanurate closed cell board.

.4 Frame Construction:
.1 Fully welded frame construction
.2 16 gauge construction
.3 Exterior frame thermally broken.

.5 Air/vapour Barrier:
.1 Air/vapour barrier adhered to metal framing with 8” overlap. Ensure overlap material from adjacent substrate is married into same.
.2 Voids in frame and surrounding construction filled with injection foam.

.6 Hardware:
.1 Entrances shall be fitted with appropriate hardware suiting the functional and operating characteristics of the door and security requirements of the user.
.2 Dedicated entrance door systems will be activated by:
.1 Automatic Entrance Barrier Free systems
.3 Keying:
.1 Keying will be Grand Master Keyed to the Owner’s specification.

.6 Exterior Louvers:

.1 Description:
.1 Welded aluminum louver blades and frames in .081 aluminum thickness.

.2 Free Air to mechanical design requirements.

.3 Clear anodized finish.

.4 Louver sub-frames to be designed to meet windloads pertinent to the place of construction.

.5 Standard of Acceptance:
.1 C/S Louvers

.7 Roofing Systems:

.1 Two Ply Modified Bituminous Roofing:
.1 Steel Deck
.1 Description
.1 Two-ply modified bituminous roofing system c/w I-90 wind-up lift.

.2 Gypsum board sheathing.
  .1 Water resistant board to CAN/CSA-A82.27-M91 ½” thick.
.3 Vapour barrier – two-ply asphalt felts #1516.
  Asphalt: Type III in compliance with CSA A123.4M 1979.
.4 Rigid Insulation:
  .1 Polystyrene Insulation:
    .1 To CAN/CGSB-51.20-M87
    .2 Standard of Acceptance:
      .1 Truefoam Type 1 certified.
      .2 Truefoam Type 1 taper certified.
    .3 Required “R” value – R-30 (RSI-5.28)
    .4 Insulation value thickness per inch based on value listed in the latest edition of NRC-Evaluation listing.
.5 Fibreboard: ½” thick fibreboard as per CAN/CSA-A257 Series-M92 (R1998).
.6 Roofing Membrane:
  .1 Membrane base sheet – Base sheet non-woven polyester reinforcement and SBS thermofusible elastomeric asphalt. The top side thermofusible plastic film, and bottom side sanded, thickness 0.1”. CGSB classification: Type 2 Class C Grade 2.
  .2 Membrane cap sheet non-woven polyester reinforcement and SBS thermofusible elastomeric asphalt. The top side coloured granules, bottom side thermofusible film. Thickness shall be ¼”. CGSB classification: Type 1 Class A Grade 2.
  .3 Base sheet flashing – non-woven polyester reinforcement and SBS thermofusible elastomeric asphalt. Both sides shall be protected by a thermofusible plastic film. Thickness shall be 1/8”. CGSB classification: Type 2 Class C Grade 2.
  .4 Walking planks same material as membrane cap sheet in locations on the roof plan for servicing of roof mounted equipment.
  .5 Standard of Acceptance:
    .1 IKO
.7 Metal Flashing:
  .1 Prefinished sheet steel thickness 22 gauge colour selected by Consultant from manufacturer’s standard colour range.
.8 Installation
  .1 Gypsum board sheathing mechanically fastened to the metal deck. Vapour barrier is hot mopped to the sheathing board.
  .2 Insulation Boards and two layers of fibreboard complete with staggered joints adhered to the vapour barrier membrane and sheathing to ensure the required up-lift standards as noted.

.3 Two-ply modified bitumen roofing system installed in accordance with CRCA and manufacturers recommendations.

.2 Garden Roof System:

.1 Wood Decking, 4" x 4" or suitable depth dependent on Structural Review.

.1 Description

.1 Two-ply modified bituminous waterproofing landscape system c/w I-90 wind-up lift.

.2 Gypsum board sheathing.

.1 Water resistant board to CAN/CSA-A82.27-M91 ½" thick.

.3 Vapour barrier – two-ply asphalt felts #1516.
Asphalt: Type III in compliance with CSA A123.4M 1979.

.4 Rigid Insulation:

.1 Polystyrene Insulation:

.1 To CAN/CGSB-51.20-M87

.2 Standard of Acceptance:

.1 Truefoam Type 1 certified.

.2 Truefoam Type 1 taper certified.

.3 Required "R" value – R-30 (RSI-5.28)

.4 Insulation value thickness per inch based on value listed in the latest edition of NRC-Evaluation listing.

.5 Fibreboard: ½" thick fibreboard as per CAN/CSA-A257 Series-M92 (R1998).

.6 Roofing Membrane and Landscaping System:

.1 Membrane base sheet – Base sheet non-woven polyester reinforcement and SBS thermofusible elastomeric asphalt. Both sides protected with a thermoplastic film torched on only. Thickness 180 g/m^2

.1 Standard of Acceptance:

.1 Bakor

.2 IKO

.3 Soprema

.2 Membrane cap sheet non-woven polyester reinforcement and SBS thermofusible elastomeric asphalt blended with a root repellant agent . The top side coloured granules, bottom side thermofusible film. Thickness shall be 250 g/m^2 .

.1 Standard of Acceptance:

.1 Bakor

.2 IKO

.3 Soprema

.3 Interlocking water retention and drainage layer.

.1 Standard of Acceptance:

.1 Bakor ELT.

.4 Filter Fabric:
  .1 Fabrene.
.5 Roof Reinforcement Layer:
  .1 Standard of Acceptance:
    .1 Bakor ELT.

.7 Metal Flashing:
  .1 Prefinished sheet steel thickness 22 gauge colour selected by Consultant from manufacturer's standard colour range.
.8 Installation
  .1 Gypsum board sheathing mechanically fastened to the metal deck at per FM-1-90 Standards. Vapour barrier is hot mopped to the sheathing board.
  .2 Insulation Boards and two layers of fibreboard complete with staggered joints adhered to the vapour barrier membrane and sheathing to ensure the required up-lift standards as noted.
  .3 Two-ply modified bitumen roof membrane system installed in accordance with CRCA and manufacturers recommendations.
  .4 Install elevated landscape system strictly in accordance with manufacturer's instructions.

.3 Wood Canopy Section:
  .1 Heavy timber construction 10" x 10" hemlock rough sawn framing c/w heavy duty hot-dipped galvanized hardware, layout as per documents.
  .2 Wood Decking 4" x 4" (or suitable depth dependent on Structural review).
  .3 Interlocking water retention and drainage layer.
    .1 Standard of Acceptance:
      .1 Bakor ELT.
  .4 Filter Fabric:
    .1 Fabrene.
  .5 Root Reinforcement Layer:
    .1 Standard of Acceptance:
      .1 Bakor ELT.

3.2 INTERIOR SUB-DIVISION

.1 Interior Partitions & Finishes:

.1 All partitions extend to the u/s of the deck were required for fire, acoustical or functional requirements, unless otherwise noted.
  .1 Metal studs to ASTM C 645-00 size 92 mm spacing @ 400 OC, roll formed, thickness as per manufacturer's recommendations, unless noted otherwise.

.2 Gypsum Board:
  .1 5/8" gypsum board standard and type 'X' to CAN/CSA-A82.27-M91, both sides.
  .2 Very High Impact (VHI) resistant gypsum board to ASTM C 1178., 5/8" thick.
.3 Sound attenuation blankets and acoustical sealant where noted.

.2 Steel Doors and Frames:

.1 Steel doors to be fabricated, in accordance with Canadian Steel Door and Frame Manufacturers' Association, "Canadian Manufacturing Specification for Steel Doors and Frames 1990".

.2 Fire labeled products provided for all openings requiring fire protection ratings as noted on schedule. All products test in strict accordance with CAN4-S104-M80 (R1985), ASTM E 152-81a or ANSI/NFPA 252-1995.

.3 Door Construction:
  .1 Interior Door:
    .1 18 gauge material – weldscan (u.n. otherwise).
    .2 Honeycomb core construction:
      .1 Structural small cell, 1" mm maximum kraft paper 'honeycomb', weight: 80 lbs per ream minimum, density: 1.0 lbs / sq. ft minimum sanded to required thickness.
    .3 Frame construction:
      .1 Fully welded frame construction
      .2 16 gauge construction

.3 Glazing:

.1 Interior:
  .1 Tempered Glass: heat treated safety glass to CAN/CGSB-12.1-M90, ¼" thickness.
  .2 Hermetically sealed double glazing units. Unit fabricated to CAN/CGSB-12.8-M90 with clear tempered ¼" thick outer pane and inner panel of 6 mm tempered. Approximately 1" thickness in total.

.4 Wood Doors:

.1 Description
  .1 Core: bonded and sanded solid particleboard doors, 1 ¾" thick.
  .2 Rails and Styles: minimum 1 ½" bonded hardwood both inner and outer bands.
  .3 Face – 1/8", 3 ply construction birch plywood, stain grade finish.
  .4 Vertical edge strips to match face veneer.
  .5 Face – 1/8"
  .6 Type:
    .1 Swing Doors
    .2 Pocket Doors

.5 Finish Hardware:

.1 Reference Standards:
  .1 Standard hardware location dimensions in accordance with Canadian Metric Guide for Steel Doors and Frames (Modular Construction) prepared by Canadian Steel Door and Frame Manufacturer's Association.
  .2 CAN/CGSB-69 Series ANSI/BHMA A156 Series, as applicable.
.2 Requirements Regulatory Agencies:
  .1 ULC listed and labeled hardware for doors in fire separations and exit doors.

.6 Movable Partition:

.1 Design Criteria
  .1 The movable partition shall have a sound rating of class H, STC 51, in accordance with ASTM-E90 specification.
  .2 All finishes shall be in accordance with CAN 4-S102 specification. Flame spread; 20, fuel contributed: 10, smoke developed: 25.

.2 Panel Construction shall be 3 7/8" thick 48 ½"(max.) width consisting of 24 gauge (min.) steel sheet laminated on appropriated structural acoustical material, mounted in full perimeter protective frame of steel reinforced aluminum. Frame fully encloses and protects all edges of the surface material. Panel faces shall be removable and replaceable on the job.

.3 Panel Finish shall be factory applied class A rated reinforced vinyl pressure bonded to appropriate acoustical material; colour as selected by the architect from the manufacturer's standards. All frames and seal closures shall be in clear anodized finish.

.4 All tracks, trolleys closures and intersecting junctions as per manufacturer's standards.

.5 Standard of Acceptance:
  .1 Moderco

.7 Folding Grille:

.1 Aluminum Curtain constructed of vertical rods of 5/16" diameter spaced at 3", linked together with flat horizontal bars 1/8" x 5/8" x 6 5/8" bars, spaced vertically @ 12" by ½" aluminum sleeves.

.2 System complete with track, supports, locking mechanisms, etc.

.3 Standard of Acceptance:
  .1 Mobliflex – System 126.

3.3 VERTICAL MOVEMENT

.1 Stairs:

.1 Mezzanine Mechanical Room:
- .1 Steel bent 'chequer' plate, one piece construction with closed in riser
- .2 Continuous handrail.
- .3 Painted.

3.4 INTERIOR FINISHES

.1 Flooring Finishes:

.1 Hard Tile Flooring:

- .1 Slate Flooring:
  - .1 Natural Slate, grade: high density, (not containing pyrite), Size 12" x 18", Base 4" x 12".
  - .2 Standard of Acceptance:
    - .1 Scotia Slate Products Ltd., or approved alternate.
    - .2 A low absorption rate of 0.19 as per ASTM C 121-90 (1999), natural edge, gauged with a natural cleft surface, Colour: multicolour ranging from a blue-grey to green with natural copper, brown and gold overtones. Thickness: 3/8" to 5/8" for interior application.

.2 Modular Carpet:

- .1 Pile thickness: .074 inch.
- .2 Pile density: 14,509
- .3 Colour: as selected by Consultant from manufacturer's standard colour and pattern collection.

.3 Concrete Finish:

- .1 Polished concrete in accordance with CAN/CSA-A23.1.

.2 Wall Finishes:

.1 Ceramic Wall Tile:
- .1 Standard:
  - .1 To CAN-75.1-M77, Type 5 Class MR4.
- .2 Description:
  - .1 Glazed ceramic tile
  - .2 Standard of Acceptance:
    - .1 Olympia Maple Leaf.

.2 Special Coatings:
- .1 Water borne epoxy finish, 100% acrylic, VOC compliant.

.2 Standard of Acceptance:
  .1 Degussa – Thorocoat

.3 Painting
  .1 Standards:
    .1 Conforming to Master Painting Institute Standards.
  .2 100% Latex
  .3 Standard of Acceptance:
    .1 PPG Manorhall

.3 Ceiling Types:

.1 The following are ceiling types used throughout the project
  .1 Exposed concrete/services
    .1 Painted Dry fog
  .2 Gypsum Board
    .1 5/8" gypsum board type 'X' taped and on cold formed metal ceiling grillage system and support.
    .2 Painted (epoxy in wet areas).
  .3 Suspended Acoustical tile ceiling system.
    .1 To CAN.CGSB-92.1-M89
    .2 Suspension system
      .1 Non-rated two directional exposed tee-grid system, satin sheen white, c/w carrying channels, wire and clips.
      .2 Mineral board lay-in panels
      .3 Types and Classification
        .1 General use panels
        .2 Decorative use panels

3.5 EQUIPMENT

.1 Architectural Casework:

.1 Washroom Vanities:
  .1 Plastic laminate countertop post formed to A172-M79 Grade PF
  .2 Colour as selected by Consultant from manufacturers standard color range.
  .3 Supports for countertops
    .1 1" Ø tubes to suit vanity top, painted.
  .4 Barrier free construction.

.2 Miscellaneous Millwork:
  .1 To AWMAC Premium Grade Standards, latest edition standards.

.3 Countertops:
  .1 Acid resistant plastic laminate countertops.
  .2 Special tops as required by function.
  .3 All tops complete with fastening hardware.
  .4 Concrete countertops with embedded fossils.

.2 Miscellaneous Specialties:

.1 Public Washroom Accessories:
  .1 Washroom Accessories (All Material Stainless Steel):
    .1 Towel Dispenser
    .2 Sanitary Napkin Disposal bin
    .3 Sanitary Napkin Dispenser: by owner
    .4 Toilet Tissue Dispenser
    .5 Soap Dispenser
    .6 Frame Mirror
    .7 Grab Bars
    .8 Grab Bars
    .9 Grab Bars
    .10 Waste Receptacle
    .11 Baby Change Table:
  .2 Custodial Accessories:
    .1 Mop hanging clips and shelving.

.2 Solid Core Toilet Partitions:
  .1 Floor mounted headrail braced
  .2 Description
    .1 Wall panels as per manufacturers recommendations.
    .2 Wall components made from ¾” thick stock solid phenolic c/w all manufacturer recommended mounting hardware.
    .3 Standard of Acceptance:
      .1 Decolam.

.3 Lockers:
  .1 Locker Construction:
    .1 Cold rolled steel construction with high grade hybrid epoxy polyester finish.
      .1 Body – 24 gauge
      .2 Frame – 16 gauge
      .3 Doors – 20 gauge outer panel
      24 gauge inner panel
      .4 Locking and Latching mechanism
      single point, 11 gauge 2” x ¾” padlock hasp.
      .5 Hinge – Continuous
      .6 Standard interior equipment, locks and shelf.
      .7 Type and Size:
        .1 Size: 15”w x 15”d
        .2 Type: Four tier deluxe.
      .8 Standard of Acceptance:
        .1 Shanahan’s
        .2 Hadrian

.3 Whiteboards:

.1 White porcelain enamel

.2 Satin aluminum trim and bottom marker tray

.3 Standard colour markers and magnetic brush/board.

.4 Size to be discussed.

.5 Location to be discussed.

.6 Standard of Acceptance:
  .1 ASP “Write-On, Wipe-Off” Writing Board, Series 3000

.4 Window Treatments:

.1 Roller Shade System:
  .1 Sun shade fabric.
  .2 Black out fabric where noted.
  .3 Chain operated in accordance with Manufacturer’s Recommendations.
    .1 System Description
      .1 Sun Project Manufacturer, Standard of Acceptance
        .1 Roller Shade System, Sun Project SPI-FC, clear anodized finish.
        .2 Frontal mount.
        .3 Fabric: 3000 fabric, colour to be selected.
        .4 Blackout where noted.
        .5 Double cassette

.5 Signage

.1 Washroom:
  .1 Male pictogram
  .2 Female pictogram

.2 Room Names and Numbers

4.0 Mechanical

.1 Plumbing:

.1 All work will be done to the requirements of the National Plumbing Code 1995 edition.

.2 Above ground waste pipe will be copper with soldered joints or cast iron with mechanical joints. Water piping will be Type L copper with lead free solder. PEX piping will be used for individual runouts to fixtures up to 1". Underground storm will be PVC SDR35 and sanitary sewer will be PVC DWV.

.3 Water closets will be white vitreous china, floor mounted, with manual flush valves. The flush valves will be dual flush type, 4.2 litre flush for liquids and 6.0 litre flush for solids.

.4 Urinals will be vitreous china, waterless type.

.5 Lavatories will be counter top self-rimming stainless steel.

.6 Public lavatory faucets will have aerators and self-closing valves. Waste stoppers will not be provided.

.7 The domestic cold water supply will be provided from a drilled well complete with a water treatment system as required. Depending upon the maximum recommended flow rate of the well, a domestic cold water storage tank and domestic water supply pump c/w standby pump will probably be required. It is recommended that the well be drilled and tested at the earliest opportunity.

.8 A hot water storage heater will be installed for domestic hot water, complete with an electric resistance heater in the tank. A solar domestic hot water collection system will also be considered as a demonstration project.

.9 All plumbing for this contract will end 5'-0" outside the building except to the new drilled well. The sanitary system will connect to the municipal sewer where extended to the building. Controlled flow roof drains from the flat roof areas will drains down to the site water drain off system.

.2 Heating:

.1 Currently there is not a great deal of difference between the cost of heating a building by burning oil or by using electric resistance heating. If a structure is heated using air source electrical heat pumps, the seasonal operating cost is about 2.5 times less than using electric resistance heating. Therefore presently, the cost of heating a project with an electric heat pump is less than heating that project by burning oil.

.2 Over the past 25 years, the cost of oil has risen much more sharply than the cost of electricity. As a result the gap between heating with oil and using electric heat pumps is likely to widen. For the present we will assume that electric heat pumps will be used as the primary heating for the new facility.

.3 Split system heat pumps would be used. They would be designed to meet the heating loads down to an exterior temperature of approximately -6 degrees C. This would meet the building requirements for all but a few days a year. Below that temperature, a back-up electric resistant coil would be required to assist the heat pumps.

.4 Based on using electricity, the facility would primarily be heated by air using split systems connected by refrigerant piping. There would be exterior units on the ground, camouflaged with landscaping, connected to the interior units with refrigeration piping. This system will also be capable of providing air conditioning to the building as a side benefit, but this could be disabled if required.

.5 There will be separate space temperature control for the following occupancies: Multi-Purpose Room, Visiting Scientist/Curator Office, Staff Room, Individual Offices, Administrator's Office, RCMP Office, RCMP Interview Room, Central Lobby/Gift Shop/Food Service Area, Main Exhibit Area, and Exhibit Theater Area. This individual control will be provided by variable air volume (VAV) boxes for each room. The supply air temperature to the spaces will be determined by the room with the greatest heating or cooling requirement. The VAV box for that room will be on 100% air supply. The VAV boxes for the other rooms will be partially closed as required to maintain that room temperature setpoint.

.6 Humidification will not be provided.

.3 <u>Ventilation:</u>

.1 There will be a central fresh air supply system with intake section having 30% efficient prefilters and 95% efficient final filters, a plenum fan section with variable speed control, access section, flat plate heat recovery section, access section, and a back-up electric heating coil. The exhaust side will have a 30% efficient filter, access section, flat plate heat recovery section, access section, and an exhaust fan. See the attached diagram of the, "Fresh Air Supply System", for a schematic of the system described above.

.2 The fresh air supply system will run a fresh air supply to the two indoor heat pump units. Each duct will have a damper. When the building is occupied, the dampers to the indoor heat pumps are opened to the minimum position. If the carbon dioxide sensors detect the CO_2 rising above 800 ppm, the damper for that heat pump opens to maintain the CO_2 setpoint.

.3 If the room temperature starts to fall because the fresh air is too cool, the electric coil in the air handling unit will compensate. This should seldom occur during the normal seasonal operation. The heat pump heating system should be able to provide the additional heating most of the time if required.

.4 An attached schematic called, “Typical Heat Pump Schematic”, shows the standard heat pump arrangement. Return air from the ceiling space is ducted back to the indoor unit where it mixes with the fresh air from the fresh air supply system. The fan blows the mixed air through the coil where it can be heated or cooled. The supply air temperature will be determined by the space with the greatest heating or cooling load, depending on the season. Room sensors will control the variable air volume (VAV) boxes for individual room control. The bypass damper from the supply duct to the return duct will maintain constant air flow through the indoor unit regardless of the operation of the VAV boxes.

.5 The indoor heat pumps will be mounted in the mechanical rooms on 4" thick housekeeping pads and the fans will be isolated from the building structure using spring vibration isolators. The fresh air supply system will be suspended from the structure in the mechanical room. A mezzanine and ladder will be provided to service this unit.

.6 Silencers will be used for noise suppression. No duct liner will be used.

.7 Fume hoods and chemical storage cabinets will have welded stainless steel ductwork with acid resistant exhaust fans.

.8 A separate split system AC unit will be supplied for the server room.

.9 Ductwork will be galvanized steel. All ducts shall be sealed.

.10 Exhaust ductwork within 10'-0" of the exterior and all fresh air ductwork will be insulated.

.11 The Electrical Room will have a separate exhaust fan controlled from a space temperature sensor.

.12 High areas such as the Multi-Purpose Room and the Main Exhibit Area will have destratification fans to move the air around and to blow the heat down to the floor.

.13 The Outside Storage Building will have a exhaust fan running continuously to minimize odours from stored equipment.

.4 <u>Automatic Controls:</u>

.1 A DDC electronic control system will be provided to control, schedule and monitor systems including the air handling system, heat pumps, heating, exhaust fans, etc. All equipment will be interfaced with the DDC system. The DDC system will be BACnet/IP accessible and will be accessible from a remote system if the workstation is off.

.2 Such things as force flow control, AHU freezestats, etc. will be hard wired to the various pieces of equipment.

.3 Room sensors controlling standard variable air volume dampers will provide individual room control.

.4 Night setback will be achieved by the DDC system.

.5 Fire Protection:

.1 The building will have fire extinguishers installed according to NFPA 10. They will be located in semi-recessed cabinets in public spaces and on wall brackets elsewhere.

.6 Mechanical Environmental & Energy Conservation Measures

.1 Use electronic, self-closing lavatory faucets.

.2 Use waterless urinals. These 2 measures should reduce water consumption by approximately 30%.

.3 Use dual flush, flush valve water closets. The flush for these fixtures can be adjusted for the load - 4.2 litres for water waste and 6 litres for solid waste.

.4 Use heat pumps for space heating and for heating the fresh air supply to the building. On average, heat pumps will produce about 2.5 times more energy than is required to power them. They draw the additional energy used for the building from the air, ground, or water, depending on what they use for a heat source. This is much less expensive to operate than oil-fired heating. John Calder informs us that he is not aware of any information on the water temperature in the mines, the level of the water in the mines, etc. He recommends that a well driller do some holes, probably about 100' deep to intersect the mine shaft and test the water. Our understanding is that exact information on the shafts is missing and these holes would have to be drilled on a hit or miss basis. Dr. Calder could assist in locating prospective locations for drilling.

.5 Occupied rooms will have their own heating control. This will allow these rooms to be heated when used and the temperature set back otherwise.

.6 A solar heating system will be used to preheat the domestic hot water. This could produce most and at times all of the domestic hot water.

.7 All motors would be high efficiency type.

.8 The fresh air would be supplied through a heat recovery ventilator that would recover a portion of the heat from the exhaust air and use it to preheat the supply air. The units will also have motorized dampers to obtain tight air closure when not in operation.

.9 The fresh air supply for large rooms such as the Interpretation area with variable occupation, will be controlled by carbon dioxide sensors to vary the fresh air supply according to the actual inhabitant loading of the space.

.10 All large, high spaces would have variable speed de-stratification fans that would push the heat back down to the floor during cold periods but would be off during warm periods to permit the coolest air to fall to the floor level.

.11 All of the main building mechanical systems will be controlled by a Direct Digital Control system through a computer operator work station. Graphics will show the systems operating with temperature set points, actual air temperatures, etc. Schedules of operation and space temperatures can easily be modified through this system. The system can readily be tied into the internet for remote access and checking providing the user knows the proper password and identification.

.12 Display cases with micro climate control will be used where necessary for humidity sensitive displays. Otherwise, display material and signage should not require humidification control. This will eliminate the need for air conditioning units for dehumidification and electrically powered humidifiers.

.13 A method of providing natural ventilation to the building can be implemented by installing operable windows with contacts for the perimeter spaces. The window contacts will send a signal to the DDC system which will then shut-off the supply air to the room by closing the variable volume box. The fans for the fresh air supply system will be equipped with speed drives to reduce the quantity of fresh air delivered to the heat pumps.

5.0 ELECTRICAL

5.1 POWER

.1 A primary electrical service will be extended underground from a utility terminal pole on Main Street to a padmount transformer located as close as practical to the building electrical room. The transformer location will have to be sited to suit the sensitivities of the facility and may require some landscape treatment to minimize its visual impact.

.2 A secondary 347/600 volt, three phase, four wire service will be extended underground from the padmount transformer to the service entrance electrical equipment, located in the electrical room. The 347/600 volt distribution will be utilized to service any fluorescent or high intensity discharge lighting, heat pump and larger mechanical loads.

.3 A dry type transformer, located in the electrical room will transform from 600 volts to a 120/208 volts, three phase, four wire system This system will be utilized to service any incandescent lighting, receptacles and smaller equipment loads.

5.2 Wind Energy

.1 Anecdotal evidence suggests that there may be an opportunity to take advantage of wind energy. The nearby RCMP detachment at Amherst employs a 50 kilowatt wind turbine generator on a net metering basis. Some site specific measurements would be necessary to verify the potential for this site, however if we assume an average wind speed of 6m/s, a generator, such as the unit at Amherst could produce 120,000 kilowatt hours of electricity per year. At today's electricity rates that translates into a saving of approximately $10,000.00 per year and a reduction in greenhouse gas emissions of 120 tons of carbon dioxide.

5.3 Daylighting

.1 The proper use of daylight can be used to enhance the experience of the visual connection to the outside, by providing a continuum. The rendering of space, colour and texture can be used to blur the boundary of the building perimeter. We are able to accurately calculate the day lighting component, access its impact on the lighting of the space and produce accurate renderings of the lit environment. The challenge with the use of day lighting is the control of glare and the costs of implementing control and shading devices. Of course the higher capital cost is mitigated by the lower electricity cost, otherwise associated with the operation of artificial lighting.

5.4 Artificial Lighting

.1 Lighting will utilize a variety of lighting technologies depending on the specific architecture of the space, integration with daylight, lighting quality (colour temperature and colour rendering), and control. Control could use daylight sensors, motion sensors, on-off control, dimming and combinations of all of these measures. General lighting would typically employ the use of environmentally friendly fluorescent and/or metal halide lamps with low mercury gases. Accent and display lighting could use metal halide and LED fixtures. LED's are gaining efficiency and products are being developed and introduced at an ever-increasing rate. The use of LED's introduces some interesting possibilities relating to simultaneous dimming and colour change. Although this possibility does have some notable cost implications, it may have application in some limited areas or displays. The lowly incandescent and its derivatives continues to have a place and can be an energy efficient and effective source when used in conjunction with motion sensors for accent and/or display lighting.

.2 Emergency lighting will be provided by battery operated unit equipment to meet the requirements of the Nova Scotia Building Code Regulations and the National Building Code.

.3 Exit lights will be LED type powered by both the building AC system and the DC supply from the emergency lighting unit equipment noted above.

5.5 Communications

.1 Service will be provided to the facility by extending underground ducts from the utility terminal pole on Main Street to the electrical room. Utility communications cable termination and a demarcation point will be set up in the electrical room. Tie cables will then be run from the demarcation point to the communications rack located in the communication/server room. A system of wiring will be extended from the communications room to RJ-45 outlets located throughout the various building spaces. The installation will meet the requirements of CSA standard T529 and provide facilities for the use of both voice and data communication.

5.6 Fire Alarm System

.1 The building will be provided with a single stage, non-coded, addressable fire alarm system meeting the requirements of the Nova Scotia Building Code Regulations, the National Building Code and ULC/CAN S524. This will generally involve fire alarm pull stations located next to the building exits, fire detectors in janitors rooms, storage rooms etc., audible and visual devices (horn/strobe units) located throughout the facility. The fire alarm system will be connected to a monitoring agency through a connection and dialler that is a part of the security system elsewhere.

5.7 Security System

.1 Contact switches will be installed at each exterior door wired to a security alarm panel. Dual technology, infrared and ultrasonic, motion detectors will be also located through the larger public spaces. A keypad will be strategically located so that the system can be armed and disarmed by authorized personnel, using assignable codes.

For Continuation See South Plan

Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

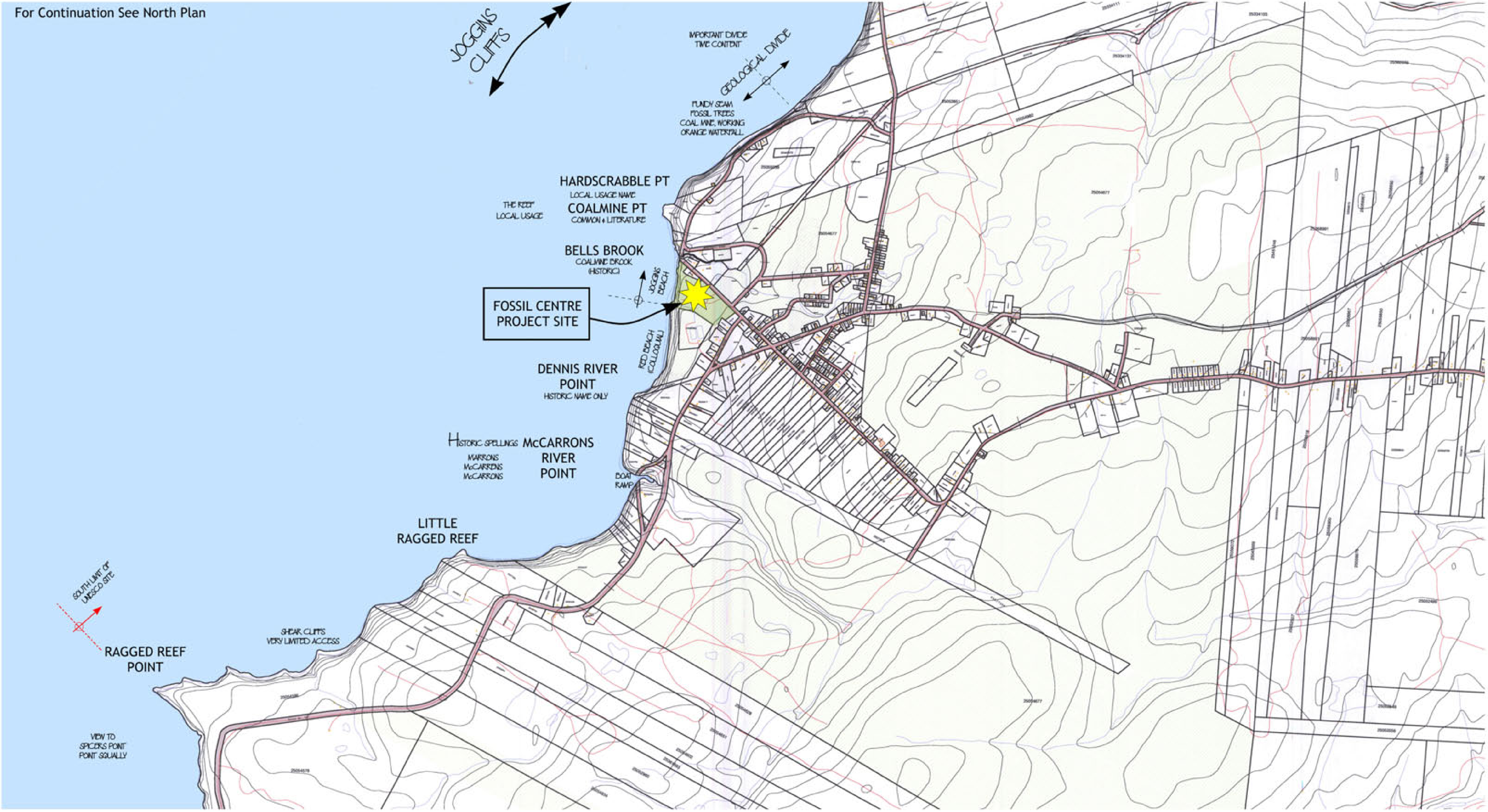
Design Development Submission - UNESCO World Heritage Site Plan - North Sector

0 500 1000 2000'

north

Vollick McKee Petersmann

whwarchitects



Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

Design Development Submission - UNESCO World Heritage Site Plan - South Sector

0 500 1000 2000'

north

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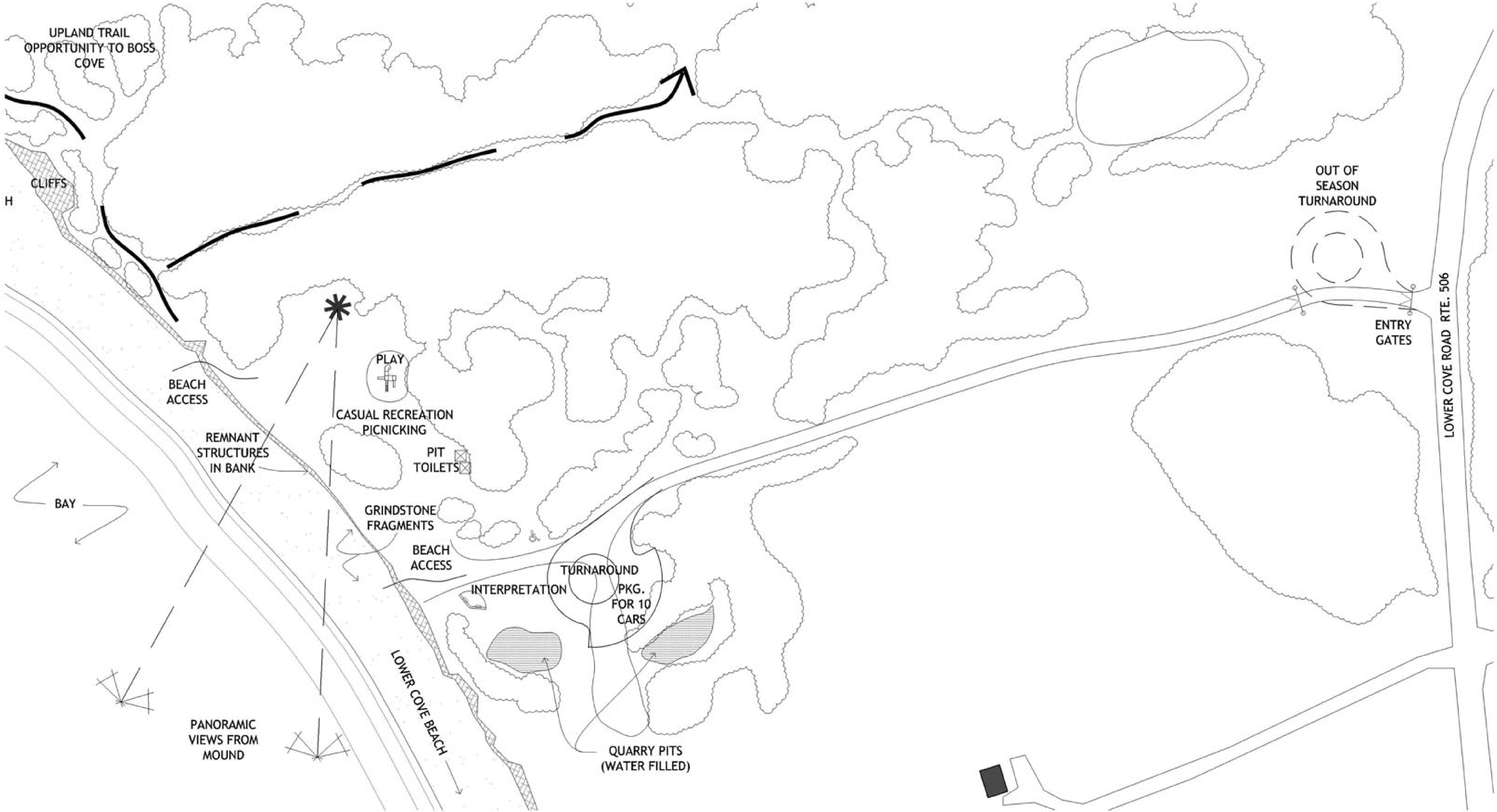
whwarchitects



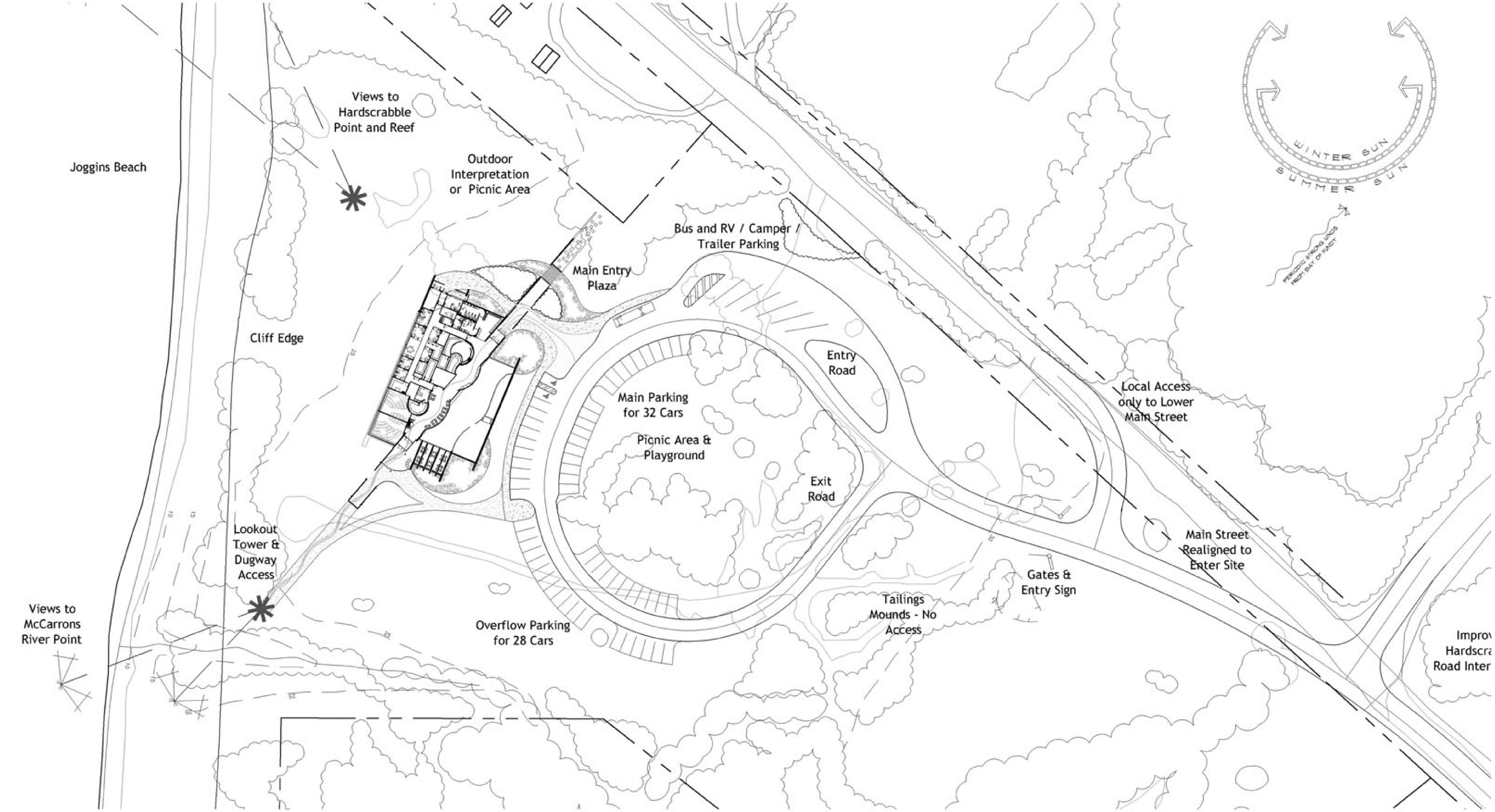
Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

Design Development Submission - Grindstone Beach - Access Point & Turnaround

Vollick McKee Petersmann

whwarchitects



Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

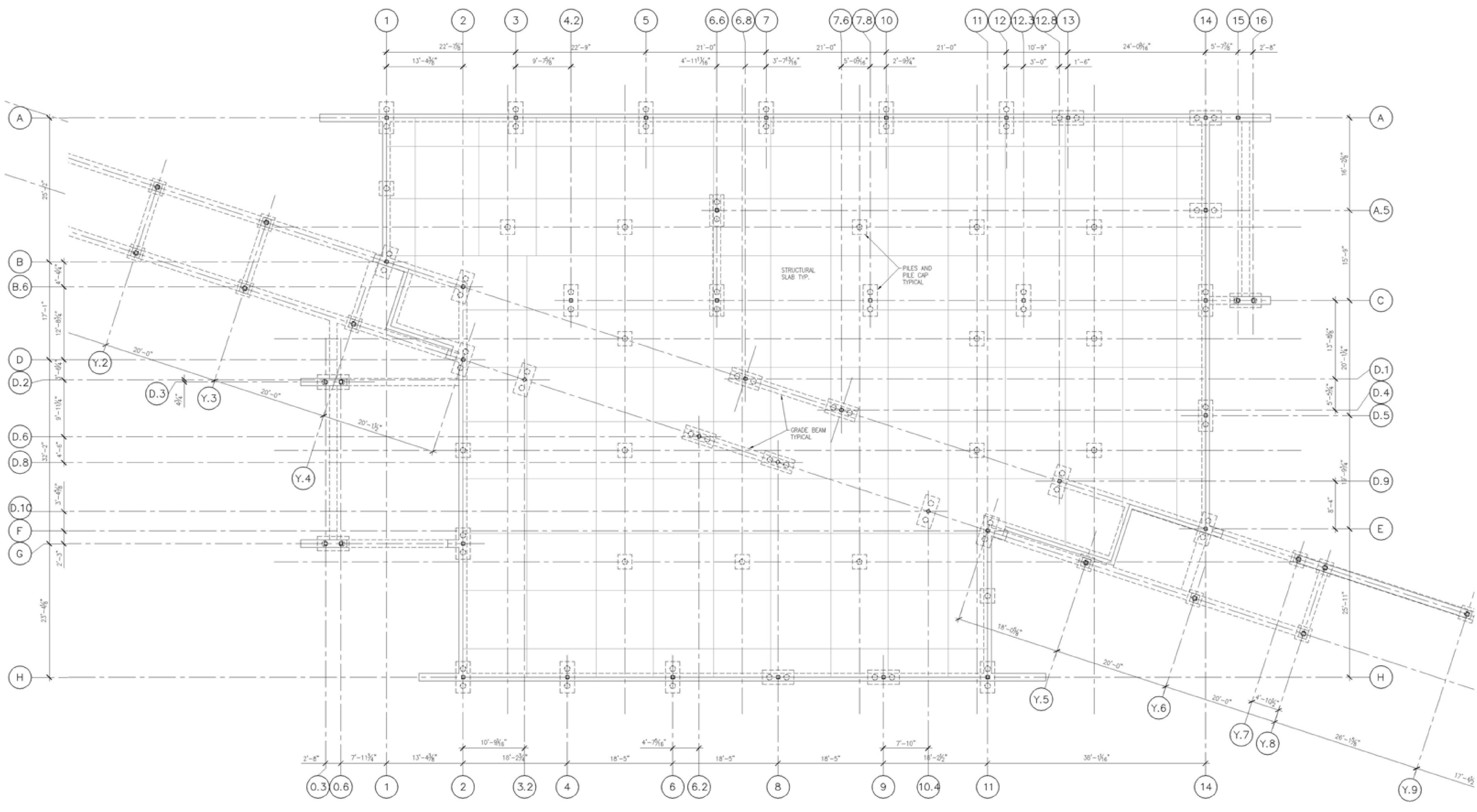
Design Development Submission - Centre Site Plan

0 10 25 50 100'

north

Vollick McKee Petersmann

whwarchitects



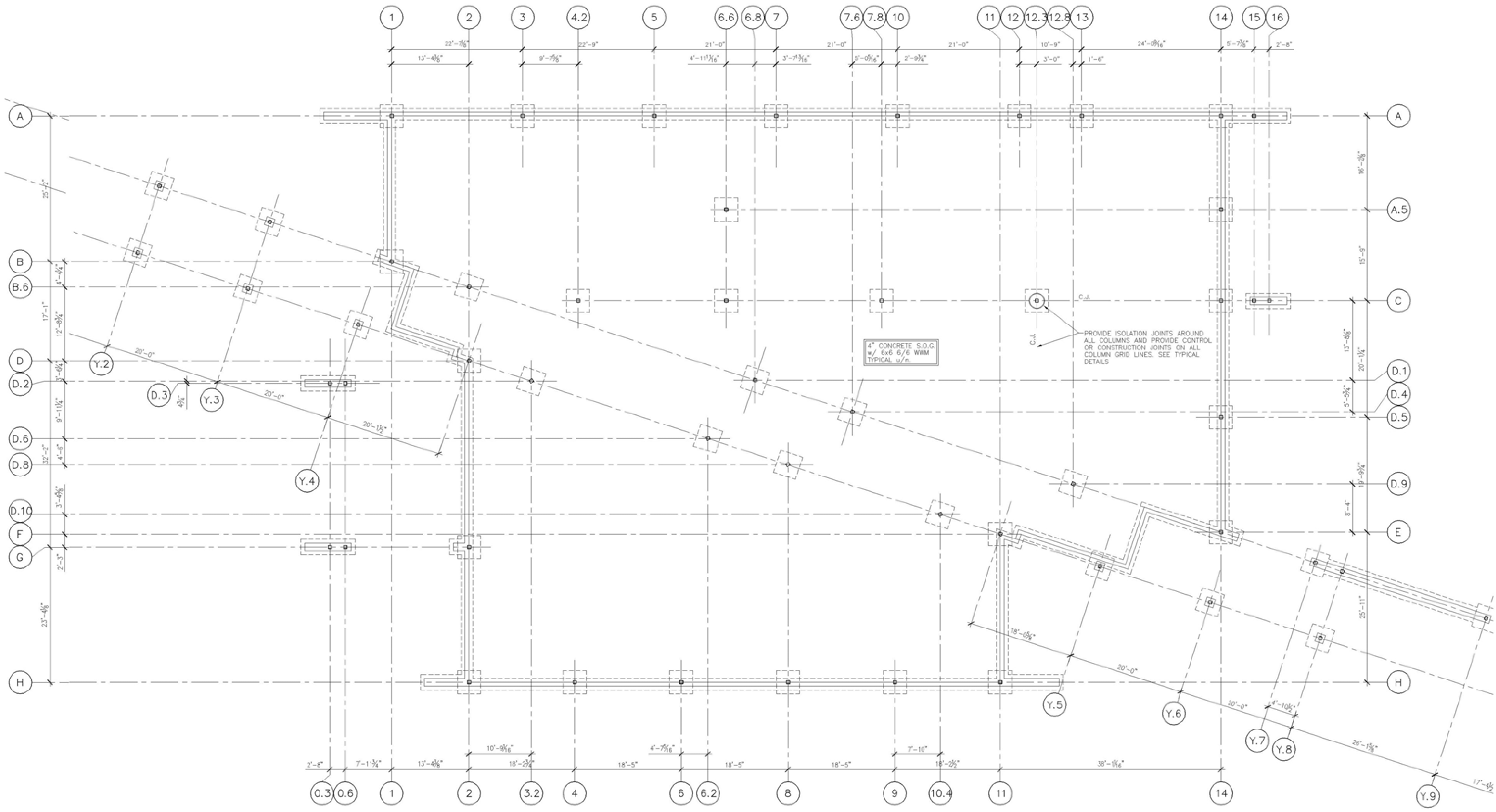
Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Foundation Plan (Pile Foundation Option)

24 February 2006

BMR Structural Engineering

whw architects



Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Foundation Plan (Conventional Foundation Option)

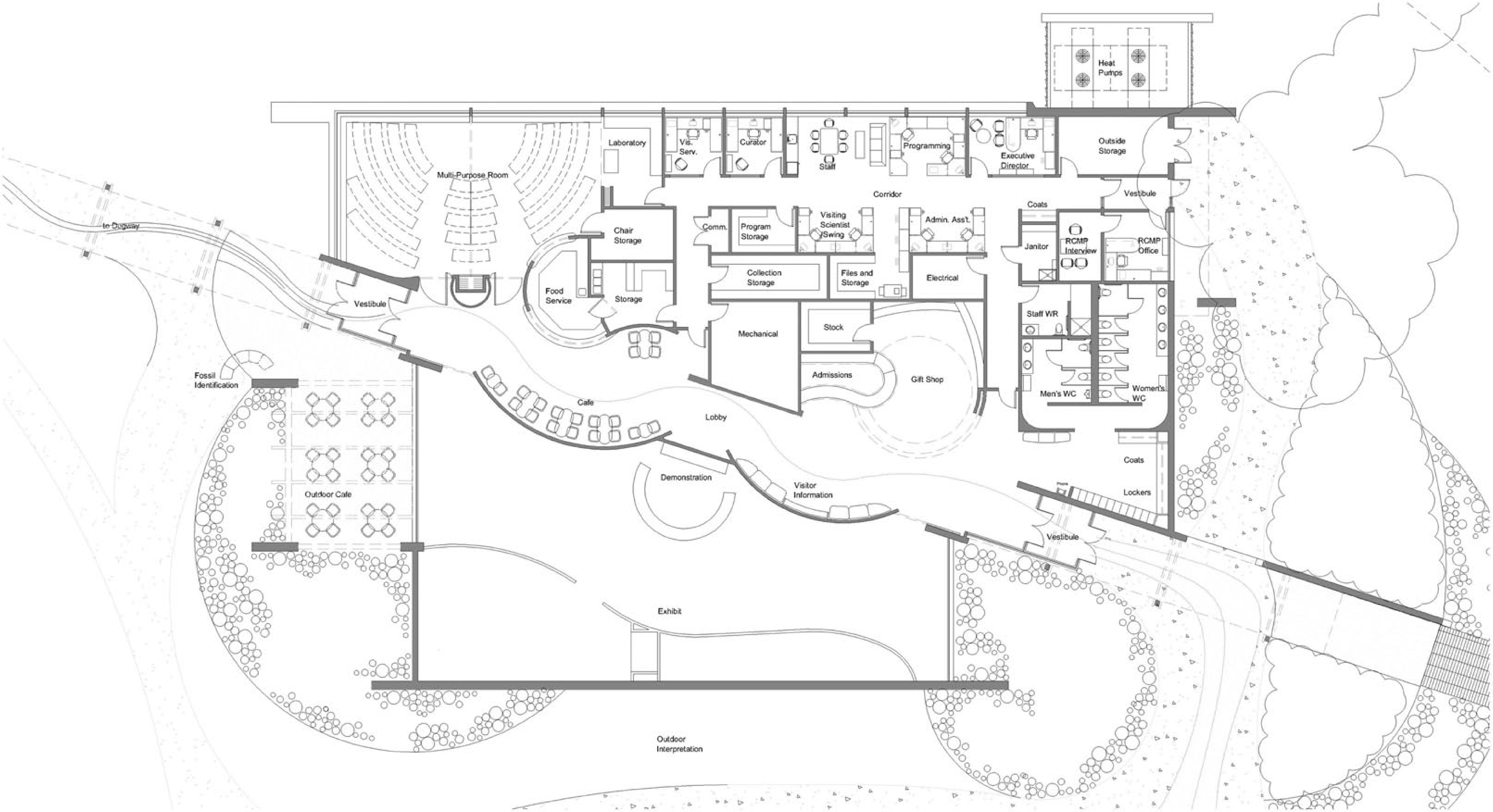
0 2 4 8 16'

north

BMR Structural|Engineering

24 February 2006

whwarchitects



Joggins Fossil Cliffs Comprehensive Site Development Plan

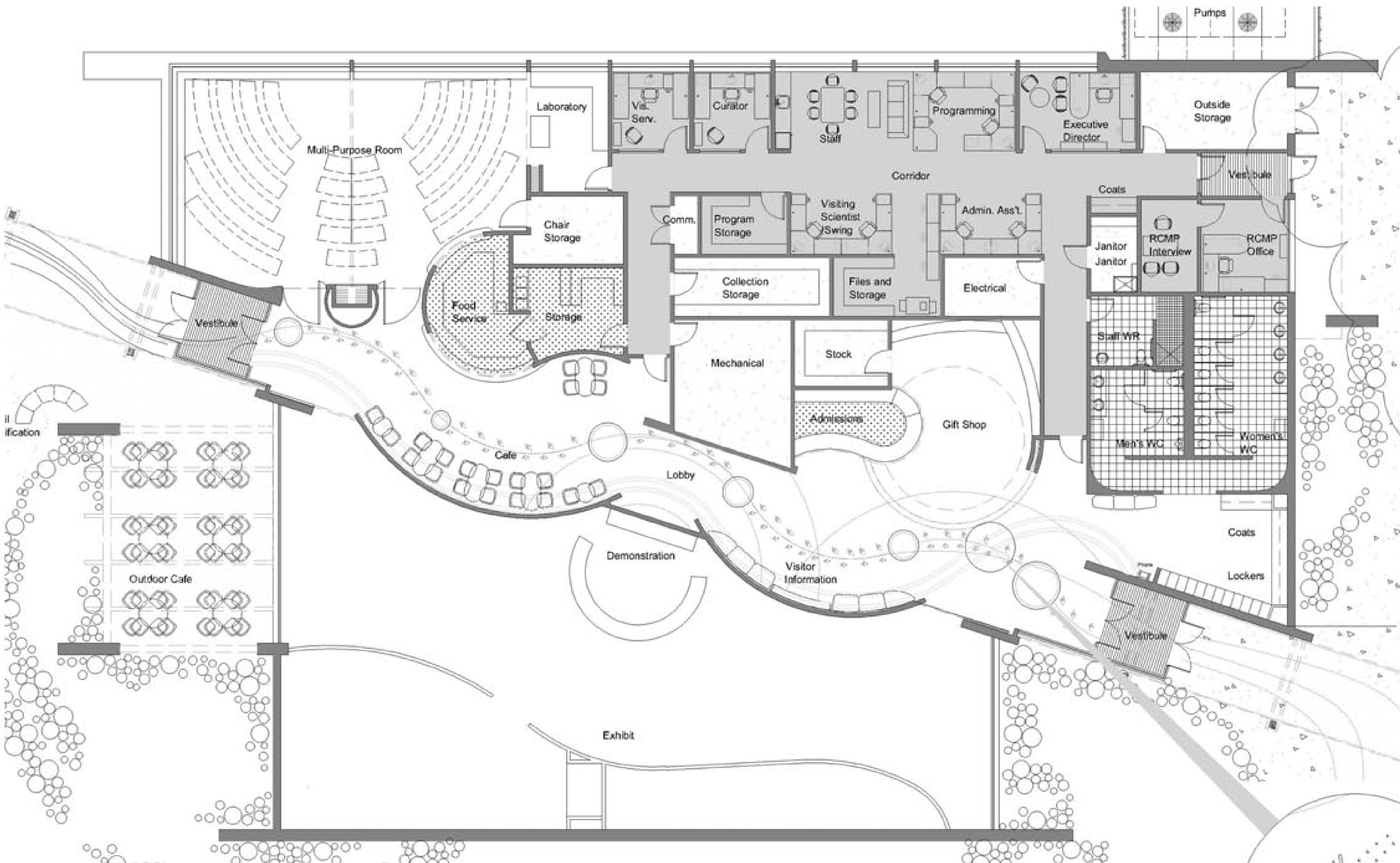
24 February 2006

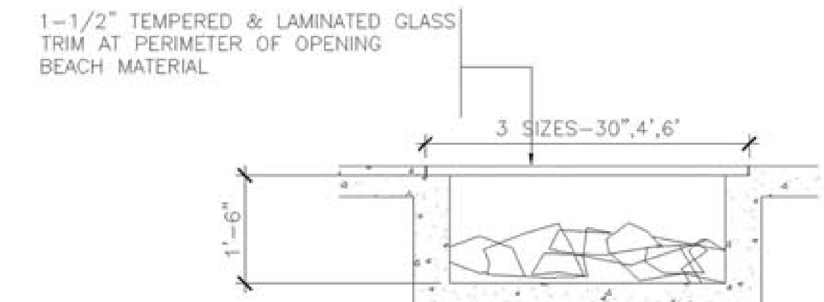
Design Development Submission - Floor Plan

0 2 4 8 16'

north

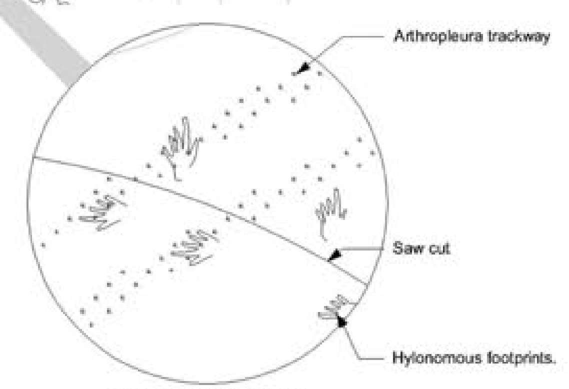
whwarchitects



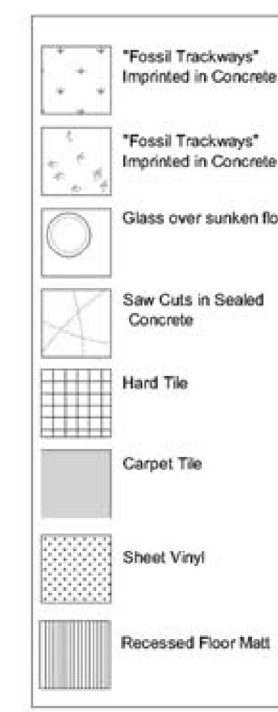


Section thru. sunken floor

SCALE: 3/8"=1'-0"

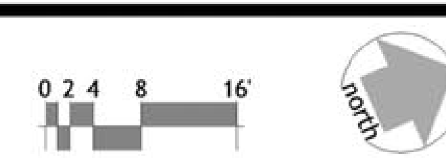


Hylonomous & Arthropleura trackways printed in concrete floor.



Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Floor Finishes Plan



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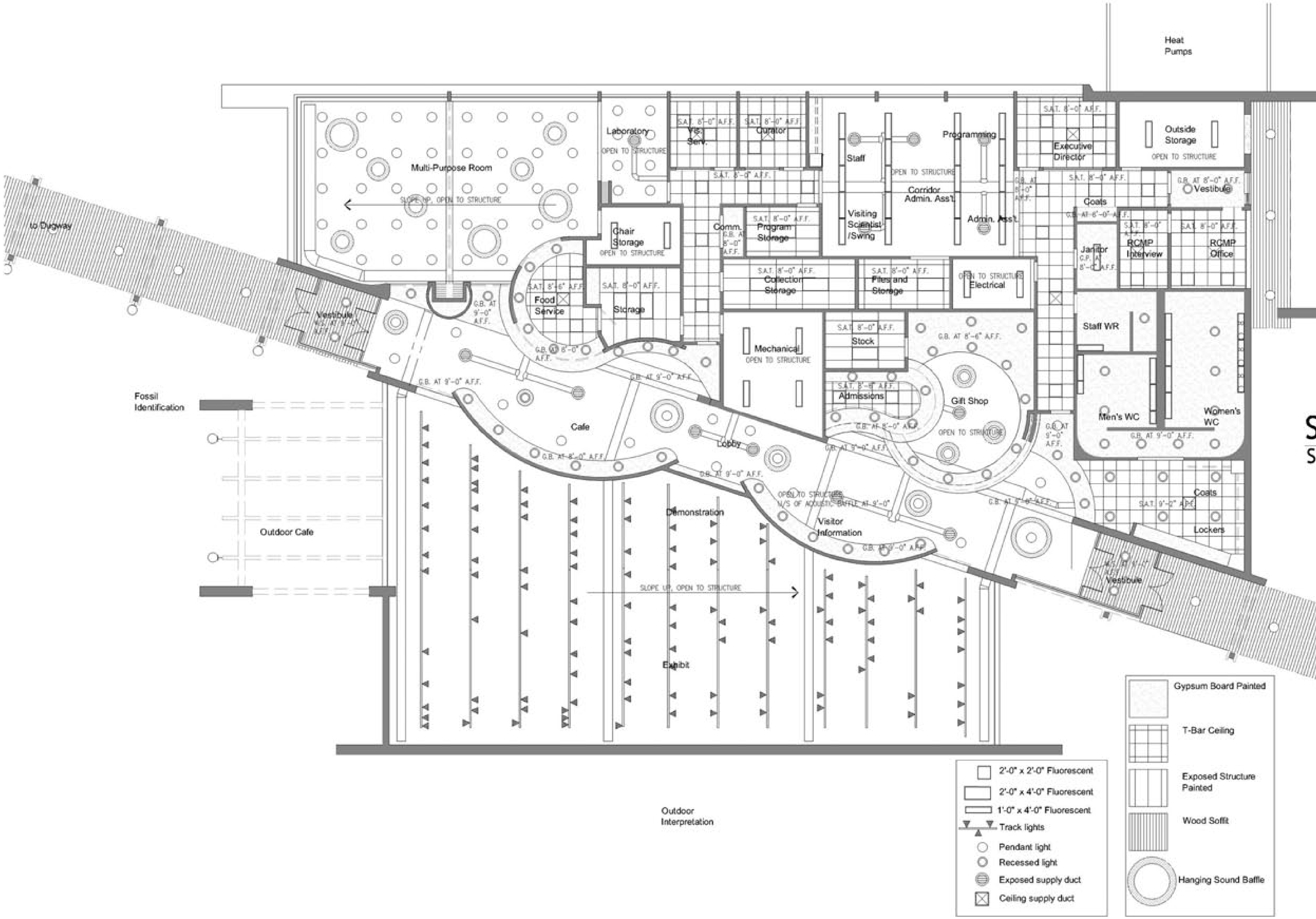

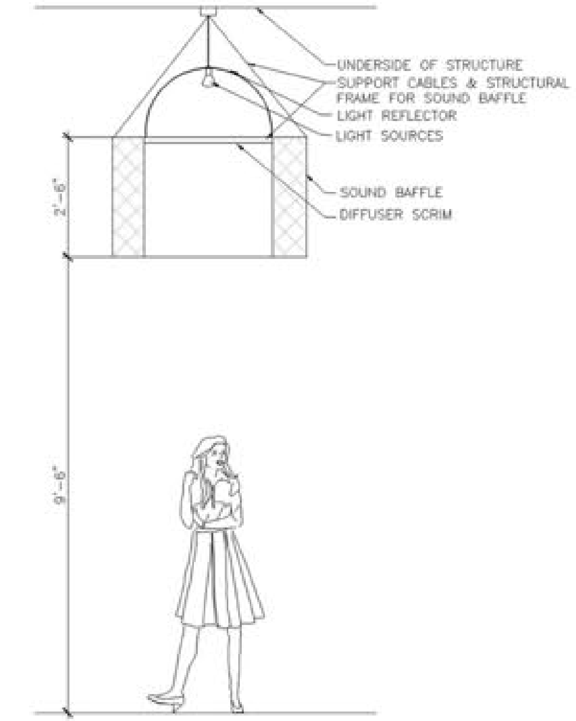

Section thru. sound baffle

SCALE: 1/4"=1'-0"

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Reflected Ceiling Plan

0 2 4 8 16'

north

17 February 2006

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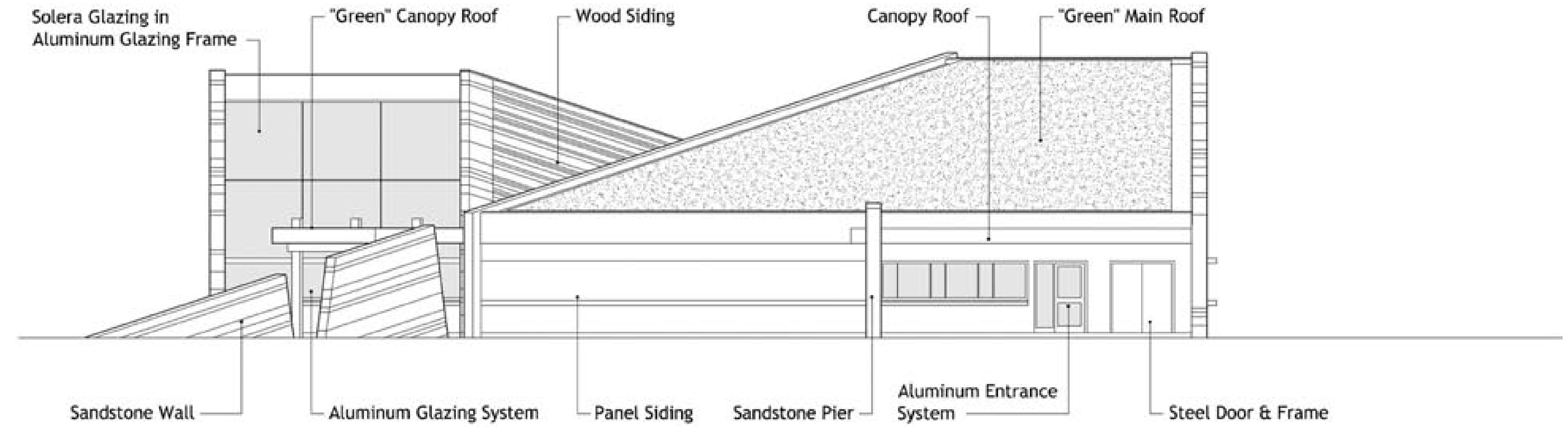
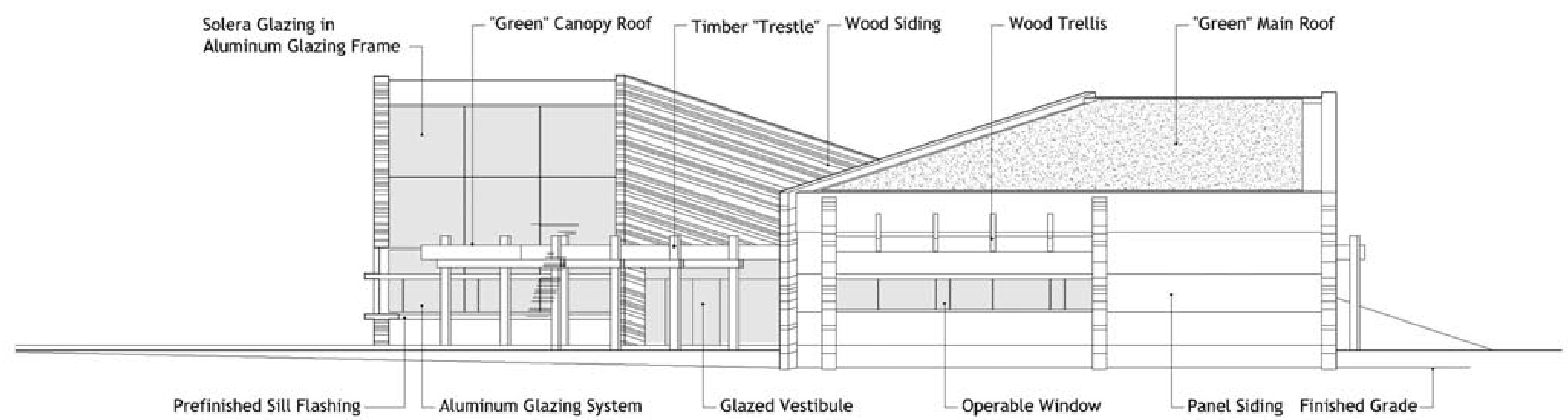


North Elevation



South Elevation

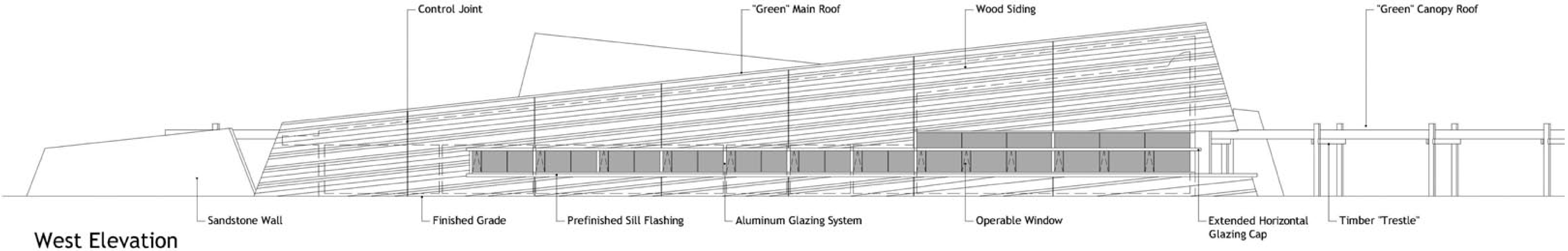
Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

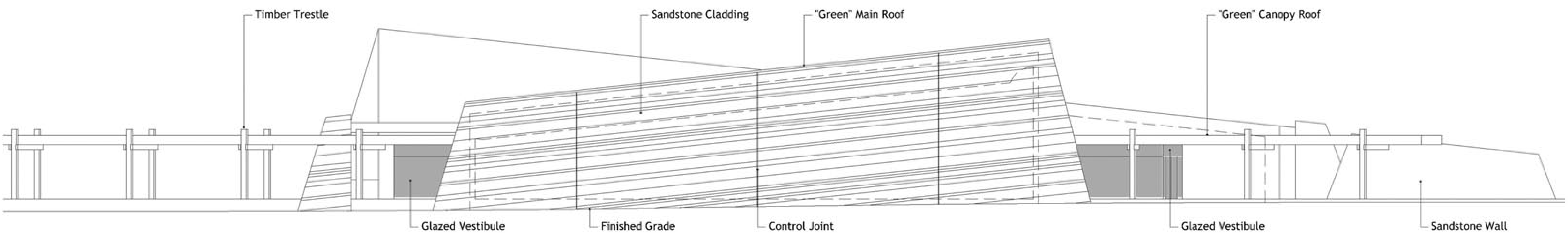
Design Development Submission - Building Elevations

0 2 4 8 16'

whwarchitects



West Elevation



East Elevation

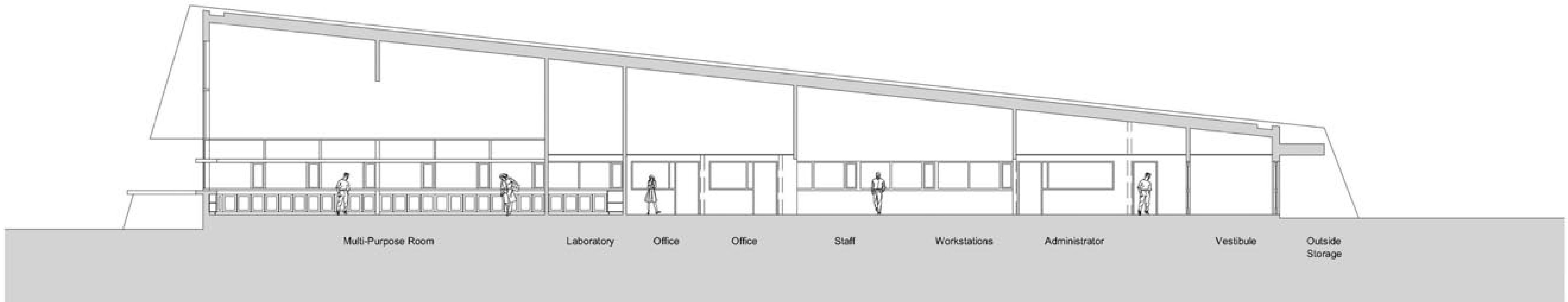
Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

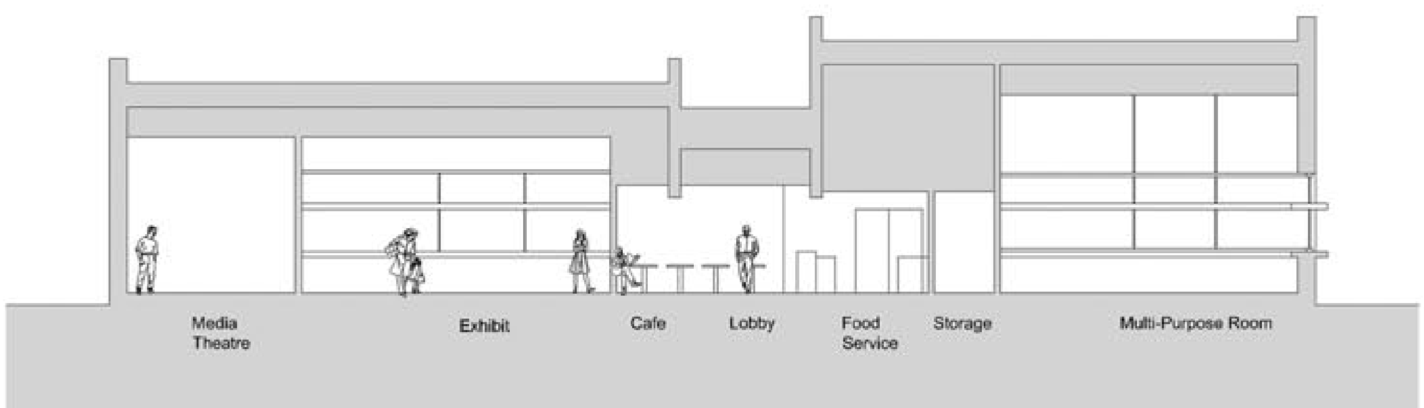
Design Development Submission - Building Elevations

0 2 4 8 16'

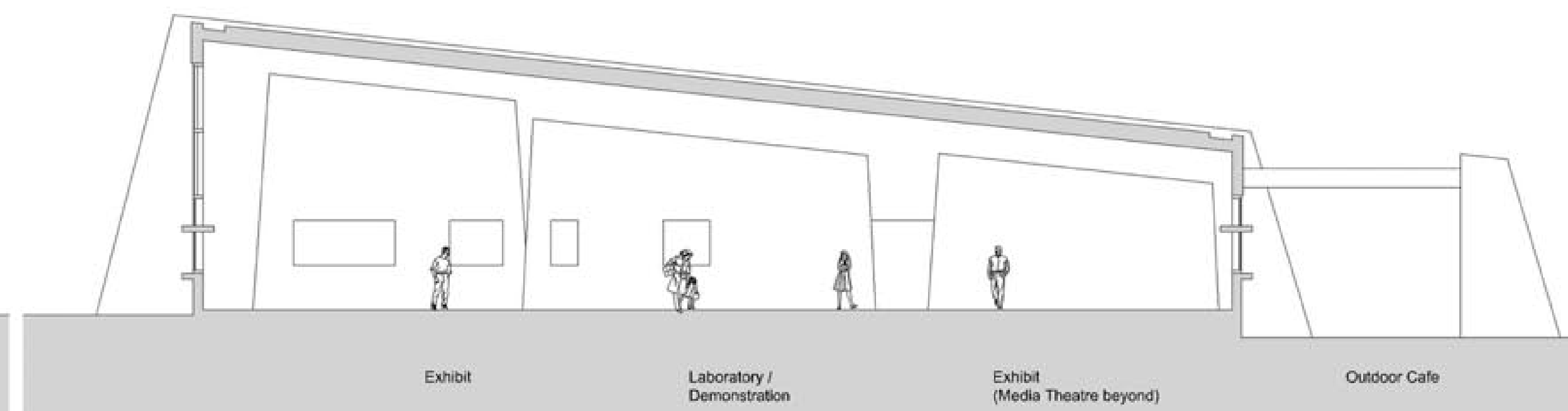
whwarchitects



Section Looking West - through Multi-Purpose Room and Offices



Section Looking South



Section Looking East - through Exhibit Space

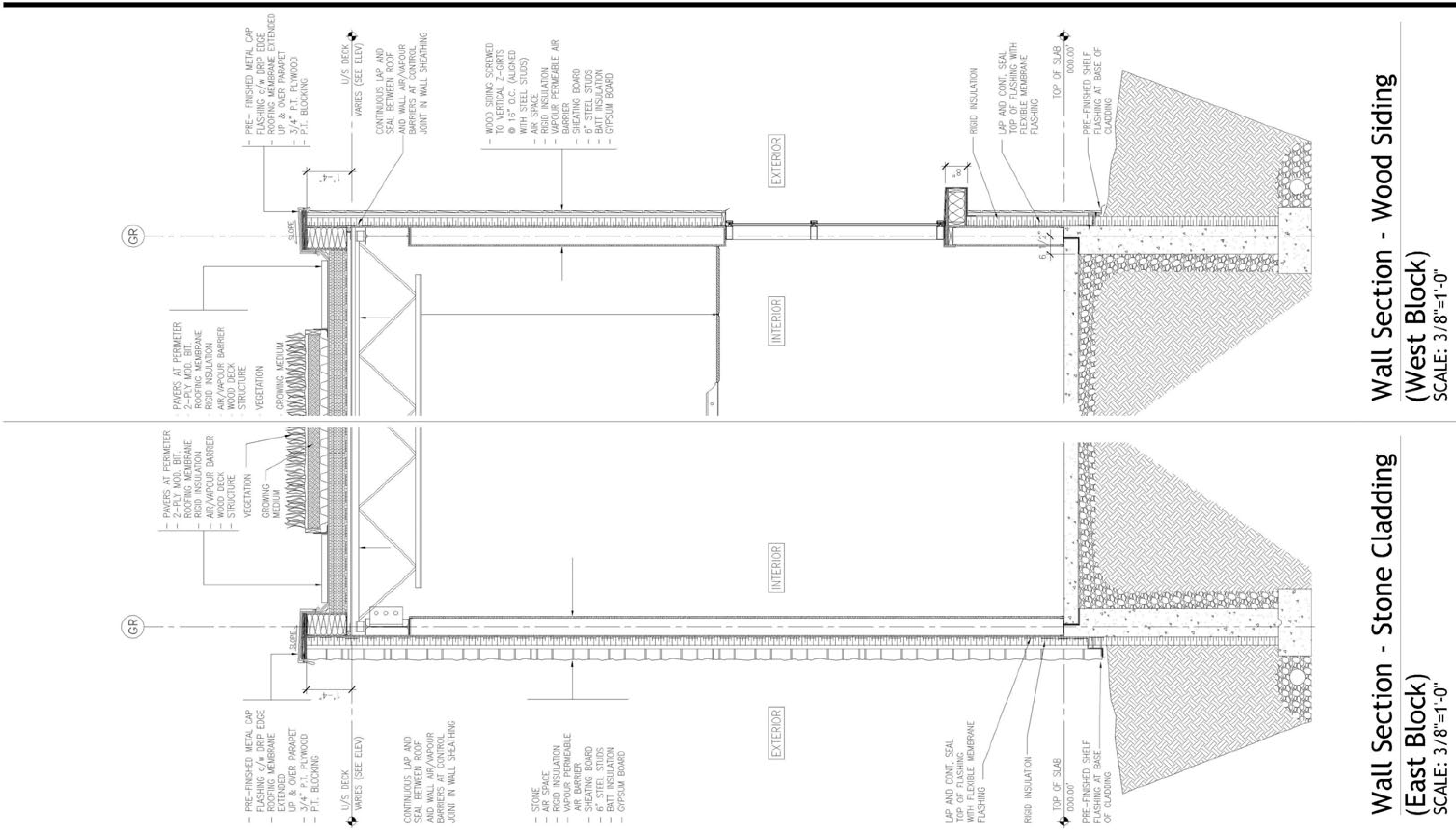
Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

Design Development Submission - Building Sections

0 2 4 8 16'

whwarchitects

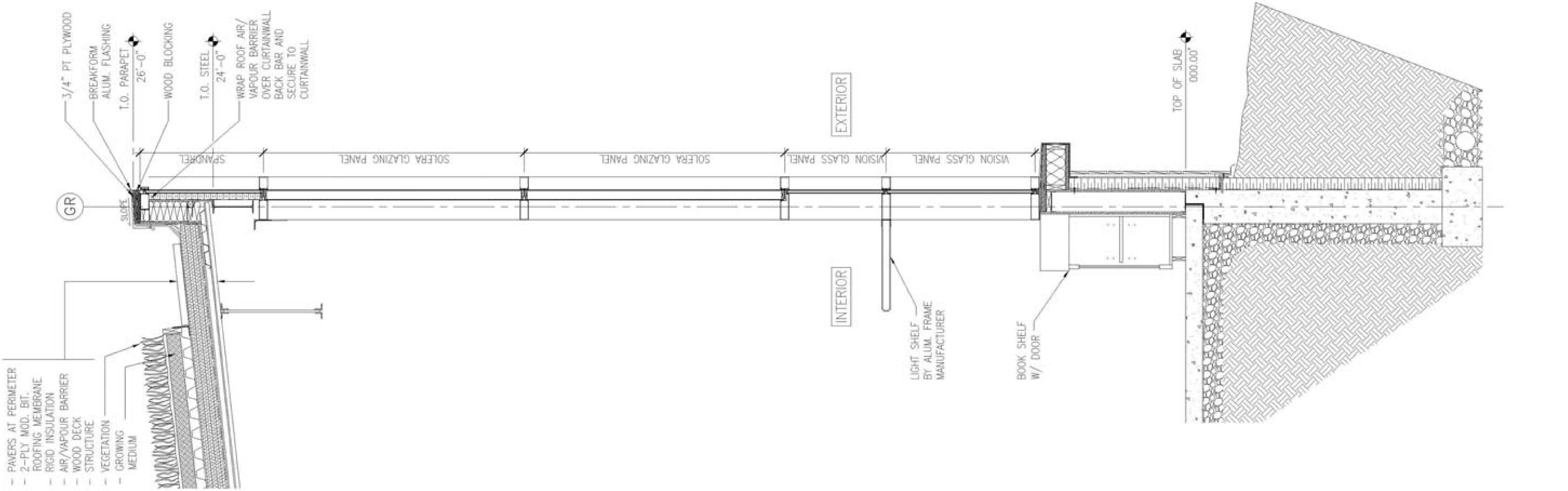


Joggins Fossil Cliffs Comprehensive Site Development Plan

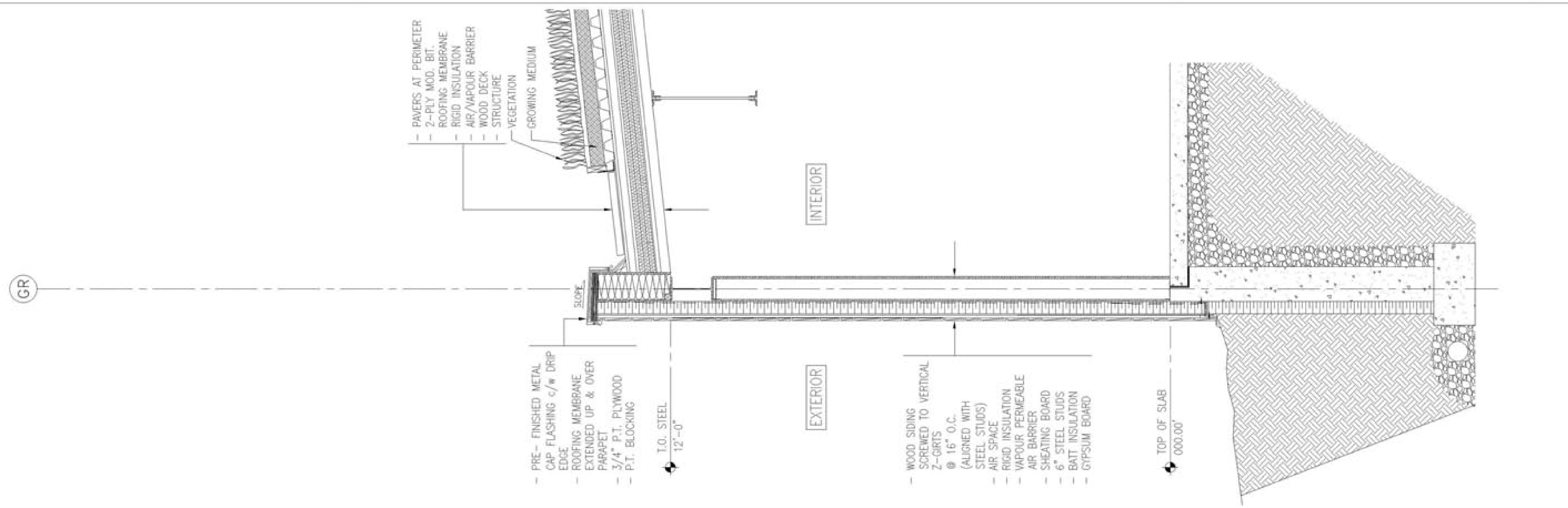
24 February 2006

Design Development Submission - Wall Sections 1

whwarchitects



Curtainwall Section
SCALE: 3/8"=1'-0"



Low Wall Section
SCALE: 3/8"=1'-0"

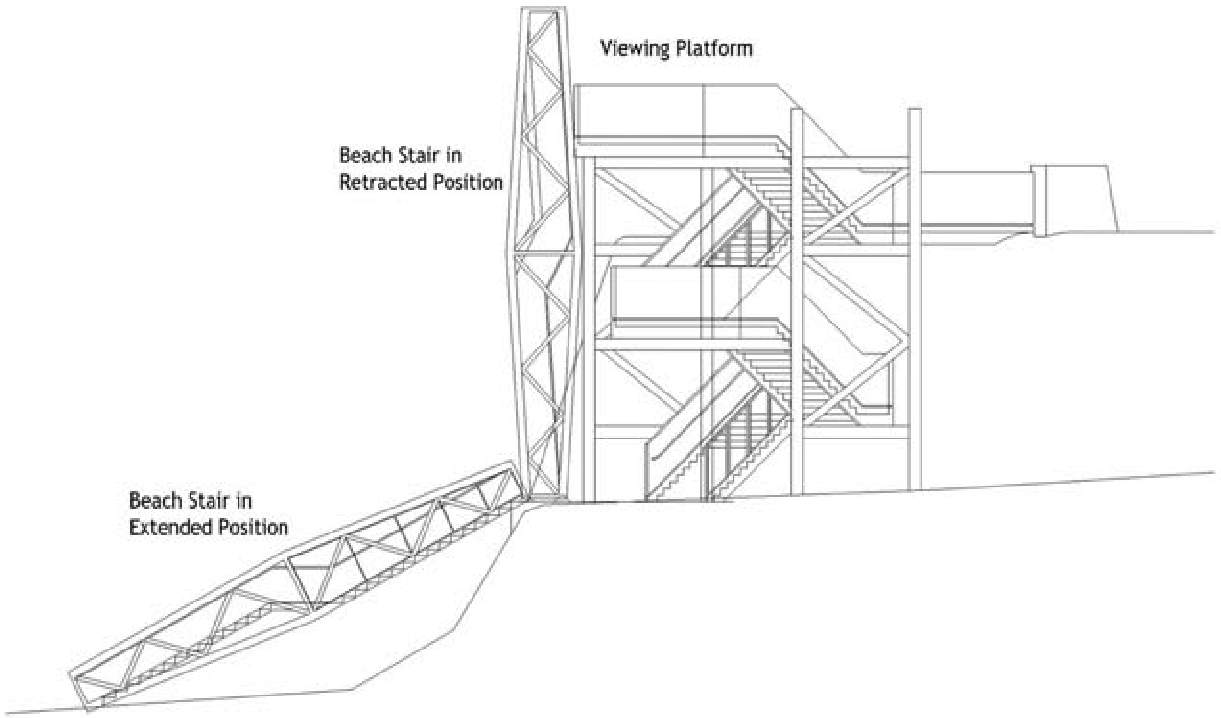
Joggins Fossil Cliffs Comprehensive Site Development Plan

24 February 2006

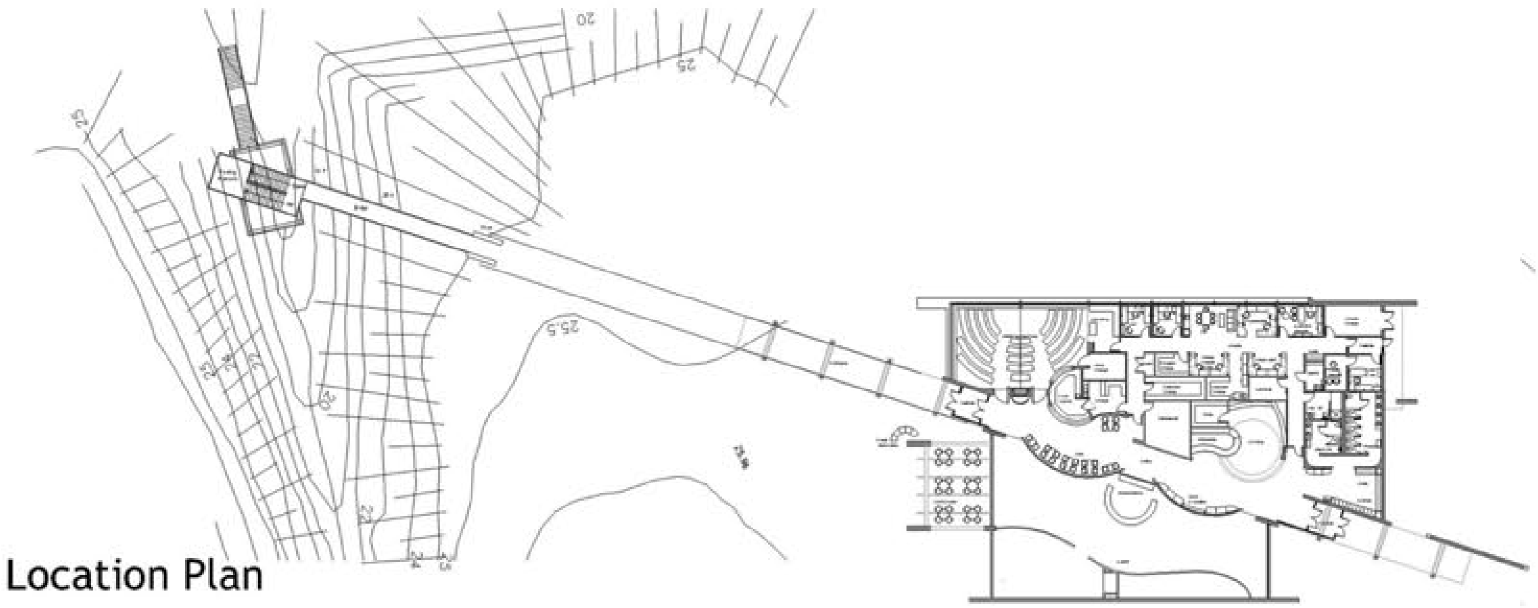
Design Development Submission - Wall Sections 2

0 1 2 4'

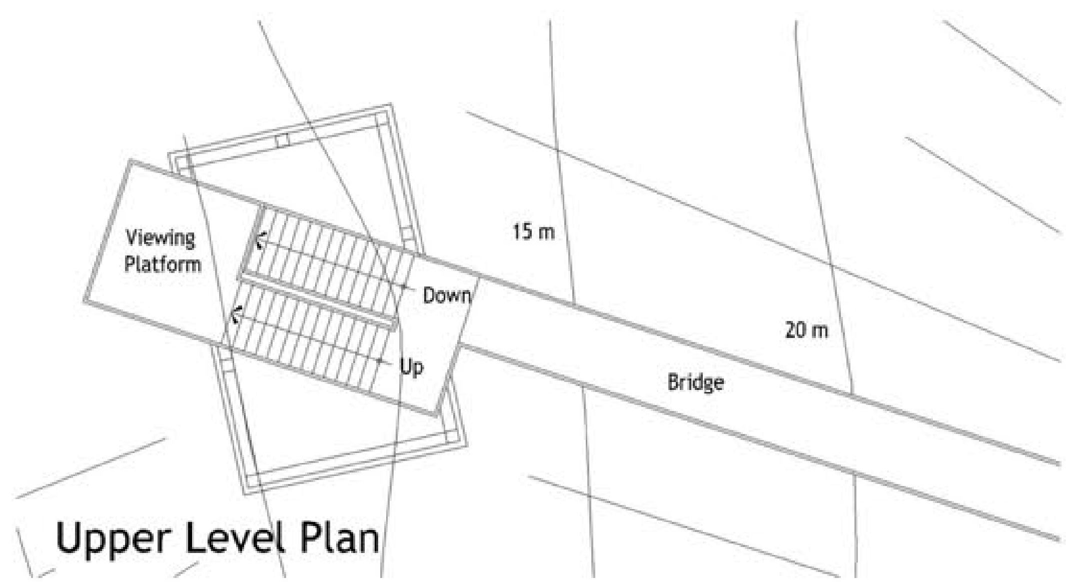
whwarchitects



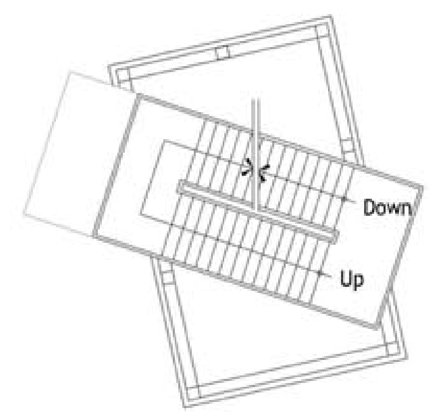
South Elevation



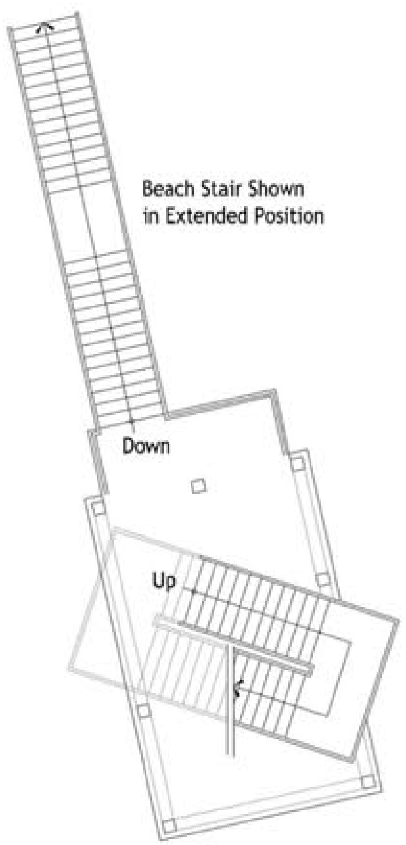
Location Plan



Upper Level Plan



Middle Level Plan



Lower Level Plan

Joggins Fossil Cliffs Comprehensive Site Development Plan

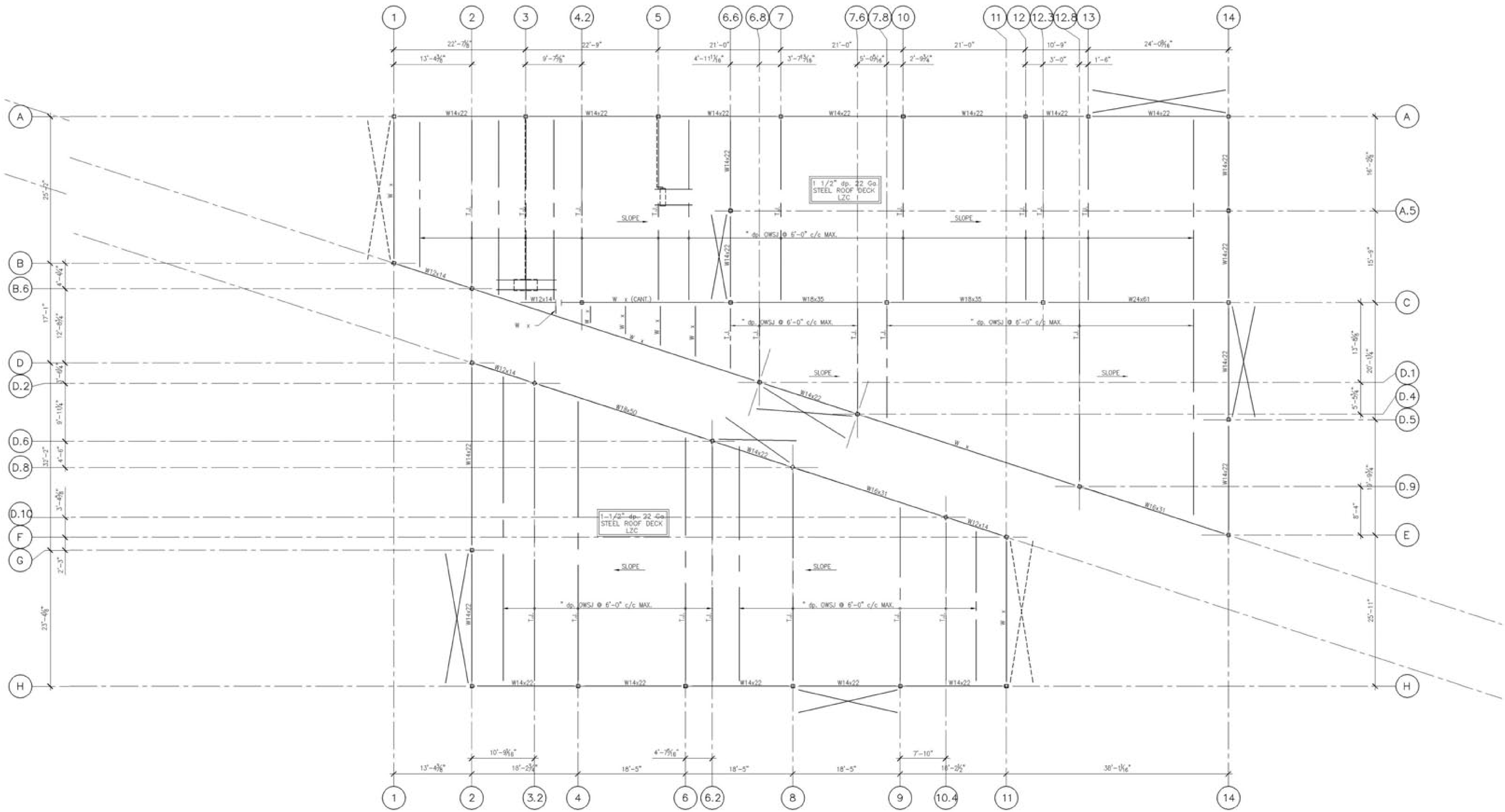
17 February 2006

Design Development Submission - Beach Access Tower at Dugway

0 2 4 8 16'

north

whwarchitects



Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Roof Framing Plan

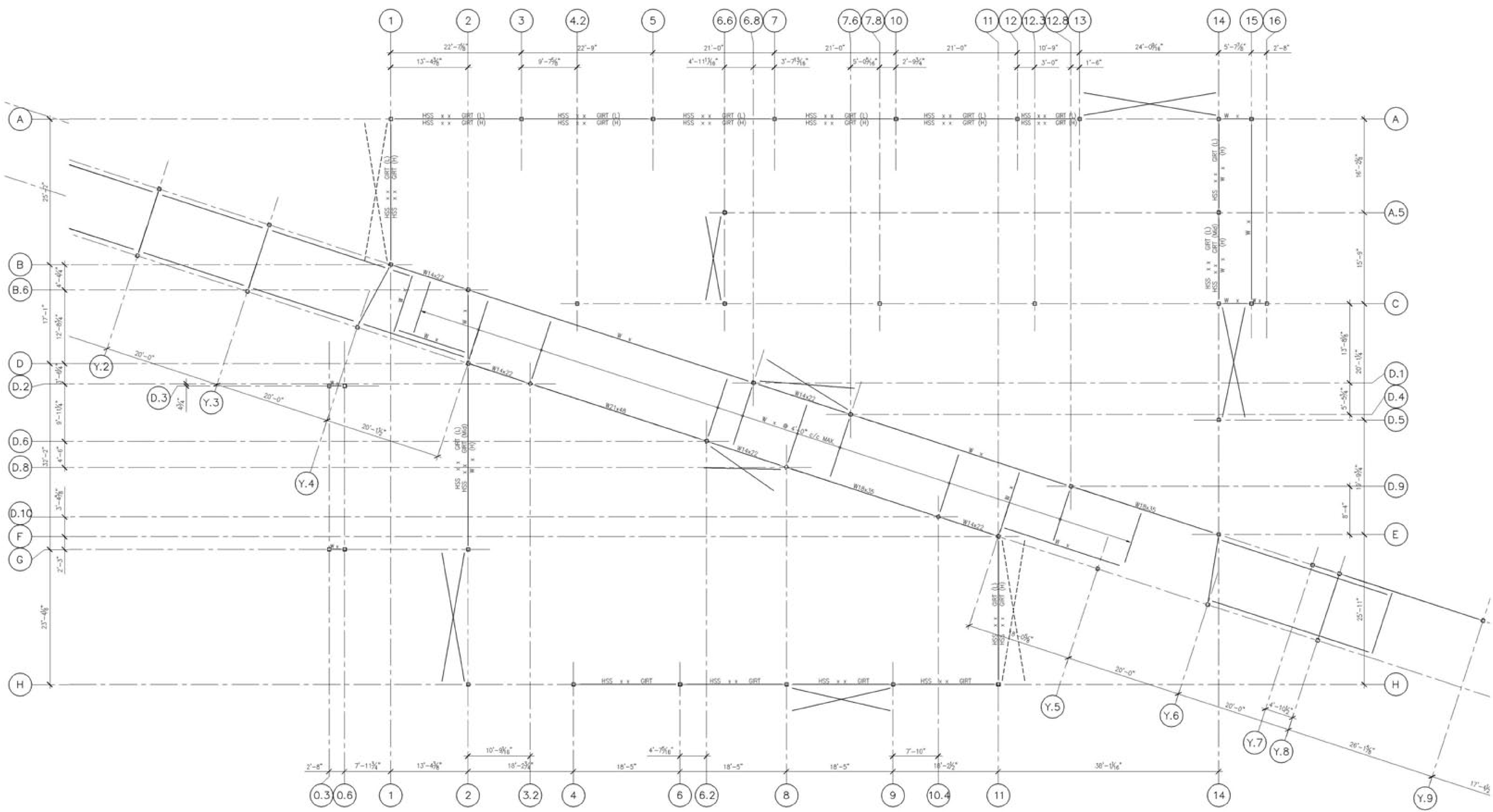
0 2 4 8 16'

north

BMR Structural|Engineering

24 February 2006

whwarchitects



Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Low Roof & Low Framing Plan

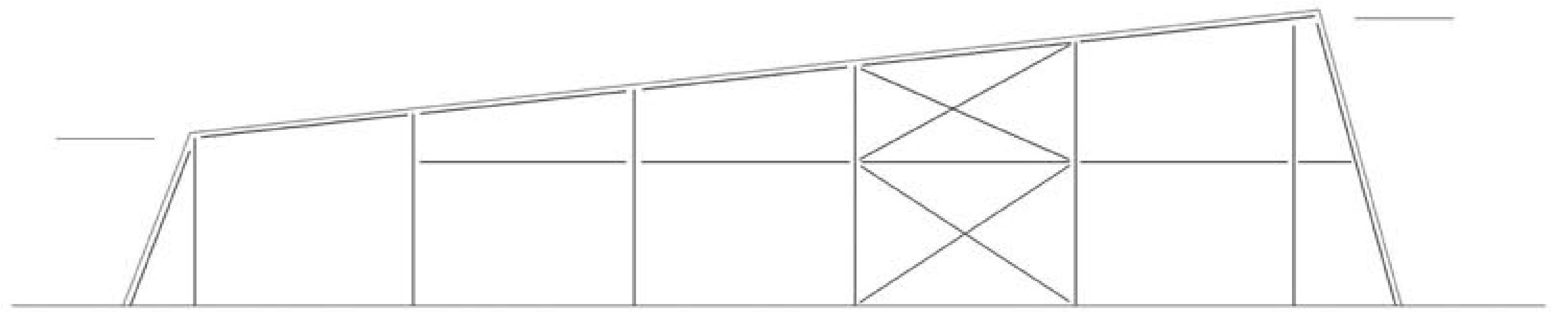
0 2 4 8 16'

north

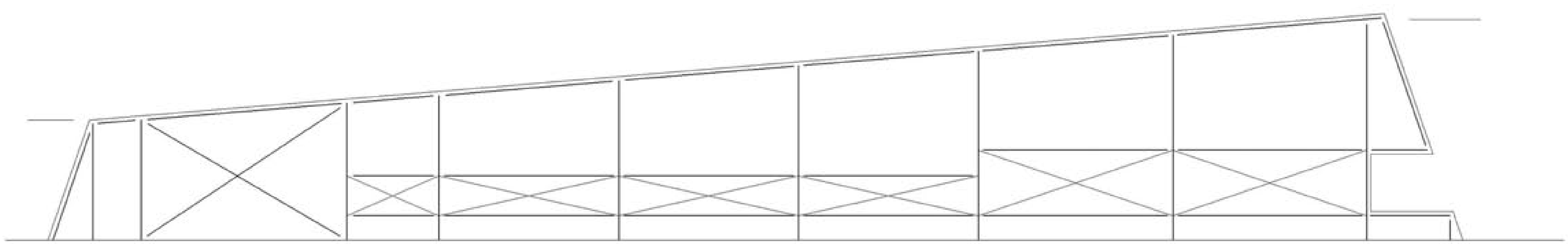
BMR Structural|Engineering

24 February 2006

whwarchitects



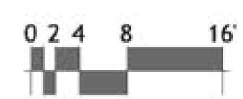
ELEVATION LINE H
1/16"=1'-0"



ELEVATION LINE A
1/16"=1'-0"

Joggins Fossil Cliffs Comprehensive Site Development Plan

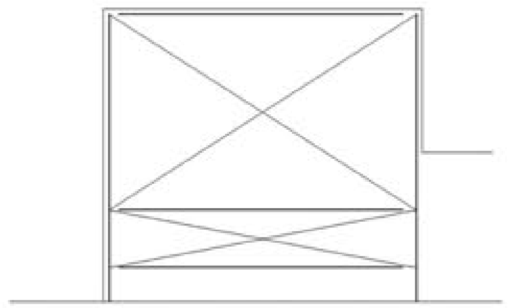
Design Development Submission - Structural elevations



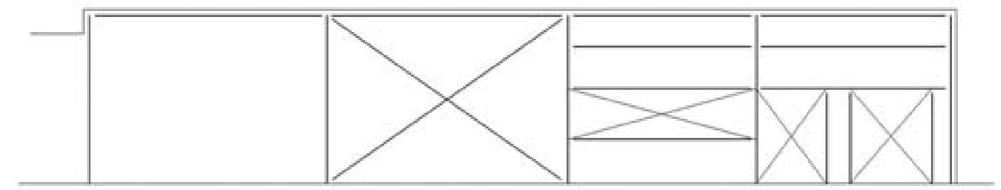
BMR
Structural|Engineering

24 February 2006

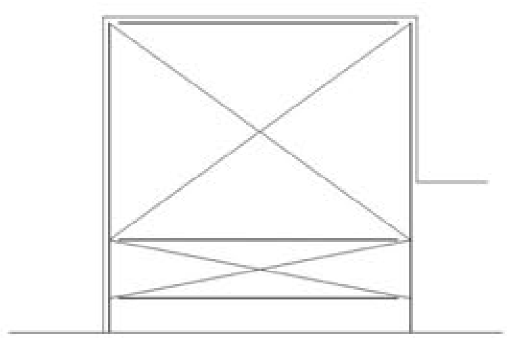
whwarchitects



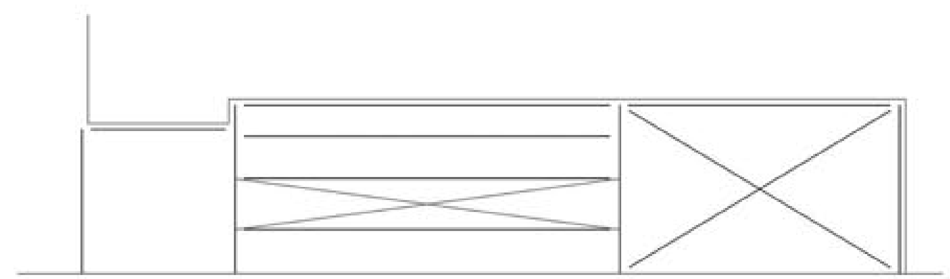
ELEVATION LINE 11
1/16"=1'-0"



ELEVATION LINE 14
1/16"=1'-0"



ELEVATION LINE 1
1/16"=1'-0"



ELEVATION LINE 2
1/16"=1'-0"

Joggins Fossil Cliffs Comprehensive Site Development Plan

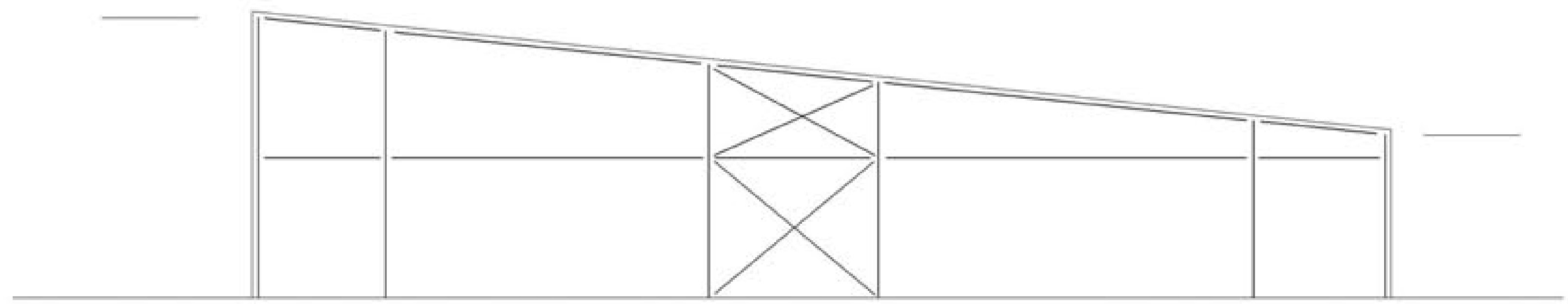
Design Development Submission - Structural elevations

0 2 4 8 16'

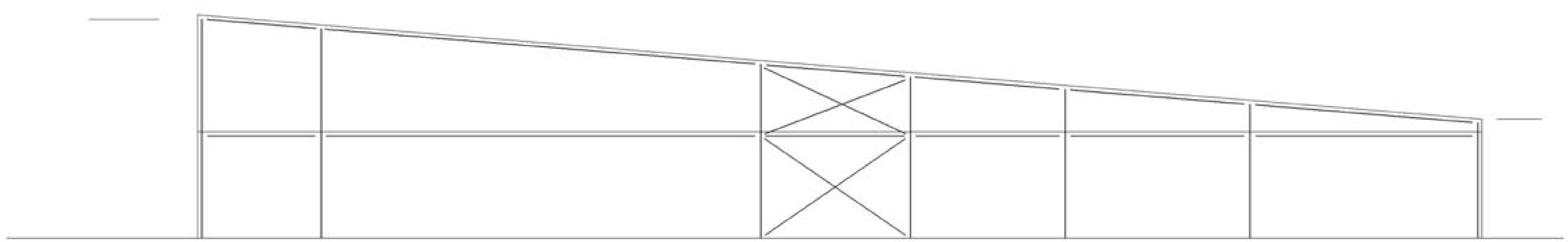
BMR Structural|Engineering

24 February 2006

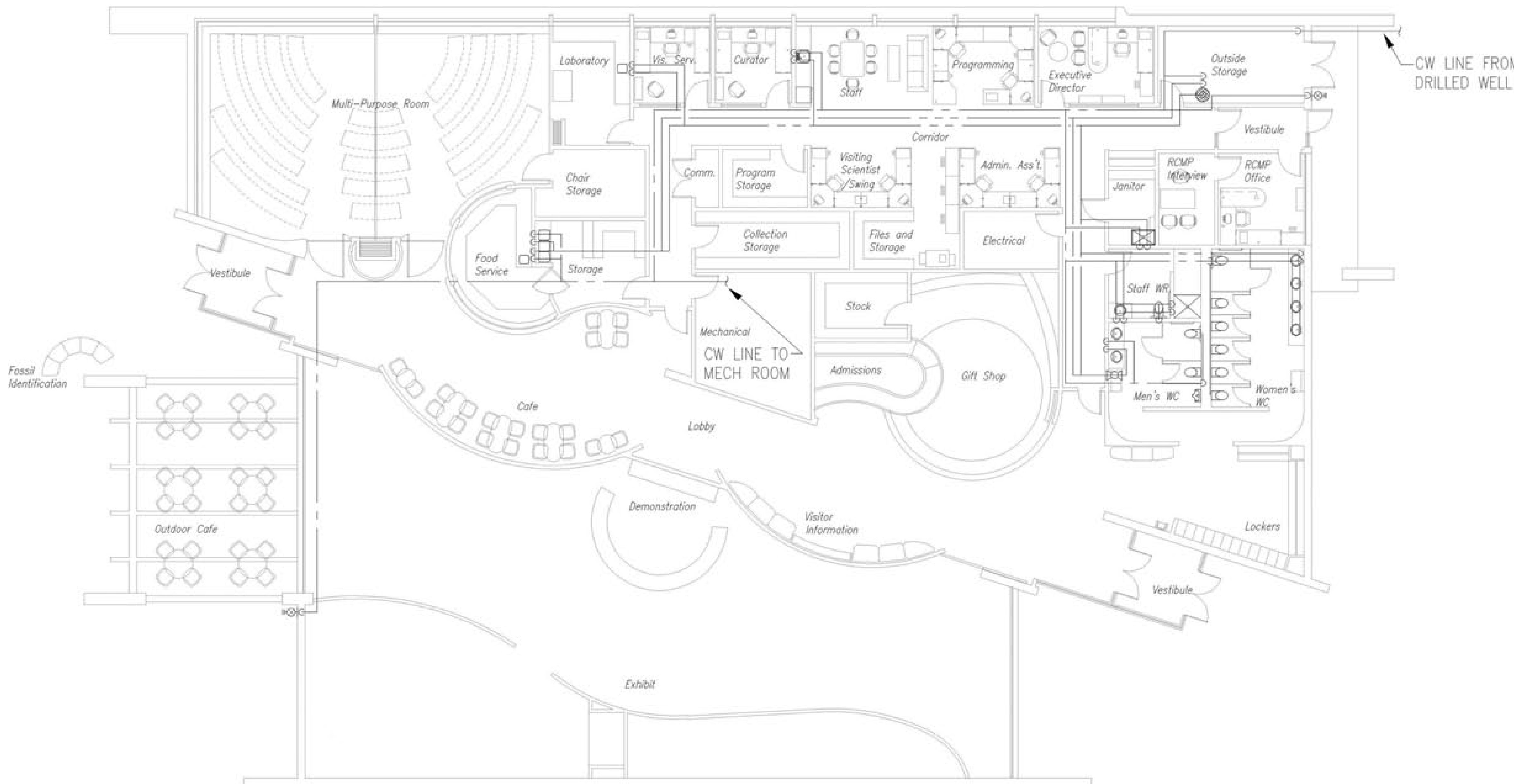
whwarchitects



ELEVATION LINE Z.2
1/16"=1'-0"



ELEVATION LINE Z.1
1/16"=1'-0"



Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Domestic Water

0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD. Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA PHONE: (902) 429-0701, FAX/BBS: (902) 429-9729
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA PHONE: (902) 562-8090, FAX: (902) 562-6621

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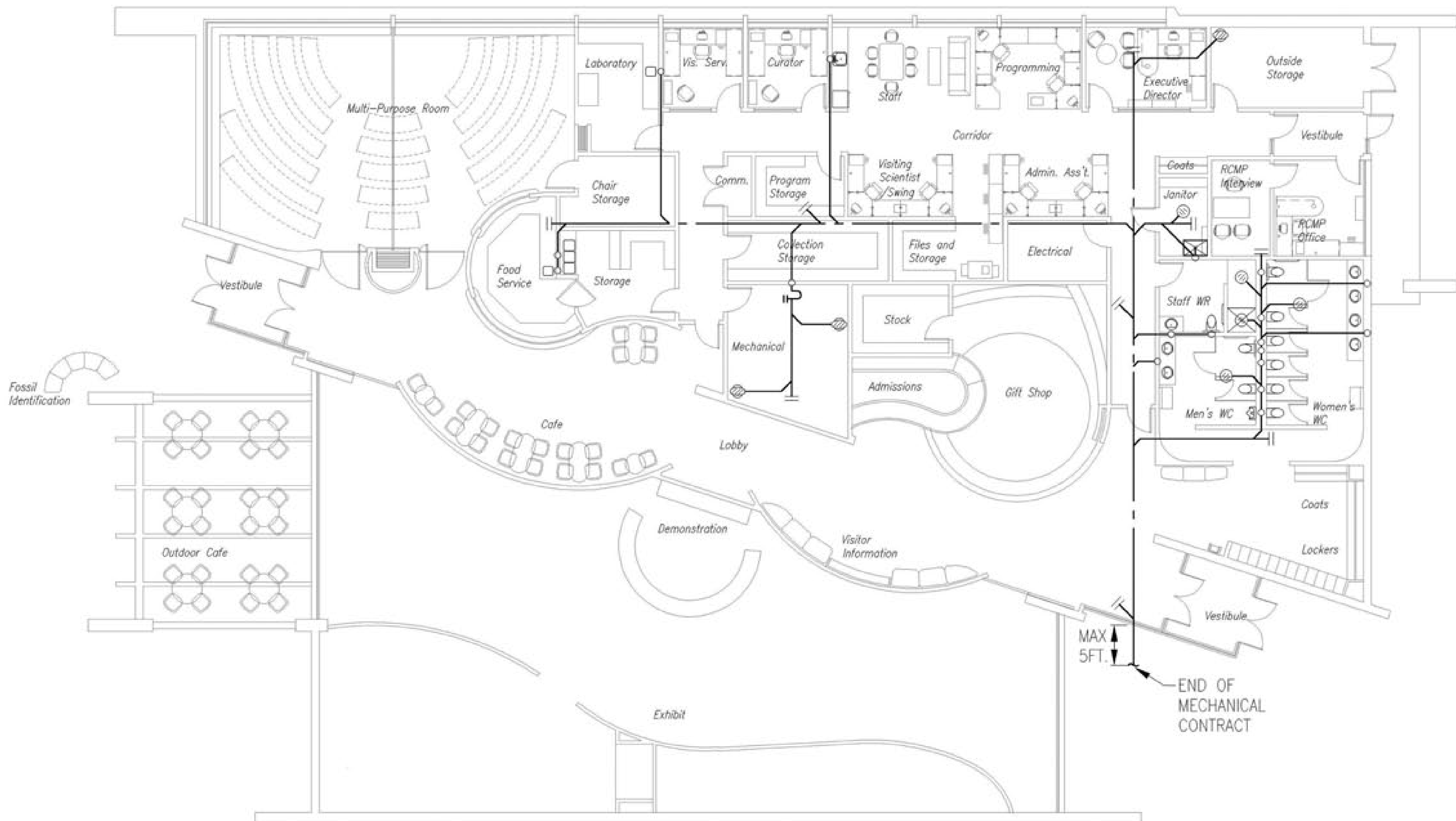

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Plumbing - Sanitary Plan

0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
PHONE: (902) 429-0701, FAX/BBS: (902) 429-9729
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA
PHONE: (902) 562-8080, FAX: (902) 562-6621

24 February 2006

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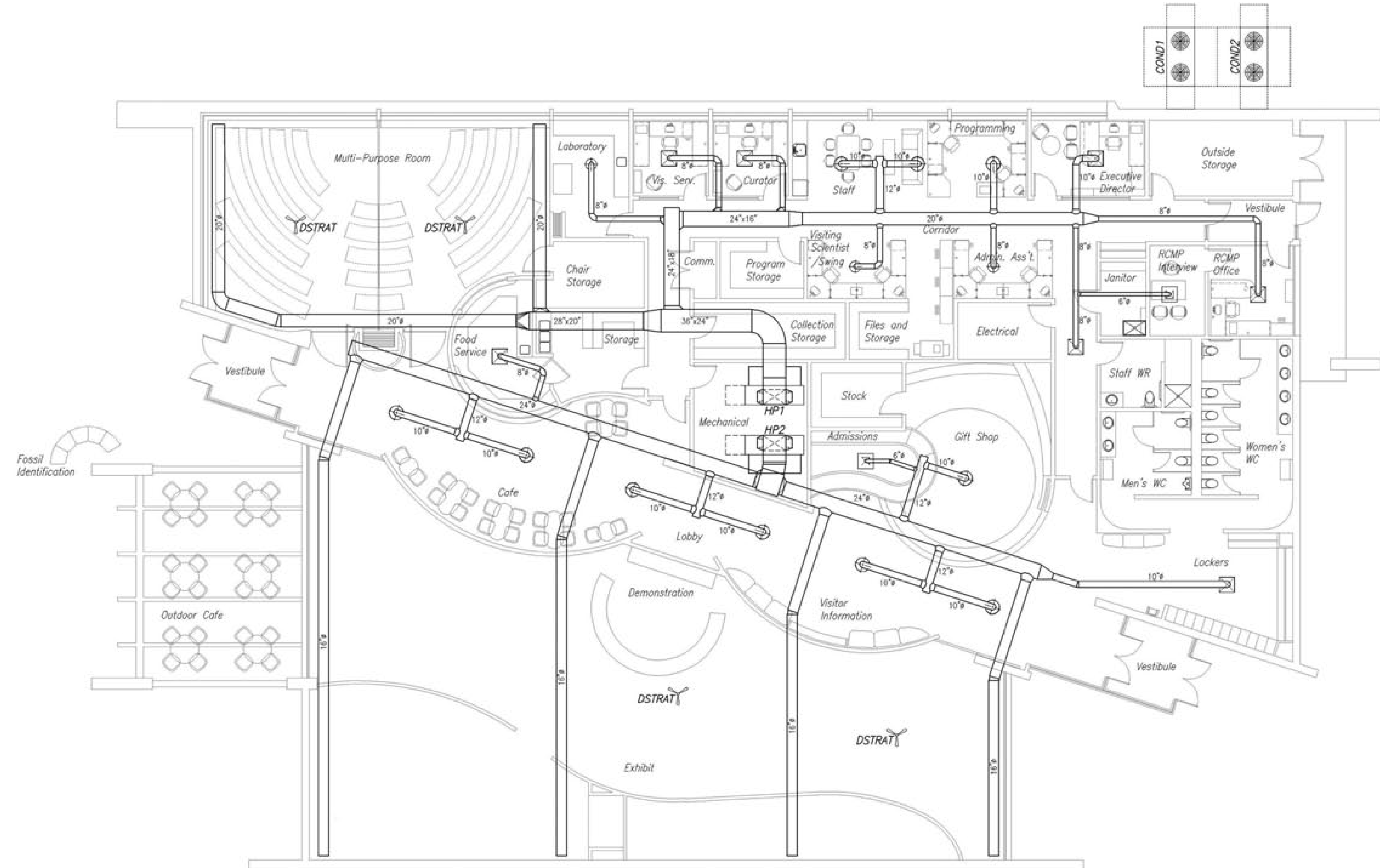

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - HVAC Ventilation Plan

0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA

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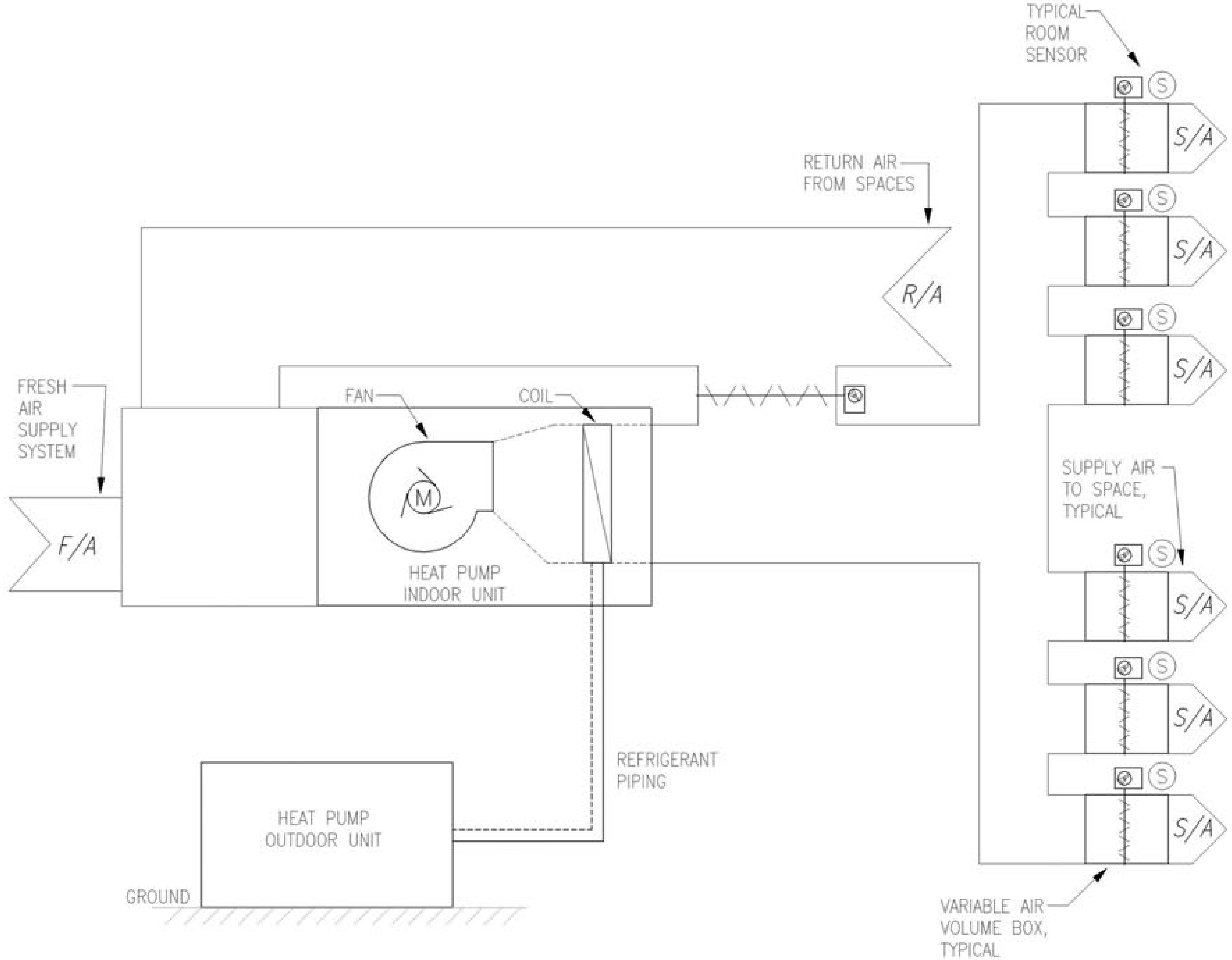

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Typical Heat Pump System

No Scale

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
PHONE: (902) 429-0701, FAX/BBS: (902) 429-8729
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA
PHONE: (902) 562-8090, FAX: (902) 562-6621

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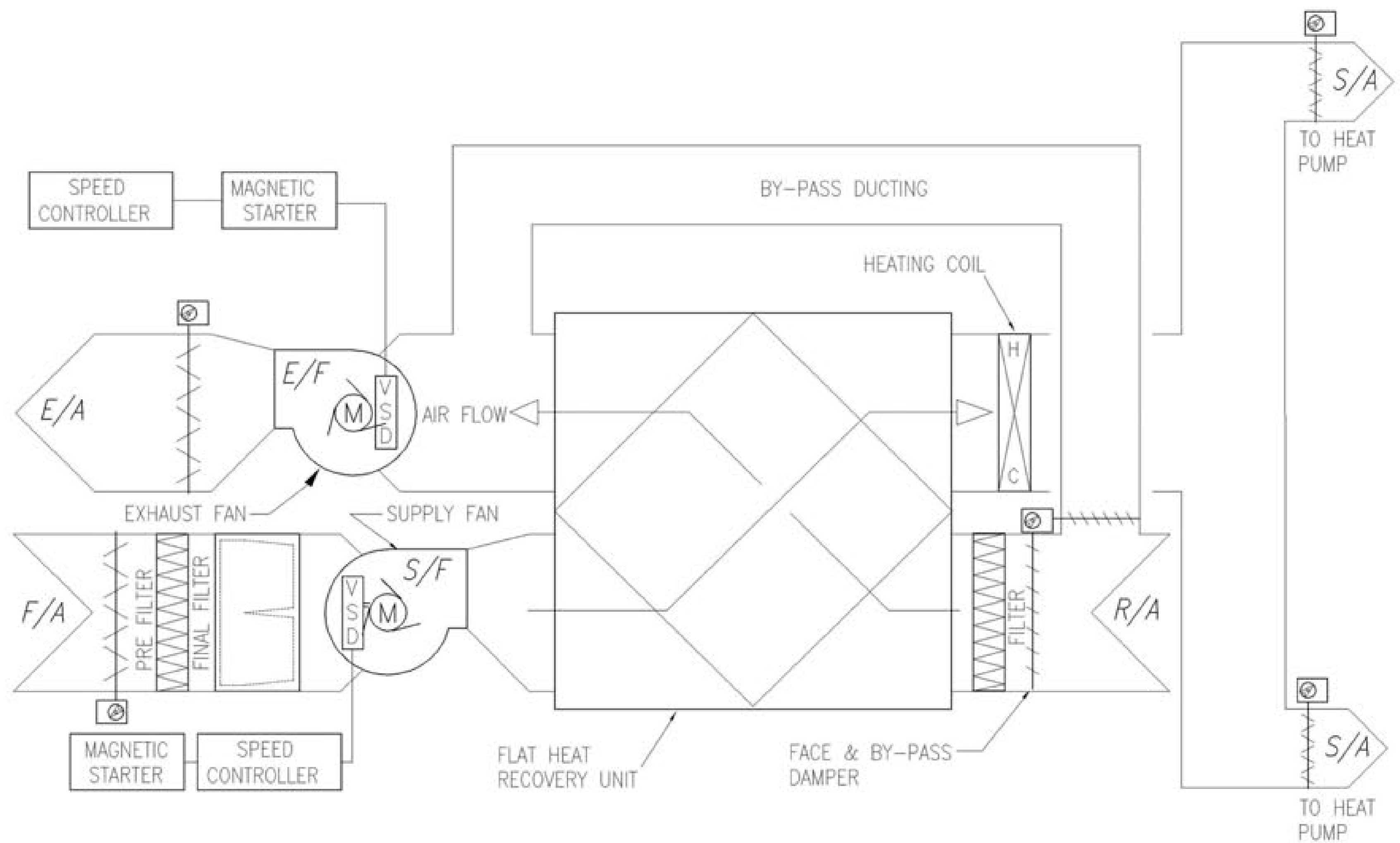

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Fresh Air Supply System

No Scale

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA

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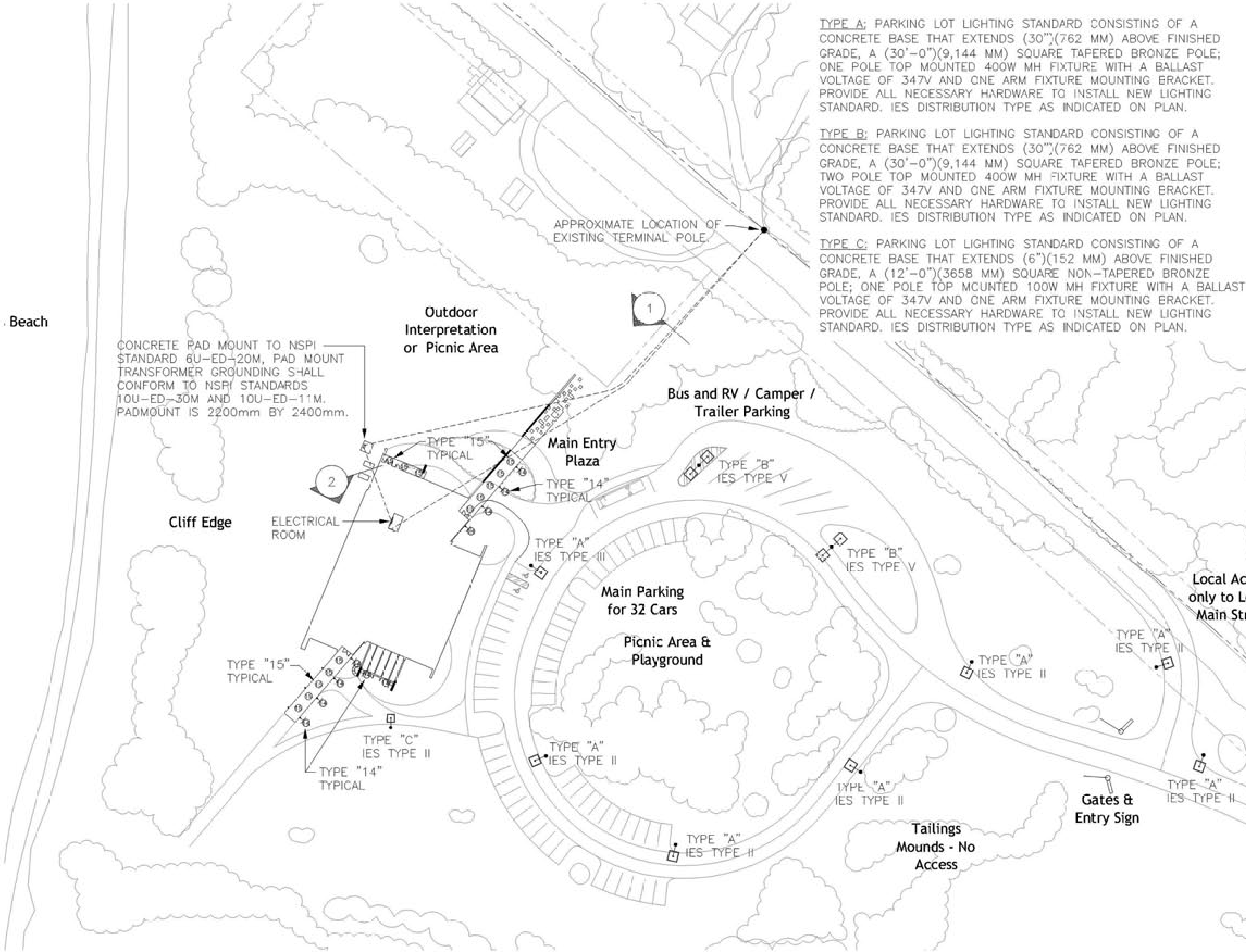
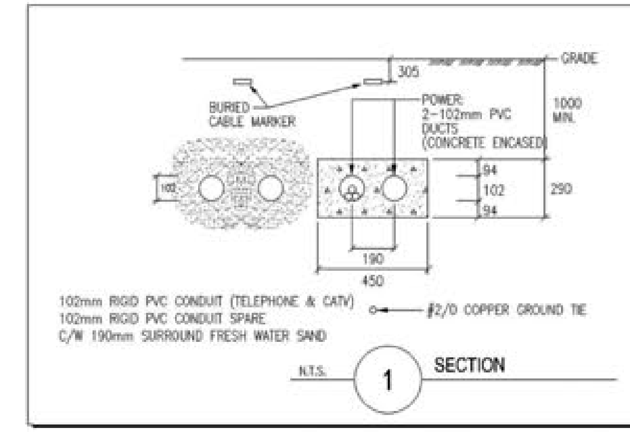
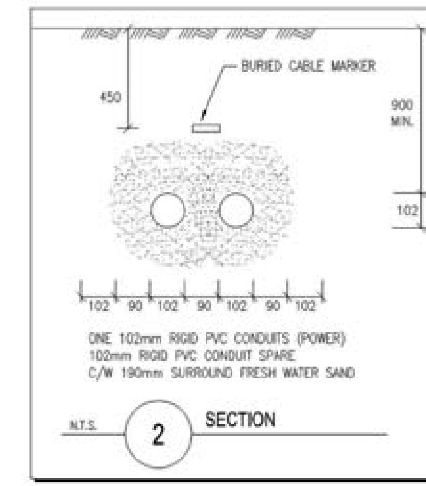


TYPE A: PARKING LOT LIGHTING STANDARD CONSISTING OF A CONCRETE BASE THAT EXTENDS (30")(762 MM) ABOVE FINISHED GRADE, A (30'-0")(9,144 MM) SQUARE TAPERED BRONZE POLE; ONE POLE TOP MOUNTED 400W MH FIXTURE WITH A BALLAST VOLTAGE OF 347V AND ONE ARM FIXTURE MOUNTING BRACKET. PROVIDE ALL NECESSARY HARDWARE TO INSTALL NEW LIGHTING STANDARD. IES DISTRIBUTION TYPE AS INDICATED ON PLAN.

TYPE B: PARKING LOT LIGHTING STANDARD CONSISTING OF A CONCRETE BASE THAT EXTENDS (30")(762 MM) ABOVE FINISHED GRADE, A (30'-0")(9,144 MM) SQUARE TAPERED BRONZE POLE; TWO POLE TOP MOUNTED 400W MH FIXTURE WITH A BALLAST VOLTAGE OF 347V AND ONE ARM FIXTURE MOUNTING BRACKET. PROVIDE ALL NECESSARY HARDWARE TO INSTALL NEW LIGHTING STANDARD. IES DISTRIBUTION TYPE AS INDICATED ON PLAN.

TYPE C: PARKING LOT LIGHTING STANDARD CONSISTING OF A CONCRETE BASE THAT EXTENDS (6")(152 MM) ABOVE FINISHED GRADE, A (12'-0")(3658 MM) SQUARE NON-TAPERED BRONZE POLE; ONE POLE TOP MOUNTED 100W MH FIXTURE WITH A BALLAST VOLTAGE OF 347V AND ONE ARM FIXTURE MOUNTING BRACKET. PROVIDE ALL NECESSARY HARDWARE TO INSTALL NEW LIGHTING STANDARD. IES DISTRIBUTION TYPE AS INDICATED ON PLAN.





Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission- Electrical Site Services

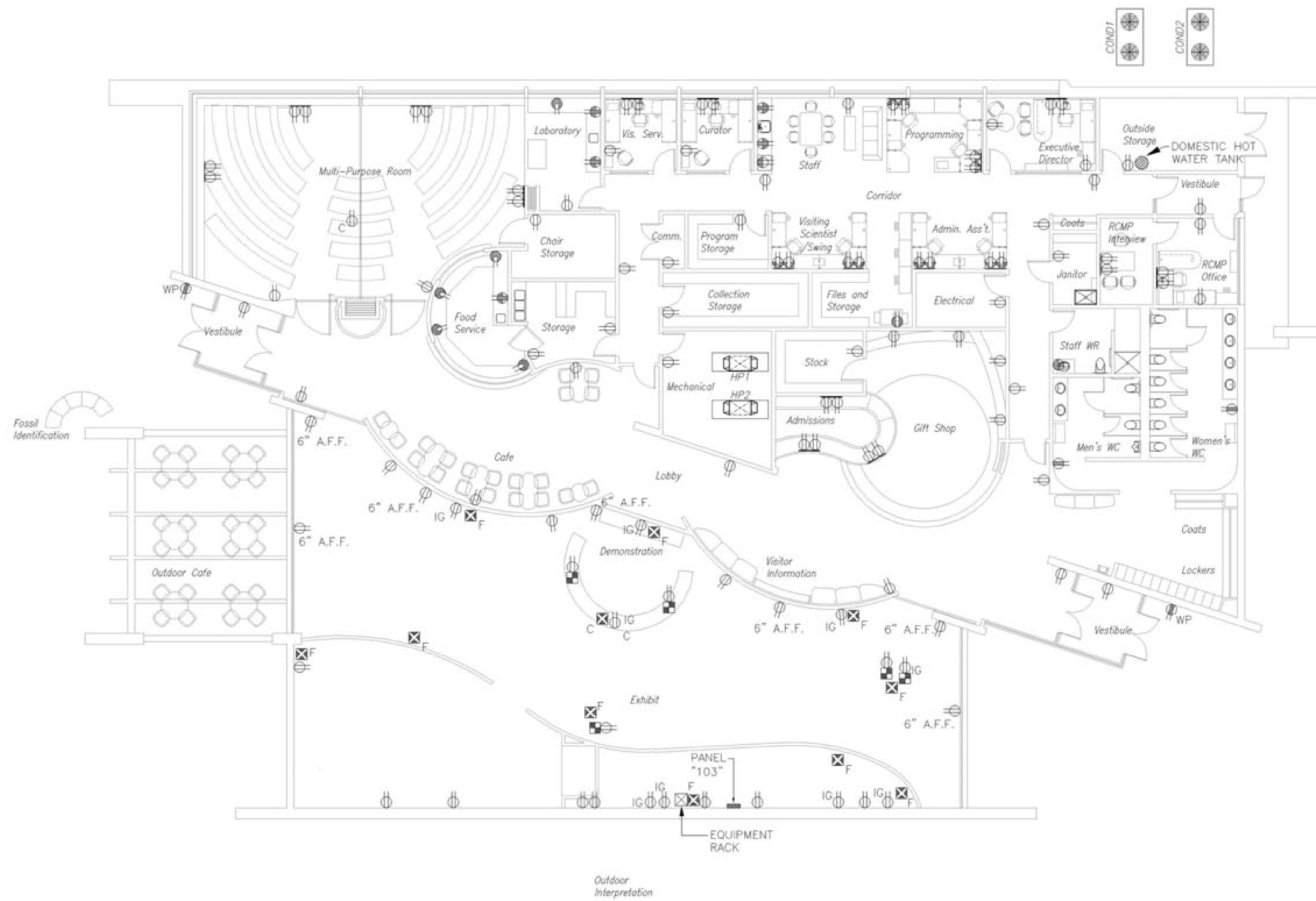
0 10 25 50 100'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD. Consulting Engineers

24 February 2006

whwarchitects

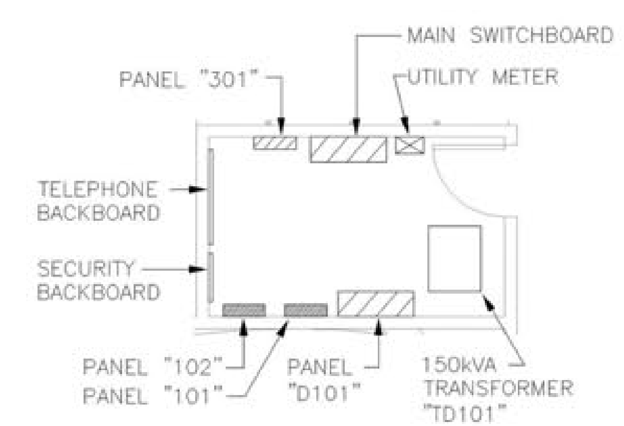


POWER

- PULL BOX, JUNCTION BOX, DIRECT CONNECTION, OR EQUIPMENT AS INDICATED ON THE DRAWINGS.
- 347/600V AND 120/208V PANELS, SURFACE MOUNTED.
- DUPLEX U-GROUND RECEPTACLE FLUSH WALL MOUNTED 18" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE.
- DUPLEX U-GROUND RECEPTACLE FLUSH WALL MOUNTED 18" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE. (5-20RA)
- DUPLEX U-GROUND RECEPTACLE FLUSH WALL MOUNTED 6" ABOVE COUNTER BACKSPLASH, OR 46" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE.
- TWO DUPLEX U-GROUND RECEPTACLES MOUNTED WITHIN A COMMON BACKBOX 18" A.F.F. WITH A COMMON STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE.
- TWO DUPLEX U-GROUND RECEPTACLES MOUNTED WITHIN A COMMON BACKBOX 6" ABOVE COUNTER BACKSPLASH, OR 46" A.F.F. WITH A COMMON STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE.
- DUPLEX U-GROUND RECEPTACLE FLUSH WALL MOUNTED 6" ABOVE COUNTER BACKSPLASH, OR 46" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE (5-20RA).
- GFCI DUPLEX U-GROUND RECEPTACLE FLUSH WALL MOUNTED 6" ABOVE COUNTER BACKSPLASH, OR 46" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE (5-20RA).
- GFCI DUPLEX U-GROUND RECEPTACLE, FLUSH WALL MOUNTED 18" A.F.F. WITH STAINLESS STEEL COVERPLATE, UNLESS INDICATED OTHERWISE.
- GFCI DUPLEX U-GROUND RECEPTACLE, FLUSH WALL MOUNTED 6" ABOVE COUNTER BACKSPLASH, OR 46" A.F.F., UNLESS INDICATED OTHERWISE.
- IG — RECEPTACLES AS ABOVE BUT FLOOR MOUNTED.

DEFINITIONS:

G.F.C.I.	–	INDICATES GROUND FAULT CIRCUIT INTERRUPTER.
W.P.	–	INDICATES WEATHER PROOF GASKETED COVER OR ENCLOSURE.
A.F.F.	–	ABOVE THE FINISHED FLOOR.
C	–	INDICATES CEILING MOUNTED.
K	–	INDICATES KEY OPERATED DEVICES
F	–	INDICATES FLOOR MOUNTED
IG	–	INDICATES ISOLATED GROUND DEVICE



ELECTRICAL ROOM LAYOUT

0 1 2 4 8'

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Electrical Power

0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA

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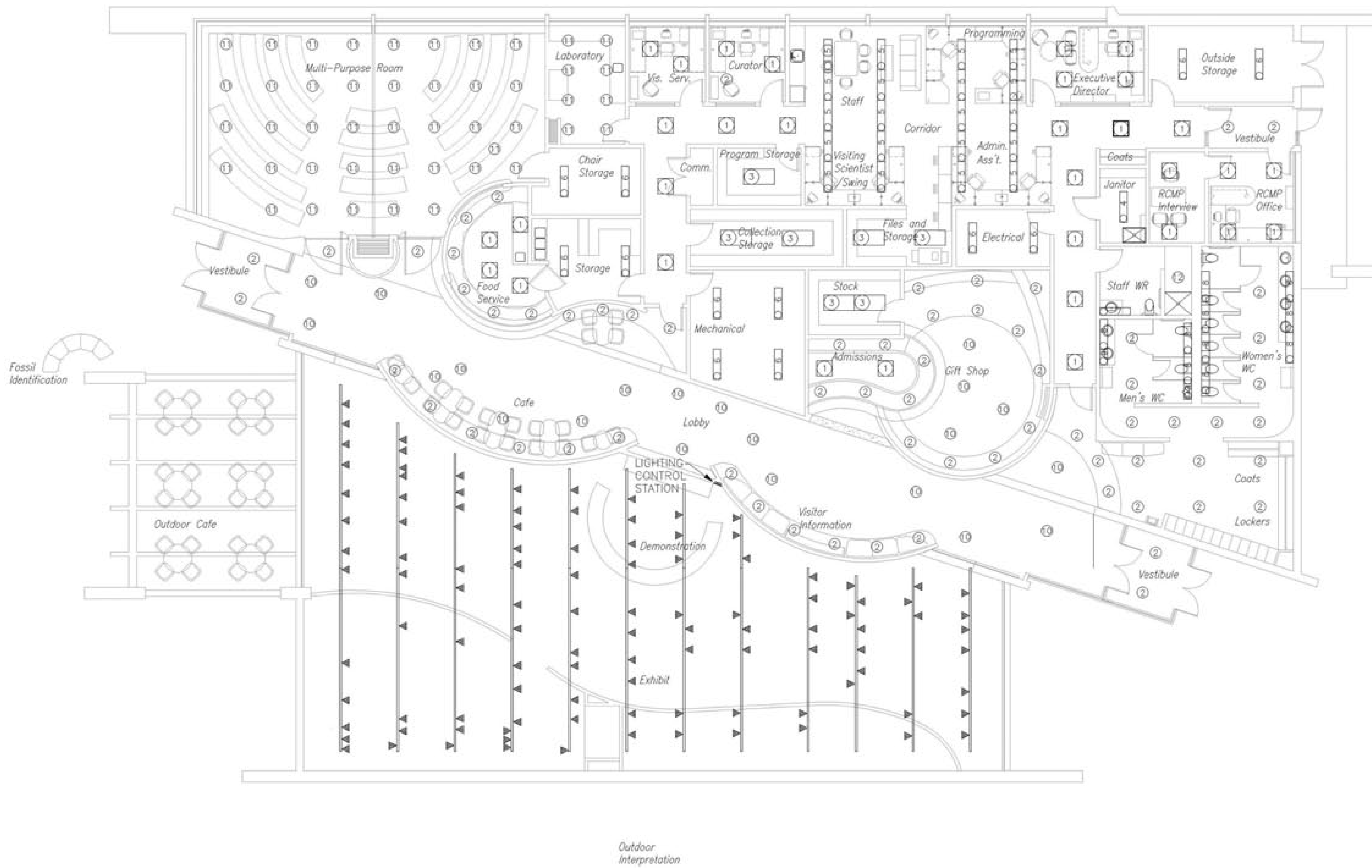


- TYPE 1: 2'X2', 2 LAMP, DIRECT/INRECT FLUORESCENT FIXTURE, RECESSED IN T-BAR CEILING SYSTEM.
- TYPE 2: COMPACT FLUORESCENT DOWNLIGHT RECESSED IN T-BAR OR GYPSUM BOARD CEILING.
- TYPE 3: 2'x4', 2 LAMP FLUORESCENT UNIT, RECESSED IN T-BAR CEILING SYSTEM.
- TYPE 4: 1'x4', 2 LAMP FLUORESCENT UNIT, RECESSED IN GYPSUM BOARD CEILING.
- TYPE 5: 4' LONG, 2 LAMP, DIRECT/INDIRECT LINEAR FLUORESCENT UNIT, CABLE HUNG SUCH THAT THE BOTTOM OF THE FIXTURE IS 24" BELOW UNDERSIDE OF ROOF STRUCTURE.
- TYPE 6: 4' LONG, 2 LAMP, INDUSTRIAL FLUORESCENT UNIT WITH APERTURED REFLECTOR, CHAIN HUNG TO 9'-0" A.F.F..
- TYPE 7: 4' LONG, 2 LAMP, FLUORESCENT WALL BRACKET UNIT WALL MOUNTED TO 7'-0" A.F.F. OR ABOVE MIRROR.
- TYPE 8: 4' LONG, 2 LAMP, FLUORESCENT STRIP UNIT MOUNTED IN ARCHITECTURAL VALENCE.
- TYPE 9: 2' LONG, 2 LAMP, FLUORESCENT STRIP UNIT MOUNTED IN ARCHITECTURAL VALENCE.
- TYPE 10: 42 WATT, COMPACT FLUORESCENT CYLINDER PENDANT MOUNTED SUCH THAT THE BOTTOM OF THE FIXTURE IS 9'-6" A.F.F.. CYLINDER HOUSING SHALL BE PAINTED BLACK.
- TYPE 11: DIMMABLE, 42 WATT, COMPACT FLUORESCENT CYLINDER PENDANT MOUNTED SUCH THAT THE BOTTOM OF THE FIXTURE IS 9'-6" A.F.F.. CYLINDER HOUSING SHALL BE PAINTED BLACK.
- TYPE 12: COMPACT FLUORESCENT DOWNLIGHT FOR SHOWER, WET LOCATION LISTED.
- TYPE 13: SUSPENDED TRACK LIGHTING.
- TYPE 14: 50W, METAL HALIDE, EXTERIOR WALL MOUNT FIXTURE, MOUNTED TO 8'-0" A.F.F.. SEE SITE SERVICE PLAN FOR LOCATIONS.
- TYPE 15 70W, METAL HALIDE FIXTURE, RECESSED IN EXTERIOR SOFFIT. SEE SITE SERVICE PLAN FOR LOCATIONS.

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Electrical Lighting

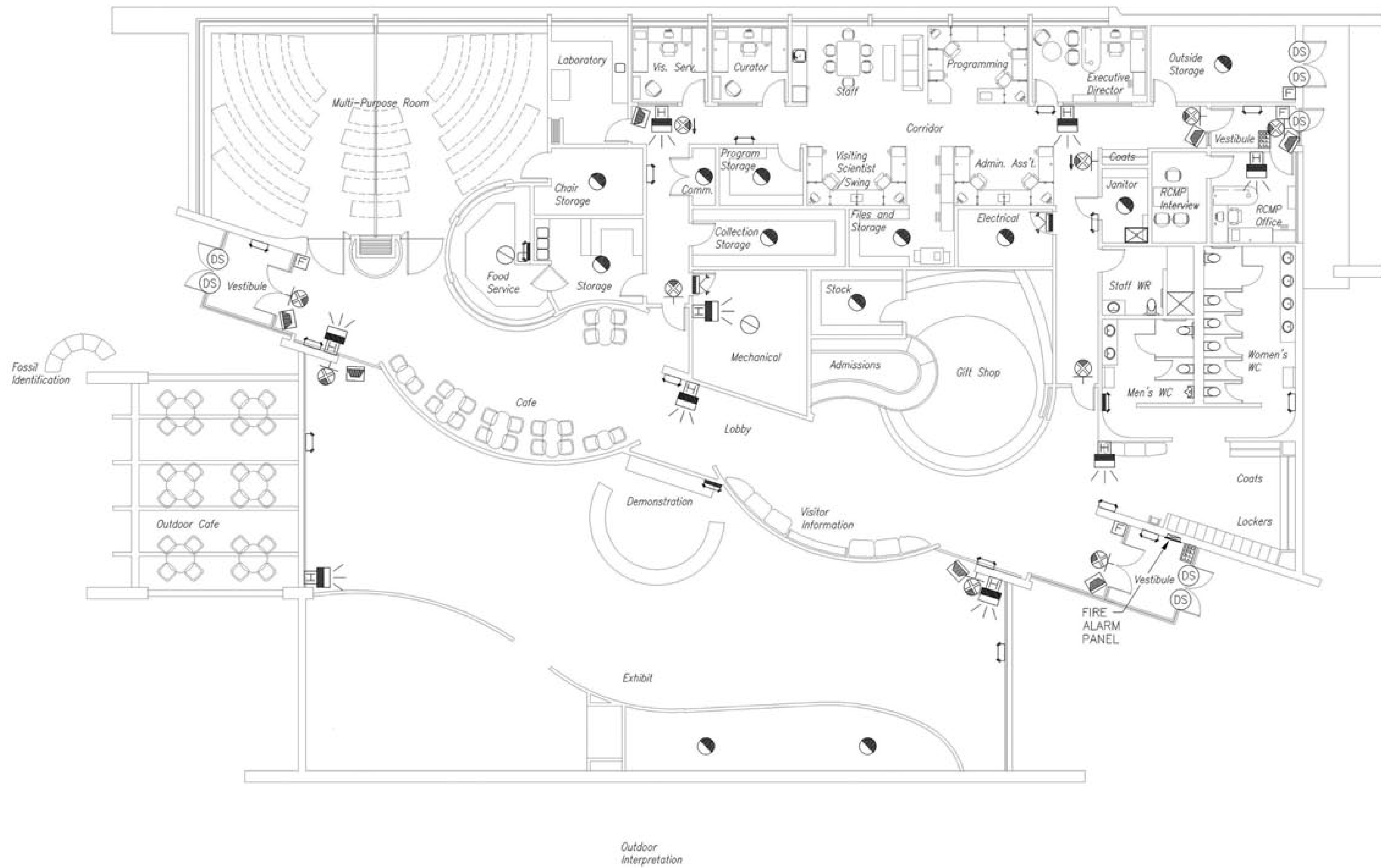
0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
PHONE: (902) 429-0701, FAX/BBS: (902) 429-9729
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA
PHONE: (902) 562-8090, FAX: (902) 562-6621

24 February 2006

whwarchitects



FIRE ALARM

COMBINATION STROBE AND HORN UNIT, WALL MOUNTED 7'–6" A.F.F. UNLESS INDICATED OTHERWISE.

ADDRESSABLE FIRE ALARM PULL STATION MOUNTED 48" A.F.F.

ADDRESSABLE CEILING MOUNTED IONIZATION–TYPE PRODUCT–OF–COMBUSTION DETECTOR

ADDRESSABLE CEILING MOUNTED HEAT DETECTOR

INTRUSION ALARM/CCTV

INTRUSION ALARM MOTION SENSOR, CEILING MOUNTED UNLESS INDICATED OTHERWISE.

DS INTRUSION ALARM DOOR SWITCH.

INTRUSION ALARM DIGITAL KEYPAD, FLUSH WALL MOUNTED 54" A.F.F. IN "T" CABINET C/W LOCKING DOOR AND KEY UNLESS INDICATED OTHERWISE.

EMERGENCY/EXIT LIGHTING

EXIT LIGHT CEILING MOUNTED OR WALL MOUNTED 7'–6" A.F.F., SINGLE OR DOUBLE FACED, WITH ARROWS AS INDICATED.

EMERGENCY LIGHTING UNIT C/W BATTERY, CHARGER, AND TWO 12 WATT LAMPS WALL MOUNTED 7'–6" A.F.F.. BATTERY SIZED AS INDICATED ON THE DRAWINGS. INSTALLED IN EXPOSED AREAS.

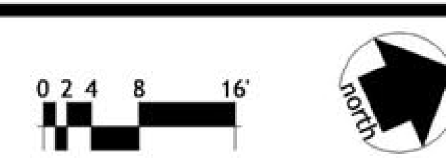
EMERGENCY LIGHTING REMOTE HEAD C/W TWO 12 WATT LAMPS WALL MOUNTED 7'–6" A.F.F.. INSTALLED IN EXPOSED AREAS.

EMERGENCY LIGHTING UNIT C/W BATTERY, CHARGER, AND TWO 12 WATT LAMPS WALL MOUNTED 7'–6" A.F.F.. BATTERY SIZED AS INDICATED ON THE DRAWINGS. INSTALLED IN FINISHED AREAS.

EMERGENCY LIGHTING REMOTE HEAD C/W TWO 12 WATT LAMPS WALL MOUNTED 7'–6" A.F.F.. INSTALLED IN FINISHED AREAS.

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Electrical Systems



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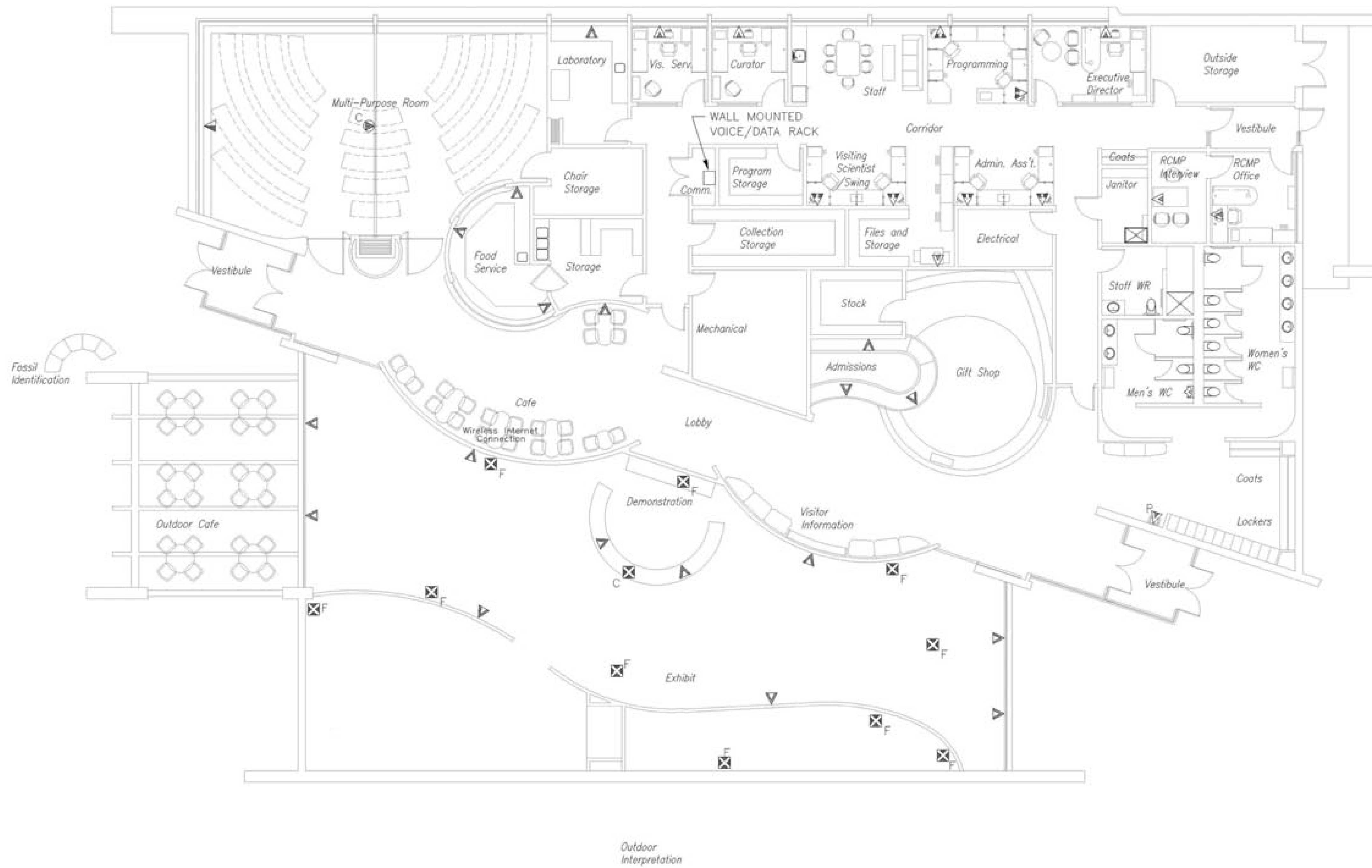
24 February 2006

whwarchitects



STRUCTURED WIRING

- PAYPHONE OUTLET FLUSH WALL MOUNTED AT 46" A.F.F. (SINGLE OUTLET ONLY).
- SINGLE VOICE AND SINGLE DATA OUTLET ON A COMMON PLATE, FLUSH WALL MOUNTED 46" A.F.F. OR 6"mm ABOVE COUNTER BACKSPLASH, UNLESS INDICATED OTHERWISE.
- SINGLE VOICE AND SINGLE DATA OUTLET ON A COMMON PLATE, FLUSH WALL MOUNTED 46" A.F.F. OR 6"mm ABOVE COUNTER BACKSPLASH, UNLESS INDICATED OTHERWISE.
- SINGLE VOICE AND SINGLE DATA OUTLET ON A COMMON PLATE, MOUNTED IN SYSTEMS FURNITURE.
- IN-FLOOR A/V JUNCTION BOX (6" x 6" x 4").
- MULTIMEDIA OUTLET C/W PROJECTION ADAPTER OUTLET, FLUSH WALL MOUNTED 18" A.F.F. UNLESS INDICATED OTHERWISE.
- PROJECTION EXTENSION OUTLET AND DATA OUTLET (MALE CONNECTORS ON CABLE ENDS: ONE HD-15, ONE DSUB 9 PIN, ONE STEREO MINI, THREE RCA)

DEFINITIONS:

A.F.F. – ABOVE THE FINISHED FLOOR.
C – INDICATES CEILING MOUNTED.
F – INDICATES FLOOR MOUNTED

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Communications

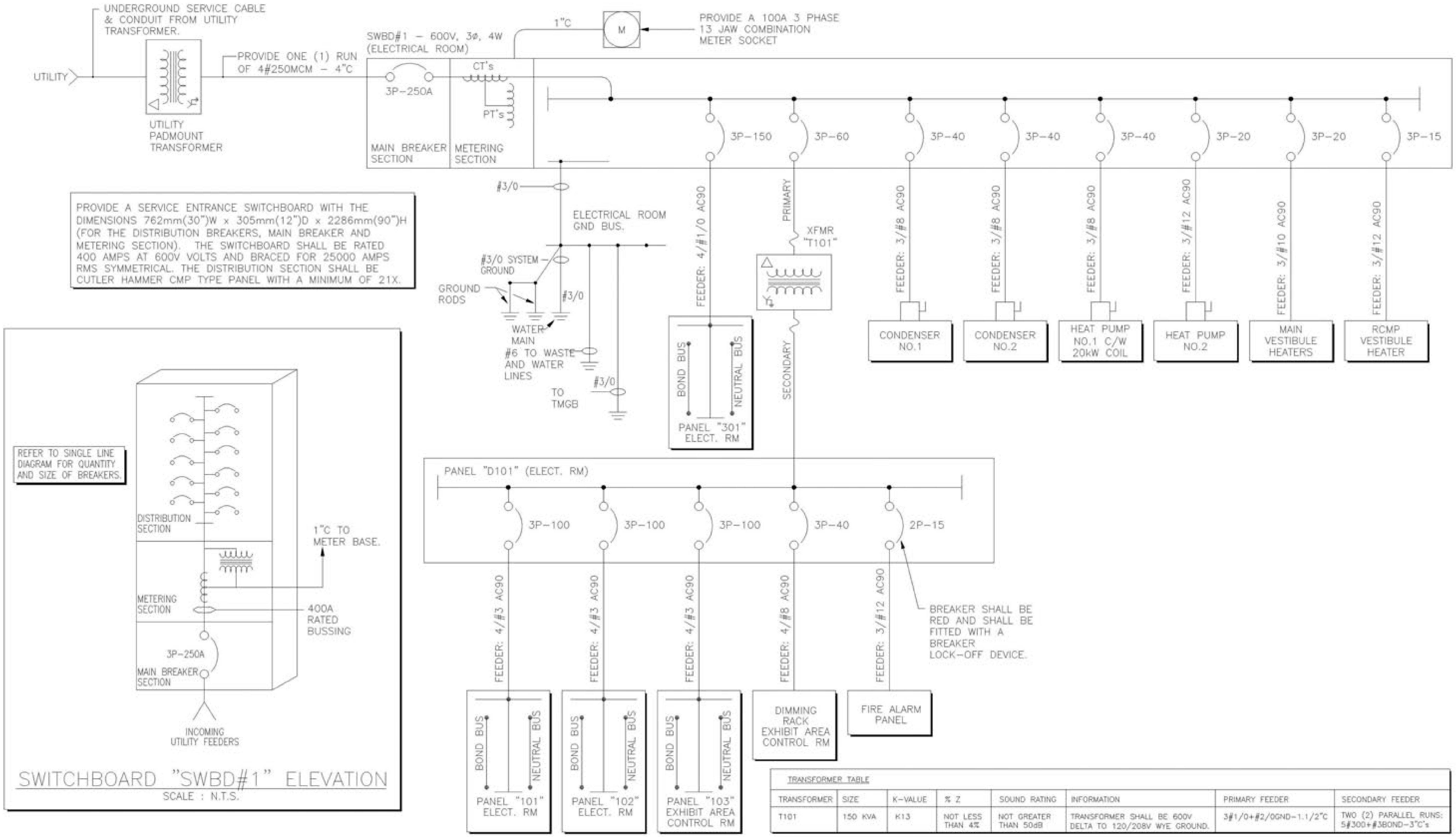
0 2 4 8 16'

north

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
341 TOWNSEND ST., SYDNEY, NOVA SCOTIA

24 February 2006

whwarchitects



TRANSFORMER TABLE

TRANSFORMER	SIZE	K-VALUE	% Z	SOUND RATING	INFORMATION	PRIMARY FEEDER	SECONDARY FEEDER
T101	150 KVA	K13	NOT LESS THAN 4%	NOT GREATER THAN 50dB	TRANSFORMER SHALL BE 600V DELTA TO 120/208V WYE GROUND.	3#1/0+#2/0GND-1.1/2"C	TWO (2) PARALLEL RUNS: 5#300+#3BOND-3"C's

Joggins Fossil Cliffs Comprehensive Site Development Plan

Design Development Submission - Electrical Single Line Distribution

F.C. O'NEILL, SCRIVEN & ASSOC. LTD.
Consulting Engineers
5450 CORNWALLIS ST., HALIFAX, NOVA SCOTIA
PHONE: (902) 429-0701, FAX/BBS: (902) 429-8729
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24 February 2006

whwarchitects

Introduction

This **Schematic Design Report** for the Joggins Fossil Cliffs is presented in the form of a working document that will serve as the basis for further development in subsequent stages of design.

At the schematic design stage, the level of detail and information provided is intended to offer an overview of all major interpretive components, permitting the evaluation of the design concept as a whole. The document thus provides an overview of the visitor experience planning, including the overall design direction, the thematic breakdown, a graphic approach and overall directions for exhibit components.

The report builds on workshops and consultation with the client and other stakeholders, supplemented by existing documentation and ongoing research. It also draws on extensive discussion and consultation between the different teams responsible for developing an integrated visitor experience at the Joggins Fossil Cliffs.

The report contains several distinct sections. These include:

→ **Final results from the Visioning Study that initiated the design process.** In addition to providing overall guidelines and direction for the project, this study led to the development of the final Master Concept – "The Power of the Cliffs" – that is now serving as inspiration for all design team members. Perhaps most importantly, this Master Concept has served as the foundation for integration between the architectural and interpretive design teams.

→ **Datasheets** describing all major interpretive components of the visitor experience. These include:
  - **Descriptions and key messages** for all **major exhibit themes and subthemes** to be featured in the exhibit spaces at the Fossil Centre;
  - An **exhibit thematic breakdown** and **exhibit layout** for the exhibit hall and other spaces in the Fossil Centre, together with sketches and renderings;
  - A preliminary **site plan**, together with a list of **potential interpretive site interventions**, both for the current phase of the project and for future development; and
  - A preliminary list of potential **activities and programs.**

→ Preliminary **building requirements** for the Centre.

→ A **schedule** showing the timeline for the project development.

Taken together, these documents provide a portrait of all interpretive components of the visitor experience that will be offered at the Joggins Fossil Cliffs Visitor Centre.

TABLE OF CONTENTS

LEXICON

TERM	DEFINITION
People	Visitors, Community, Staff
Knowledge	Education, Research, Thematic Content
Collection	Artifacts, Objects, Specimens
Media	At its simplest interface media could be a graphic panel and at its most complex a simulator
Space	Interior, Exterior, Architecture, Public Areas
Paradox Cards	Planning Exercise: Debating fundamental issues to reach a consensus
Museology Map	Planning Exercise: Inspiration from archetypes in museum evolution
Key Questions	Planning Exercise: Assessing unique characteristics and values
Experience Drivers	Planning Exercise: Prioritizing influential forces in Museology
Master Concept	Developing an overarching core concept that structures ideas, guides the design process and provides a backbone for the exhibits

Introduction

This document has been developed by Design+Communication Inc. in collaboration with WHW Architects Inc. for the Joggins Fossil Cliffs World Heritage Advisory Board, a sub-committee of Cumberland Regional Economic Development Association (CREDA). It represents the initial step in the design and development of interpretive programming for the Fossil Cliffs at Joggins Nova Scotia.

In order to establish a firm foundation and a shared vision for the project, two intensive and spirited workshops were held: the first on September 8, 2005 in Joggins and the second on September 30, 2005 in Amherst..

The Start-up Workshop (September 8) introduced the consultants to the committee and began the task of planning the visitor experience by identifying the driving forces. Prioritizing the drivers is an essential step in understanding what a visit to Joggins will be like. Participants were also introduced to current trends in museology and given the opportunity to rank how applicable to the Joggins project each one is.

The second workshop (September 30) dealt with visioning and the visitor experience. Through the "Paradox Exercise", participants were asked to examine some opposing ideas and come to a consensus on key issues related to each of the experience drivers. Individuals expressed their opinions and experiences, listened with care to one another, and identified what was at stake in order to reach agreement on each issue. A summary of participants' comments and the consensus they reached are presented in this report.

All the discussion and conclusions from these workshops will be used to establish objectives for the design team and will lead to the master concept for the Joggins project.

Workshop Participants

September 8

Jenna Boon	Joggins Fossil Cliffs
Rhonda Kelly	CREDA
Gerald Read	CREDA
Ron Robinson	CREDA
Mary-Jo Mackay	NS Tourism Culture & Heritage
Bob Ogilvie	NS Tourism Culture & Heritage
Christine Sykora	NS Tourism Culture & Heritage
John Calder	NS Dept. of Natural Resources
Scott Swinden	NS Dept. of Natural Resources
John Reid	Cumberland Municipal Council
Bernice Vance	Joggins Community
Steve Ferguson	Municipality of Cumberland
John Kellegrew	Municipality of Cumberland
Ken Adams	Fundy Geological Museum / Fundy Shore Tourist Destination Area
Todd Keith	Parks Canada
John Crace	WHW Architects Inc
Ron Burdock	WHW Architects Inc
Jon Carmichael	WHW Architects Inc.
Jean Saint-Syr	Design + Communication
André Bilodeau	Design + Communication
Hélène Bertrand	Design + Communication
Sheila Stevenson	Design + Communication
Stephen Archibald	Design + Communication
Cary Vollick	Vollick McKee Petersmann
Andrea Arbic	A.L. Arbic Consulting
Roy McBride	BMR Structural Engineering
Rick Moulton	F.C. O'Neill Scriven & Associates
Glenn Brunt	F.C. O'Neill Scriven & Associates
April MacIntyre	Davis Archeological Consultants

Steve Davis	Davis Archeological Consultants
Tom Austin	ABL Environmental
Meghan Milloy	Strum Environmental
Bruce Strum	Strum Environmental

September 30

Jenna Boon	Joggins Fossil Cliffs
Rhonda Kelly	CREDA
Gerald Read	CREDA
Ron Robinson	CREDA
Mary-Jo Mackay	NS Tourism Culture & Heritage
Bob Ogilvie	NS Tourism Culture & Heritage
Christine Sykora	NS Tourism Culture & Heritage
John Calder	NS Dept. of Natural Resources
Scott Swinden	NS Dept. of Natural Resources
John Reid	Cumberland Municipal Council
Steve Ferguson	Municipality of Cumberland
Ken Adams	Fundy Geological Museum / Fundy Shore Tourist Destination Area
Todd Keith	Parks Canada
Michele Scott	Atlantic Canada Opportunities Agency
Donald Agnew	Joggins Fossil Cliffs
John Crace	WHW Architects Inc
Ron Burdock	WHW Architects Inc
Cary Vollick	Vollick McKee Petersmann
Andrea Arbic	A.L. Arbic Consulting
Jean Saint-Syr	Design + Communication
André Bilodeau	Design + Communication
Sheila Stevenson	Design + Communication
Stephen Archibald	Design + Communication

PROCESS

Below is a description of each of the Planning Exercises that contribute to the definition of a new vision and to the development of a Master Concept.

Drivers

Identifying Forces that Drive the Planning of the Visitor Experience – Seeking an Equilibrium

A discussion is facilitated on the different forces at play shaping the visitor experience. The aim is to decide upon a clear order of the driving forces which in turn directly impacts the type of experience created for the visitor.

Outcome: A clear understanding of the influential forces that affect the visitor experience.

Trends in Museology

Comparison with Current Trends – Where do we Stand?

Present trends in Museology are identified and the Institution is asked to react to these trends and assess how they relate to the future vision.

Outcome: A clear statement of where the Institution stands in relation to the trends helps us understand what direction the Institution is heading toward.

Paradox Exercise

Museum Planning Alternatives and Issues

Through this exercise, the nature of the visitor experience is probed, defining criteria upon which to build the Institution's unique identity. Assumptions are discerned, aired and debated. Essential forces, influencing the nature of the Institution are weighed. Project stakeholders and museum staff are unified by the creation of a solid, consensual foundation for the future vision.

Outcome: Results of consensus workshop, response analysis, summary and identification of apparent values.

Key Questions

Identifying Present and Future Orientations
The Key Questions exercise aims to focus the Institution's critical view of itself, to identify what needs to be changed and what should be built upon.

Outcome: A clearer view of where the Institution stands at present and the direction for the future.

The Challenges

The Challenges – Focusing our Energies
The Challenges are the result of sorting through the answers provided to the Paradox Cards in the previous workshop. By narrowing down the core issues that need to be addressed, clear objectives can be set for the new direction of the Institution.

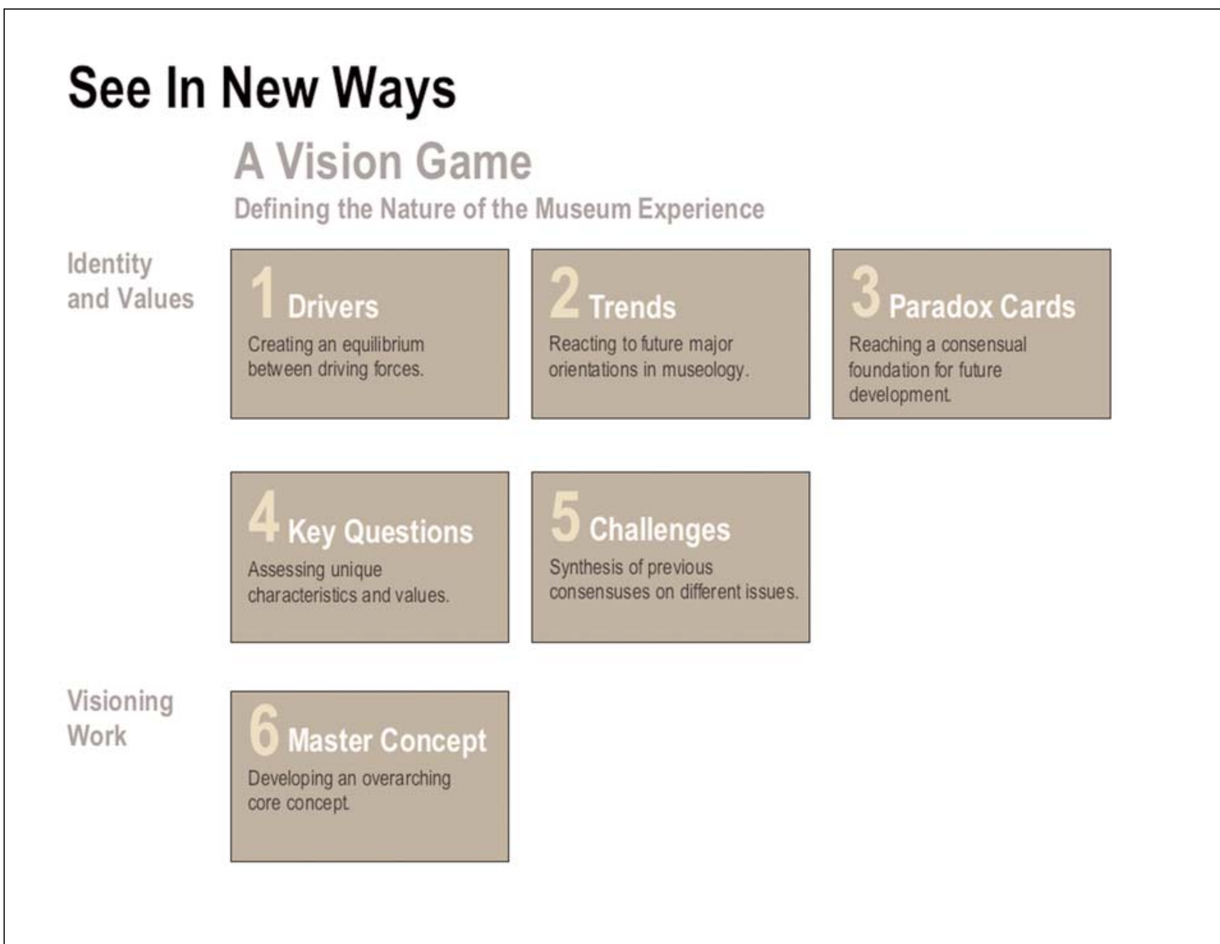
Outcome: Clearly articulated Challenges are spelled out. These will help determine what concrete action is to be taken.

Master Concept

Unifying the Components

Developing an overarching core concept that structures ideas, guides the design process and provides a backbone for the exhibits. The Master Concept allows us to articulate the importance of establishing connections both in terms of the physical facilities and the thematic spaces, connecting the different components of the Institution. The sought-after conceptual framework will draw inspiration from subjects pertinent to the museum and will, in turn, spark new ideas – acting as a dynamic trigger - organizing and structuring development.

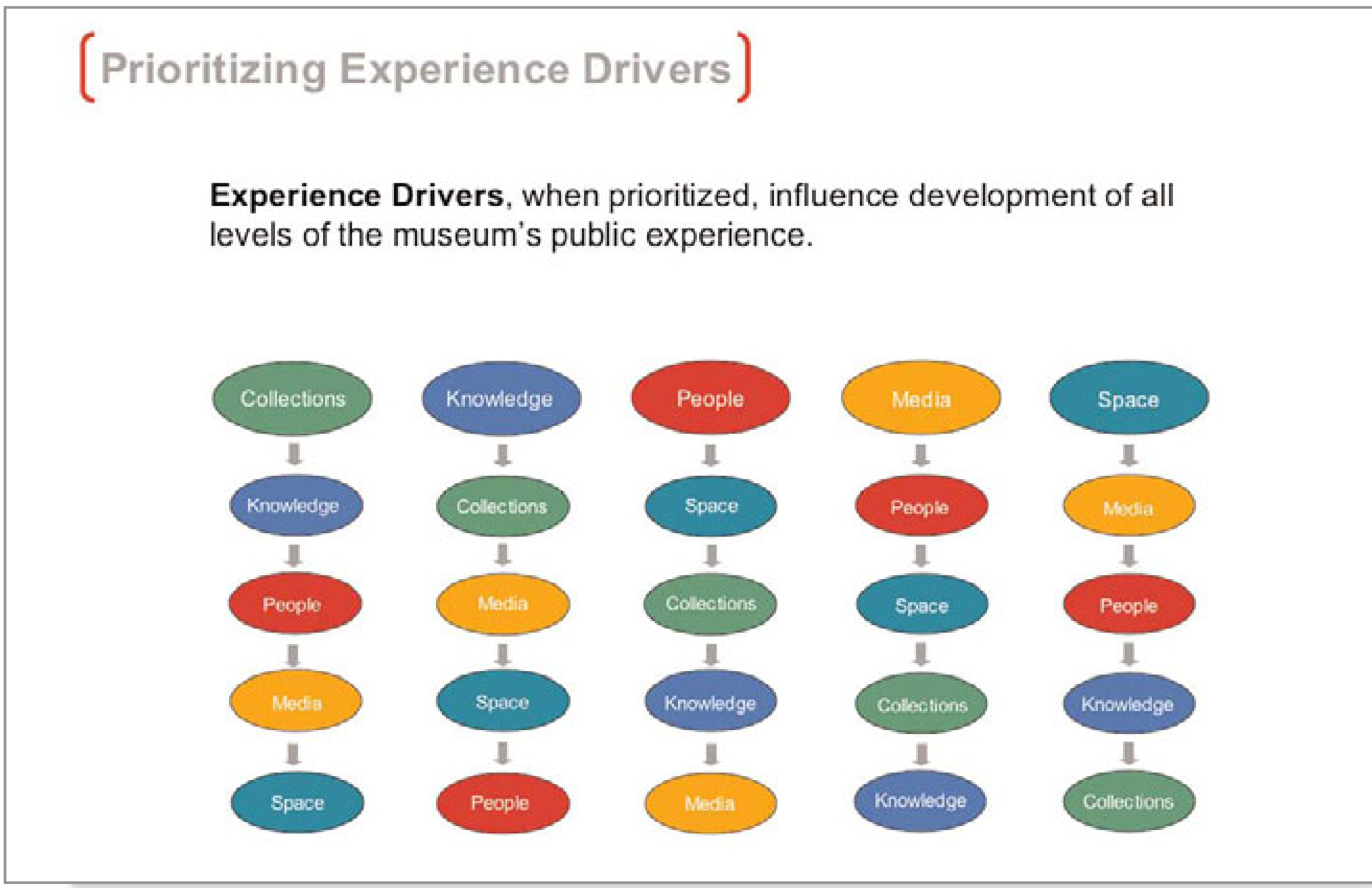
Outcome: A common and inspiring vision for the future.



DRIVERS *Identifying Forces that Drive the Planning of the Visitor Experience – Seeking an Equilibrium*

A discussion is facilitated on the different forces at play shaping the visitor experience. The aim is to decide upon a clear order of the driving forces which in turn directly impacts the type of experience created for the visitor.

Outcome: A clear understanding of the influential forces that affect the visitor experience.



(Experience Drivers)

SEE IN NEW WAYS begins by defining 5 driving forces that influence the nature of the public experience. We call these "**Experience Drivers**" and they will be used throughout the game.

People
Visitors, Community, Staff

Collections
Artifacts, Objects, Specimens

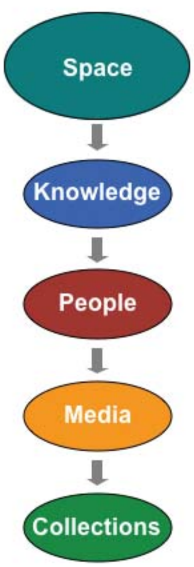
Media
Exhibits, Programs

Knowledge
Education, Research, Content

Space
Interior, Exterior, Architecture, Public Areas

(Drivers)

The overall experience is an equilibrium of forces working dynamically together, assuring that the resulting **VISION** responds to the needs of stakeholders, museum personnel, and the community.



At Joggins, the Bay of Fundy tides expose amazing fossil-filled cliffs. Stories told by these fossils and the debates about their significance fascinate visitors and draw them to dynamic media and exceptional evidence that bring the Carboniferous to life.

DRIVERS

The Joggins Fossil Cliffs, as they continue to reveal details about the Carboniferous environment and the evolving web of life, play an enduring and major role in the development of science and the history of ideas. The eroding cliffs and the powerful Fundy tides provide visitors with a challenging opportunity to explore the seacoast at the most significant Carboniferous exposure anywhere in the world. All visitors will be enchanted by exhibits and programs that present remarkable evidence of ancient ecosystems and provide insight into the role that Joggins plays in our knowledge of earth history.

Space

We will create functional spaces that satisfy the needs of visitors and provide a resource for the community. The architecture will communicate both the distinction of a World Heritage site and the warm welcome of a small community in a cool location. The local and regional community should embrace the facility as a useful and even essential part of their lives.

The eroding fossil cliffs and the powerful Fundy tides provide for a dynamic, changing visitor experience on the beach. Our built displays and spaces will be planned and constructed so they can satisfy first time and repeat visitors for many years without substantial changes. There will be some flexibility to allow for smaller scale changes such as new fossil discoveries and current research. The design of the building should allow for a possible addition in the future.

Knowledge

The story is primarily about the significant role that the Carboniferous fossil cliffs at Joggins have played in the development of science and in the history of ideas about the web of life on earth. While helping visitors understand this global perspective, we will also give them a sense of where they are: in a coastal village rooted in coal; at an outstanding fossil site in the Fundy region, which has benefitted from a tradition of local “keepers of the cliffs.”

Our primary mission is to provide opportunities for visitors to learn about the fossil discoveries at Joggins and their significant contribution to human knowledge, past, present, and future. The centre will also facilitate research by cultivating relationships with universities and other groups and ensuring that appropriate services are available for visiting researchers. This should have a positive economic impact on the area.

We will give visitors the most fun they can have while providing solid intellectual content. By understanding the needs and expectations of visitors we will be able to provide memorable, challenging, and satisfying experiences.

DRIVERS

Our educational strategy is to provide visitors with the thrill of discovery and the satisfaction that comes with understanding. What makes Joggins special can be difficult to comprehend without help but by giving visitors some historical and scientific background and some learning tools, they will be able to identify and understand the evidence they see of Carboniferous ecosystems and to appreciate the thought and debate that surrounds the Joggins discoveries.

People

We want to reach that large audience of people who are interested in learning. Those with a knowledge or curiosity about paleontology, evolution, the history of ideas, and the development of science are a key audience, some of whom already visit the site throughout the extended season. People with a more general interest will be attracted by the wonders of the Fundy seacoast and be intrigued by the fossil discoveries. World Heritage status will enhance the lure of the site to a wide spectrum of visitors.

We want to engage a diverse audience by using interpretive approaches that address multiple intelligences. This approach will ensure that everyone is able to use the learning styles they find most stimulating.

Media

Visits to sites like Joggins are most satisfying when people have opportunities to talk with staff. To appreciate the hidden wonders and real dangers of the cliffs and beach, visitors must have interaction with skilled interpreters at the cliffs. Exhibits will be designed to communicate and be enjoyed on their own. Staff, when available, will be able to make these exhibit experiences even more satisfying to the visitor.

We will use appropriate technology to tell the Joggins story in a way that informs, enchants, and entertains our visitors. This will be accomplished by selecting communication technologies that are both affective and sustainable.

Collections

In order to appreciate the significance of the cliffs at Joggins and their fossils, it is necessary to use media. Specimens will appear insignificant until their leading role in the drama of scientific debate is appreciated.
The quantity and variety of fossils found here will help visitors to appreciate the biodiversity of Carboniferous life and allow them to personally examine some specimens.

DRIVERS

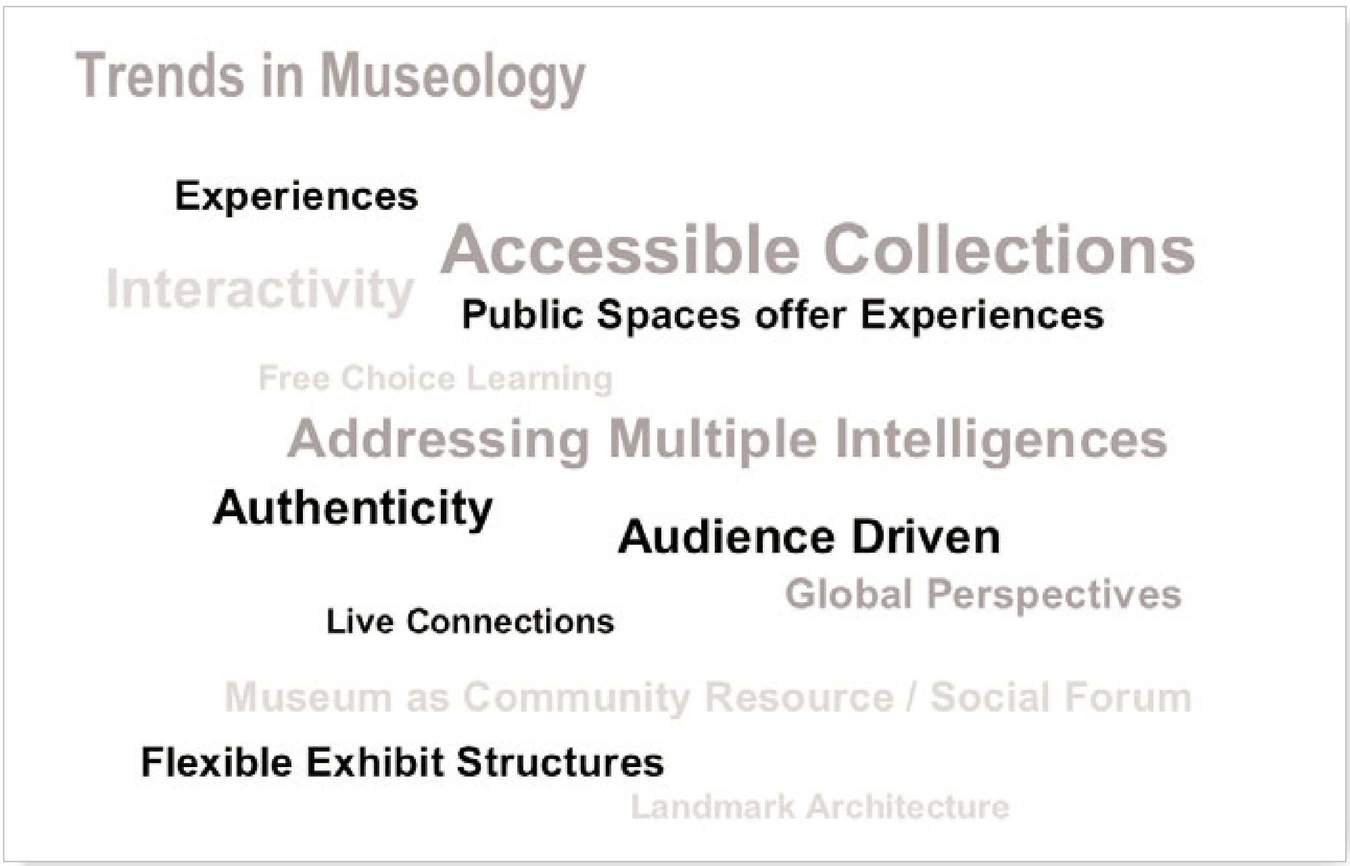
The Joggins centre has an essential role to play in the preservation of the Joggins fossil heritage. The centre should display all the fossils required to support its mission and should ensure that these specimens are both secure and available for visual examination.

By appreciating the richness of past discoveries and debates about the significance of Joggins, visitors will become aware of how relevant Joggins remains. The ongoing erosion of the cliffs guarantees that new fossil finds and new research will add additional chapters to the history of the earth; analysis of past discoveries will guarantee a lively debate into the future.

Trends in Museology

Comparison with Current Trends – Where do we Stand?
Present trends in Museology are identified and the Institution is asked to react to these trends and assess how they relate to the future vision.

Outcome: A clear statement of where the Institution stands in relation to the trends helps us understand what direction the Institution is heading towards.



Trends

Thirteen dots were given to 16 Stakeholders to attribute by order of importance.
The total amount of dots attributed to each trend is represented below.

Trends in Museology	Atttribution by Stakeholders
Experiences, not exhibits	34
Accessible collections	11
Interactivity	15
Public Spaces offer Experiences	12
Free Choice Learning	7
Addressing Multiple Intelligences	15
Authenticity	29
Integrated Themes	14
Global Perspectives	17
Live Connections	6
Museum as Community Resource/ Social Forum	20
Flexible Exhibit Structures	13
Landmark Architecture	15

Trends

Thirteen dots were given to 6 Consultants to attribute by order of importance.
The total amount of dots attributed to each trend is represented below.

Trends in Museology	Atttribution by Consultants
Experiences, not exhibits	12
Accessible collections	10
Interactivity	5
Public Spaces offer Experiences	4
Free Choice Learning	6
Addressing Multiple Intelligences	9
Authenticity	6
Integrated Themes	6
Global Perspectives	5
Live Connections	0
Museum as Community Resource/ Social Forum	12
Flexible Exhibit Structures	1
Landmark Architecture	1

PARADOX

Paradox Exercise

Museum Planning Alternatives and Issues

Through this exercise, the nature of the visitor experience is probed, defining criteria upon which to build the Institution's unique identity. Assumptions are discerned, aired and debated. Essential forces, influencing the nature of the Institution are weighed. Project stakeholders and museum staff are unified by the creation of a solid, consensual foundation upon which to build the vision.

Outcome: Results of consensus workshop, response analysis, summary and identification of apparent values.

INTRODUCTION

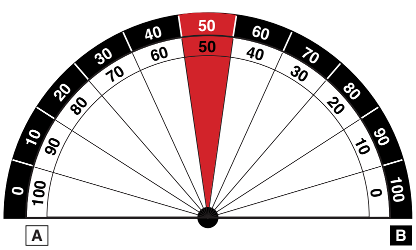
The purpose of the Paradox Cards was to ask difficult questions about key issues centered around the driving forces. Each "paradox" posed a question that prompted the various members on the development team (scientists, community representatives, museum professionals, tourism specialists, consultants) to voice, query, discuss, and confirm their assumptions about the Joggins Fossil Cliffs site and its operation.

Through this exercise, we have made choices about the identity and priorities of the project. Our decisions establish parameters for the site. By reaching consensus on each of these paradoxes, we build a foundation upon which the visitor experience can grow. From this point forward, we all work toward a mutually understood and shared vision.

PEOPLE

Consensus:

We want to reach that large audience of people who are interested in learning. Those with a knowledge of or curiosity about paleontology, evolution, the history of ideas are a key audience, already showing a willingness to visit the site. People with a more general interest will be attracted by the wonders of the Fundy seacoast and be intrigued by the fossil discoveries at a site of international significance.



1.A
Niche Market
50%

1.B
General Public
50%

Paradox:

Who do we want to reach?

1.A Niche Market. vs. 1.B General Public

Comments:

It depends on how narrowly we define “niche”. I’d say we’re hoping to reach people who are interested in furthering their own knowledge about something, not to ride a tilt-a-whirl. In this case, the Carboniferous and the development of science.

The site appeals to people interested in furthering their knowledge, someone with an interest in engaging themselves.

The general public comes to Nova Scotia looking for a seacoast experience. If they have no interest in fossils but come to Joggins and have an opportunity to learn about fossils as well then from a revenue point of view that’s good.

It’s a niche market.

It’s the ecotourism market, the learning market: people who want to learn.

I tend to favour the general public in the long term that would include the niche market. We want to reach people who are coming to the area for scenery and to promote the loop: Cap d’Or , and so on. The site must appeal to many tastes. For example Cape Chignecto Park initially marketed itself as a destination for wilderness camping but it will not survive on that market alone. They needed to provide opportunities for people who were generally interested in the scenery.

You already have the niche market visiting Joggins. There is a great opportunity to invite more people to explore and experience this World Heritage site. If we limit ourselves it’s not going to work from a numbers point of view.

You already have a niche market if it’s a World Heritage site. We need to move on to the general public.

PEOPLE

The range of people who already come is diverse. But the common denominator is people who want to learn - it's a broad niche.

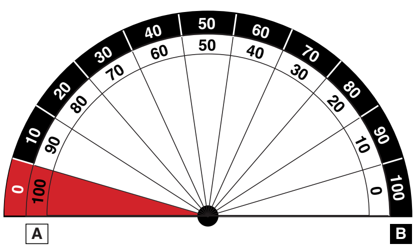
We want to reach the broadest possible audience but not at the expense of the niche.

It's also seasonal. The opportunities for niche are in the shoulder season, for general public in the summer.

Anything that plays into the evolution debate will attract the attention of people.

Consensus:

We want to engage a diverse audience by using interpretive approaches that address multiple intelligences. This approach will ensure that everyone is able to use the learning styles they find most stimulating.



2.A Multiple Intelligences 100%

2.B Common Denominator 0%

Paradox:

How will we engage our visitors?

2.A Multiple Intelligences vs. 2.B Common Denominator

Comments:

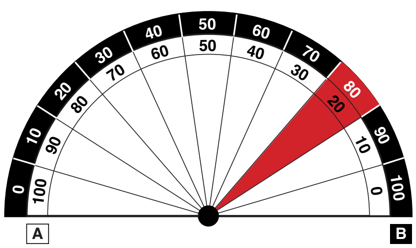
Unanimous agreement.

This is the more expensive option.

It is more complex this way. We will have more layers.

Consensus:

The principal story is about the significance of the Carboniferous fossils found at Joggins and the role they have played in both our understanding the web of life and in the history of ideas. While helping visitors appreciate geological time, we will also give them a sense of where they are now: beside the Bay of Fundy in a village rooted in coal.



1.A
Local
20%

1.B
Global
80%

Paradox:

When we tell the story, what's our perspective?

1.A Local vs. 1.B Global

Comments:

100% B. This is a story of human global importance and as a World Heritage Site it is the importance of Joggins in the context of the world.

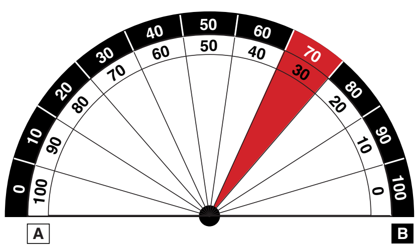
I'd give 10% to the local because the story also has to include Don Reid who has brought this to the attention of people.

In the nomination for World Heritage Site designation, we have to interpret the outstanding and enduring value of this site from a global perspective.

Even if, heaven forbid, this doesn't get World Heritage Site designation, this is still an important site.

The emphasis is global but there should be some room for talking about a town rooted in coal, the people of Joggins who have worked with the scientists, not just Don Reid but historically, and the tradition of community members who act as "keepers of the cliffs".

Consensus:
Our primary mission is to provide opportunities for visitors to learn about the fossil discoveries at Joggins and their significant contribution to human knowledge, past, present, and future. The Centre will also facilitate research and make sure that appropriate services are available for visiting researchers.



2.A
Research
30%

2.B
Education
70%

Paradox:
What's our primary mission?
2.A Research vs. 2.B Education

Comments:
There is research done at the cliffs. The cliffs are the subject of research. So a component in the centre that makes visitors aware of the research being done would be good. But education is the major component.

There is an idea that the centre facilitates research and is better off economically for having facilitated it. But what is the nature of the research activity and how is it present in the educational mission? What does the centre do to facilitate research?

We need to go back to the goals. UNESCO's goals are educational and scientific, so these have to be married. The centre should have a direct relationship, an affiliation with a research institute or a university. We're talking about some way to seek significant dollars to fund visiting scientists and operate the centre.

The Fundy Geological Museum (FGM) has a small preparation lab now but scientists don't stay. They use it as a staging area for field research. The FGM offers a classroom to Rutgers for one week. They use it to do things they can't do in a motel room - spread out maps, do presentations, etc.

There are PhD students, oil company people who have come on dedicated field trips to Joggins during the last couple of decades. There are also people who come to do active research because there is so much material to study and work on. I guess there are two types of researchers: groups that come for perhaps a week and visiting scientists who come for a field season.

Research is going to happen anyway. This operation can provide conditions to entice field groups, to come for a week or two, to encourage research. It is an opportunity that needs to be encouraged.

UNESCO asks "What is the opportunity for ongoing research?"

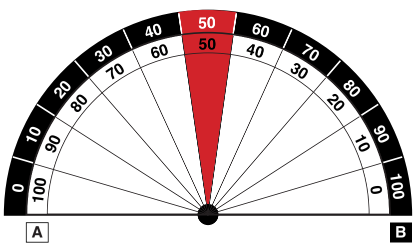
Research is actually part of the education. As a visitor you can learn what current research is being done.

The research amplifies the education.

KNOWLEDGE

Consensus:

By understanding the needs and expectations of visitors, we will present solid intellectual content in ways that are exciting, challenging, and satisfying.



3.A Education 50%

3.B Entertainment 50%

Paradox:

How will we share our knowledge?

3.A Education vs. 3.B Entertainment

Comments:

We better be having fun while we're learning, from a CREDA perspective.

Entertainment isn't fluff. Successful attractions have found out what their audience want: an experience that's fun.

Visitors had better be having fun or else they won't come back a second time!

Get rid of the "theme park" example on the entertainment side and it's 50/50.

We have a park with a theme. That changes it.

Give people the most fun they can get while giving them the intellectual content. Good solid intellectual content while telling an entertaining story.

Story telling but not fiction. The story must be factual.

The niche market has to be satisfied with an appropriate level of information. But the general public wants to learn as well.

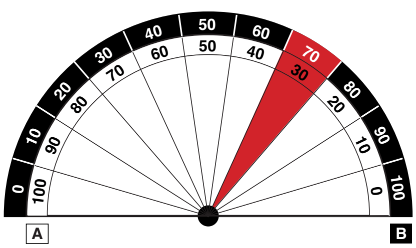
How about someone dressed up as Lyell's lizard.

Let it be recorded that John Calder said nothing.

KNOWLEDGE

Consensus:

Our educational strategy is to provide visitors with the thrill and satisfaction of learning. By giving visitors essential historical and scientific background, they will be able to understand the evidence they see of Carboniferous ecosystems and to appreciate the thought and debate that surrounds the Joggins discoveries.



4.A
Teaching
30%

4.B
Learning
70%

Paradox:

Do we have an educational strategy?

4.A Teaching, the voice of authority, passive vs. 4.B Learning, skill building, self-directed, filled with surprise, outcome is unpredictable

Comments:

Learning is the cliff experience. The visit to cliff is unpredictable, filled with surprise - flip over a rock and you don't know what you will find.

People want some teaching as well.
You need teaching to know what you are seeing on the cliff, what fossils are, what they look like. The skill is learning to observe, to see. Because of the nature of the site and fossils, teaching is more important than at some other sites.

The spectrum is broad. Teaching begins to get softer as you move across the perspective.

The centre will have to be authoritative in the positive sense in order to help people understand what Joggins means, why it's an important world site. People are coming here for knowledge about the Carboniferous and the development of science.

Don Reid did little teaching this morning when we visited him but we learned a lot because we were engaged, participating, having a conversation.

Our experience with Don Reid was a lot about standing around, seeming to be passive as he talked and answered our questions and showed us specific fossils, but we were listening and seeing. And we were able to wander off on our own and then come back to the group or to Don Reid

It is a combination of learning and teaching. Both are strategies for education, about how you encourage people to learn.

We want learning to be the outcome. To what degree do we use teaching?

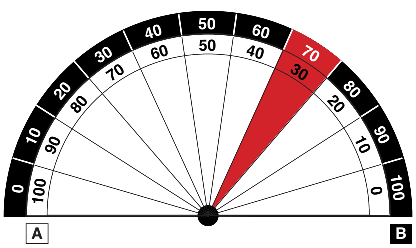
Additional Comments:

John Calder noted two books with Joggins references that teach and enttain:

Bonner, Hannah. *When Bugs Were Big, Plants Were Strange, and Tetrapods Stalked the Earth*, 2003 National Geographic.

Bryson, Bill. A Short History of Nearly Everything.

Consensus:
Media will enable people to appreciate the cliffs and the leading role of Joggins fossils in the drama of scientific debate. The quantity and variety of specimens allow visitors to understand and examine the biodiversity of Carboniferous life.



1.A
Objects
30%

1.B
Media
70%

Paradox:
What will drive our experiences?
1.A Objects, collections shape the experience vs. 1.B Media

Comments:
Objects need to support the big ideas. They also require the support of media in order to tell a story and support education. We need the right media to be able to show how Dendropupa made a difference to the history of science. If it's among a lot of other fossils, it gets lost. It needs to be on its own to make the point.

Time and tide have already done their damage to the fossils. There should be some chance for people to do a hands-on examination and touch some specimens.

A biodiversity display can include a range of fossils to illustrate that all fossils have importance in the web of life. But not all fossils are equally important in the story of evolution. We will have to be selective.

Additional Points arising from discussion

1. Will we build a collection?
Are we creating a reserve collection, kept in secure storage? Will the (an) authoritative collection be housed at Joggins, or elsewhere, like Parrsboro or Halifax?

Everyday there is a possibility to grow the collection.

John Reid:
If no one builds a collection, then we'll lose fossils. We don't want to lose specimens to people or the weather. If we want to be able to change what's in the exhibits, then we should be making a collection. We have to have a collection but not thousands of fossils. We want the best, and on view.

Gerald Read:
To have any credibility, we have to have a collection here.

Ken Adams:
If you're looking at storing a collection, you're looking at increased costs with no financial return.
The Fundy Geological Museum is 45 minutes away, with storage capacity.

Scott Swinden:
If you're a researcher from Washington, or elsewhere from away, and you want to study Joggins fossils in a collection in Nova Scotia, it's of little consequence if the collection is in the building at Joggins. It could be Parrsboro or Halifax.
Do fossils require strict environmental controls?

Ken Adams:
Some do. Pyrites can be active. Once you put stuff that's been exposed to fluctuating conditions, like what's been in Don Reid's barn for 30 years, into a building with controls, you can start to have problems.

John Calder:
Most don't [require strict environmental controls].

Bob Ogilvie:
We already have legislation in place that is cut and dried. It puts us in good shape as far as UNESCO is concerned because the legislation says that any fossils belong to the Province. Details can be sorted out from there. The legislation is there to ensure that the material will go into a collection and isn't dispersed to rock shops and private collectors.The Province wants to build a Joggins collection. But that doesn't mean that it's going into a basement in a building in Joggins. All collections belong to the Province. The Province can put them wherever it chooses and there are lots of precedents for lending collections to appropriate locations around the province. My understanding is that there will be specimens from a collection on display at Joggins but storage will be some other place, like Parrsboro or Summer St in Halifax.
You will have access to the best specimens.

If you're building a collection, that requires curatorial expertise and that's another level of cost. The Fundy Geological Museum already has curatorial expertise and if there's another museum within 45 minutes that has that expertise, then you're duplicating costs. Early on I thought we were talking about doing an interpretation centre here with storage at FGM. What you collect here doesn't have to be stored here. If the fossils are screened then there's the possibility of selling the fossils that are common, that are a dime a dozen.

The offer that is on the table is this: There will be a provincial fossil collection, with Joggins as a subset.. Whatever is needed for display, the best, however many you want, will be made available.

The other question is the storage of all the other stuff, the 95% that's not on display. Because it's the NSM collection we normally would take that on as our responsibility. We'd put it at Parrsboro, or the storage centre at Stellarton, or Halifax. It's curated, it's looked after, it's available for researchers, for display. That's on the table. What I can't answer is should there be an additional storage on site. If you want to proceed then that's fine. It's still the Provincial collection but you are taking care of it. That just takes some of the pressure off us. You have to take care of it at your expense.

Conclusion:

The Advisory Committee will have to resolve the issue of building a collection very soon since it has an impact on the building program.

2. Will there be a preparation lab?

John Calder:
We have had a gentlepersons agreement with Parrsboro and we need to honour it. And there's a range of requirements that can't be met in Joggins because of the range of expertise that's required, but you could have something that supports the field scientist who is cataloguing specimens.

John Crace:
Is there an opportunity for people in the village to develop a cottage industry around the preparation of specimens?

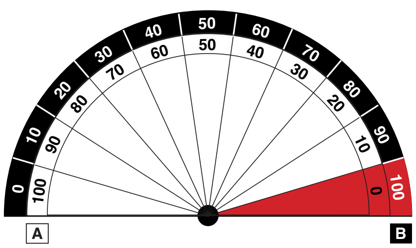
John Calder:
There are various types of fossil at Joggins requiring different methods of preparation and no one individual usually deals with all types. There are different techniques for dealing with vertebrate specimens from dealing with micro-fossils. You need a huge amount of expertise to prepare fossils. The thing that is very sophisticated is the preparation of bone material and there's not a lot of demand. Plants don't require much preparation.

Conclusion:

The centre needs the facilities necessary to support working scientists at a working stage. There should be a workstation where a
scientist could do rudimentary work even if it is just cataloguing.

We need to look at what resources are already within the region. What Fundy Geological Museum beings to the table is trained staff with 6 or 7 years of experience and storage. We can't sit in isolation. We need to bring all the players in the region together to see what we've got and how to merge and work cooperatively.

Consensus:
The Joggins Centre will play an essential role in the preservation of the Joggins fossil heritage. The Centre should display all the fossils required to support its mission and should ensure that these specimens are both secure and available for visual examination by visitors.



2.A
Restricted
0%

2.B
Accessible
100%

Paradox:
How accessible will the collection be in the building?
2.A Restricted vs. 2B Accessible, visually but secur

Comments:
We want the best specimens on display, protected under glass.

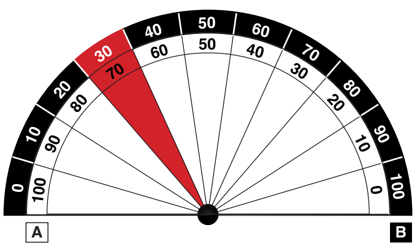
There will be specimens on display and they need to be accessible.

The Science North collection in their Interpretation Centre is in drawers that you can pull out.

100% accessible open storage with whatever limited realm the collection is.

Consensus:

Consensus: The ongoing erosion of the cliffs ensures that new fossil finds and research will provide fresh insights into earth history. Analysis of past and present discoveries at Joggins guarantee lively debates into the future.



3.A
History
70%

3.B
Present and Future
30%

Paradox:
What is our outlook with regards to time?
3.A History vs. 3.B Present and Future

Comments:

No other site in the world has what Joggins has. Joggins played into the debate on the origin of the species in the 19th century and it is still very relevant. We need to allow for new discoveries and new debates about old discoveries.

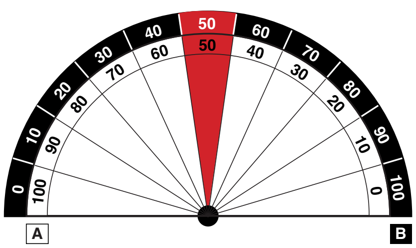
Joggins connects with debates going on today. It has a role in the history of science, and in the evolution debate that is still going on today.

Creationism is very much the current debate. It's the number one topic about Joggins on the Web.

This is a site that changes everyday due to tides, storms. A dynamic story with opportunities for ongoing discovery. We know for a fact that there will be new discoveries. And there is enough material in the deposit to face 3000 years of erosion.

Earth History is the UNESCO category.

Consensus:
Exhibits throughout the site will be designed to communicate and be enjoyed on their own. To fully appreciate the hidden wonders and real dangers of the cliffs and beach, visitors must have interaction with skilled interpreters. When available, staff will make exhibit experiences even more satisfying for visitors.



1.A
Exhibits
50%

1.B
Programs
50%

Paradox:
How will we engage our visitors?
1.A Exhibits vs. 1.B Programs

Comments:
Visitors need somebody to talk to when they are viewing the exhibits in the centre. Visitors at the FGM go through the exhibits and come back asking for someone to talk to. I think it's essential to have interpreters in the centre as well as on the beach. Adding people can create jobs in the community as well. The payback of the expenditure of public funds on this project is to the community, through jobs.

Visitors want someone to talk to. It reinforces the exhibits to have a person there to help.

This goes back to how people learn.

I think it's extremely important to have live bodies in the centre as well.

Technical language in exhibits needs interpretation.

You can always add staff but exhibits must be designed so that they work without extra help from interpreters. Exhibits should be self-directed if there is no one there. In the real world we may not be able to put staff in there all the time, so exhibits have to be done well.

I'm hoping for creative sensory exhibits, not just panels. A segment of your visitors will want to pick up their pamphlet and be able to move about on their own.

The centre is A. Cliffs is B. Programs are essential on the cliffs. Concentrate staff where they are needed most - on the beach
People without a guide come off the beach and say "I didn't see a thing."
Those who have had a tour come away saying "Fantastic story."

MEDIA

Need highly motivated dynamic guides - and that's a challenge.

Engage visitors to recognize patterns.

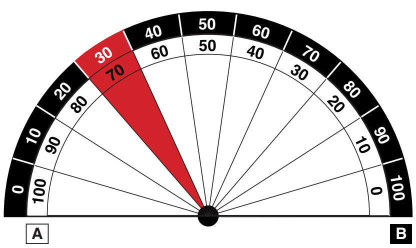
Flexibility is good: staff who can be on the beach on sunny days or in the centre on rainy days. Not everyone wants a person.

People should be able to get an introduction through the exhibits without talking to someone.

MEDIA

Consensus:

We will select appropriate, affective, and sustainable communication technologies to tell the Joggins story in a way that informs, enchants, and entertains our visitors.



2.A
Low Tech
70%

2.B
High Tech
30%

Paradox:

What will be our approach to technology?

2. Low Tech vs. 2.B High Tech

Comments:

Cost, maintenance, and keeping up-to-date with technology are all big issues. Dealing with breakdowns isn't pretty, when you have visitors waiting around, expecting something. It's added pressure on staff if things break down. High tech implies high costs for maintenance.

Exhibits should be sophisticated because visitors expect a lot. Younger audience expects high tech.

We don't want static exhibits.

Be realistic about what kind of technology you can support in Joggins. I'd think a relatively low percentage of the experience will be high tech since most of the expertise will have to come from Halifax or Montreal. Some technology has to be shipped to California, for example, to be repaired.

If we're going to limit the number of people who are working in the building, then aren't we going to have more high tech? Is there a balancing act here? If we want a range of visitors, don't we need high tech?

You can have low-tech hands-on. Low tech doesn't mean no fun!

This has to be a case of "smart tech". No gratuitous use of high tech, just to be using it. Apply it when it's appropriate, when no other solution will do. Dedicated to some really neat stuff.

Having voices, stations in the exhibit, hearing Lyell and Soapy Sam arguing about *Dendropupa* would be good.

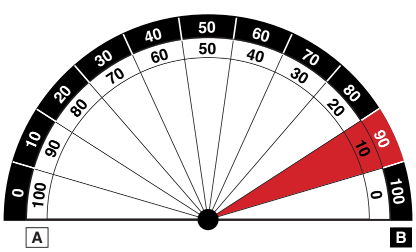
Is there an opportunity to use technology on the beach? Ipods for guided tours?

You want affordable, functional, easy to maintain high tech!

SPACE

Consensus:

Innovative use of space will satisfy the needs of visitors and provide a resource for the local and regional community. The architecture will communicate both the distinction of a World Heritage site and the warm welcome of a small community in a cool location.



1.A
Destination
10%

1.B
Network
90%

Paradox:

How will we use space to define who we are?

1.A Destination (centralized) vs. 1.B Network

Comments:

Given the weather at Joggins you wouldn't want a museum without walls.

It's B. Sometimes I go into the centre. Sometimes I'm joining a guided tour on the beach. There's a network.

The cliffs are the cathedral.

The architects always thought it should be B but we'd like to hear more.

A community resource where there could be community meetings: larger community could use it as well for talks or meetings - e.g. groups from Amherst. The community needs to feel like they own it.

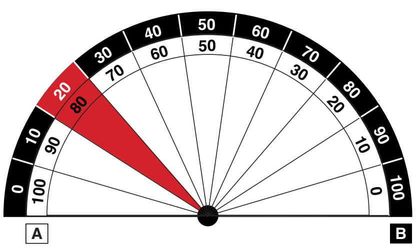
You want a building that is practical, easy to maintain, attractive, where spaces are useable. Not ugly.

The building has to have enough distinction in the community and also some distinction as a world class site.

Fewer than 50% of the visitors will ever see the cliffs. It is the best way to experience the site but because of time, tide, or age many will not get there. In all our concepts we must remember this.

The best ambassadors for the site will be the ones who actually go to the cliffs. .

Consensus:
Our displays and spaces will be planned and constructed to satisfy visitors for many years without substantial change. Some flexibility in design will allow small scale updates to the exhibit and the potential for expansion in the future. The eroding fossil cliffs and powerful Fundy tides guarantee changes on the beach.



2.A
Dedicated
80%

2.B
Multi purpose
20%

Paradox:

What will be our approach to change? How will we remain current?
2.A Dedicated vs. 2.B Multi purpose

Comments:

The centre has to have some way of being able to change. There has to be something about the building that changes.

You're not going to be changing everything all the time. It's more likely to be a 5-year approach. It's probably weighted more towards dedicated.

Some people come back who want to see the same things. Just as in the grocery store you know where things are. Childrens' museums tend to think like that.

Small units may change, like discovery of the month or a live paleontologist on display - things that don't cost much to change because they are built in to change.

Since a large percentage of visitors at the FGM are one time, first time, we've been going for 10-12 years with the same exhibits. But 20% of the audience is now repeat.

The Cliffs change. And it won't cost us a penny.

The design of the building should allow for the possibility of an addition down the road, 15 to 20 years.

Build in some multi purpose capability.

Will be a lot harder to add exhibits after the centre is completed.

How long will it take for the cliff to erode back to the centre?

Identifying present and future orientations

The Key Questions exercise aims to focus the Institution's critical view of itself, to identify what needs to be changed and what should be built upon.

Outcome: A clearer view of where the Institution stands at present and the direction for the future.

1. **Where and what is the icon?**
   What are we really about?

2. **Where are the main attractions?**
   What are the key displays?

3. **Where is the framework?**
   Conceptual framework?
   Physical framework (change/flexibility)
   What ties it together?

4. **Where are the connectors?**
   Between exhibits?
   To the outside world?

5. **What does the visitor do?**
   What process is used to trigger learning?

6. **How do we achieve layers?**
   Levels of information?
   Appealing to multiple intelligences?
   Something for different age groups?

7. **How do we encourage social interaction?**
   How do we create bonds between people?
   How do we support engaging events?
   How do we remain pertinent in the community?

8. **Where is the emotion?**
   How do we achieve the emotional build-up?

9. **How do we motivate repeat visitation?**
   Changing experiences?
   Blockbuster shows?
   Rotating collections?

The Challenges – Focusing our Energies

The Challenges result from sorting through the responses and feedback generated during the Planning Exercises workshops. The Challenges represent core issues that need to be addressed, and provide clear objectives for the Centre.

For the Joggins Fossil Cliffs, we consider that the Challenges must also take into consideration the overarching goal of achieving UNESCO World Heritage Site status, which carries with it the responsibility of becoming a world-class facility. Our experience has shown that the five factors listed below are characteristic of world-class institutions; these factors have accordingly also contributed to the development of Challenges for the Joggins Fossil Cliffs Centre.

What is world class for the Joggins Fossil Cliffs?

Definitions of world class:

- *A general term for a high level of competitive performance as defined by benchmarking and use of best practices.*[1]
- *Organizations that are recognized as the best for critical business process and are held as models for other organizations.*[2]

We believe that the Joggins Fossil Cliffs must offer a world class cultural, natural and learning experience while preserving and sharing this palæontological and scientific resource. Five factors have been identified as essential parts of this overarching goal:

1. Authenticity
2. Scope
3. Quality
4. Innovation
5. Stewardship

Authenticity: The exhibits and experiences for visitors should not be imitations, since the actual experience of the site is more important than any artifice. Supporting and enriching the real experience must be a primary goal of the planning and design teams.

Scope: The Joggins Fossil Cliffs bear witness to millions of years of geological time and millennia of human habitation. The site should strive to help visitors understand the project within a global backdrop that stretches across time.

Quality: The site must achieve a high degree of excellence. The quality of all aspects of the design is of paramount importance. In terms of the process, the human resources, the services, materials and all other dimensions of the project, it is through quality that our respect for the site will be demonstrated.

Innovation: In process, planning, materials, themes, media, operational structures and all other aspects of the facilities, we must strive for optimal solutions, building on past experience to anchor the creation of new and innovative models and methods.

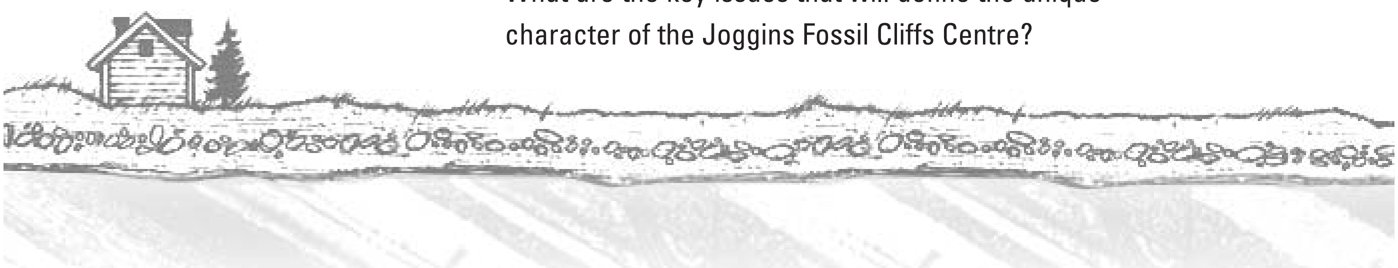
Stewardship: The prestigious nature of a UNESCO site carries with it the responsibility of leadership. The Joggins Fossil Cliffs site must become a model of excellence that will serve as a benchmark for other projects and establish a standard toward which they will strive.

The site must be managed with care and attention in order to ensure that this natural resource is maintained and improved for universal apprecia**tion.** UNESCO inscription requires that the site be sustainable, and sustainability can only be achieved through appropriate stewardship. The site is an "irreplaceable source of life and inspiration."

[1] Bridgefield Group: Planning and Education: http://www.bridgefieldgroup.com/glos10.htm
[2] USA Gov. Accountability Office: http://www.gao.gov/special.pubs/bprag/bprgloss.htm

Challenges

What are the key issues that will define the unique character of the Joggins Fossil Cliffs Centre?



Space

- How do we ensure that all visitors, even those who are unable to go to the beach, have a full and authentic experience of the site?
- How will the site, building and services balance local and regional needs against the needs of the international community?

Knowledge

- How do we provide visitors with the essential historical and scientific background knowledge that will allow them to fully appreciate the Joggins Fossil Cliffs, without drowning them in information?
- What is the best way to tell the ongoing story of research and discovery at the Joggins site?

People

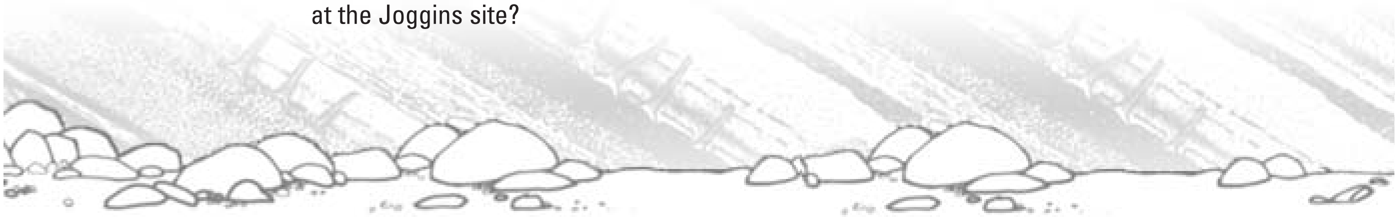
- What are the best ways to engage a diverse audience, with very different interests, needs and levels of background knowledge?
- How do we engage multiple forms of intelligence to ensure that all visitors have a satisfying experience?

Media

- How do we communicate complex scientific and historical concepts using appropriate and often low-tech media?
- How do we design media to complement the work of interpreters and guides, and to ensure that visitors have a satisfying experience even in the absence of interpreters?

Collections

- What context do we need to provide to help people appreciate the collections?
- How can we best help people to understand the scientific importance and significance of fossils that may have limited visual impact?



Master Concept for the Visitor Experience

1. Introduction

For any interpretive project, having a clear and powerful **master concept** provides a strong foundation that helps structure a unified, coherent visitor experience.

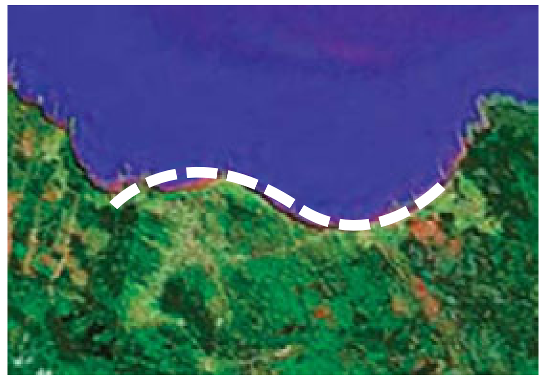
The master concept encapsulates and gives form to the issues that are at the heart of a project, in terms of themes, messages and core institutional values. It serves as a source of inspiration for all levels of an interpretive project, from site-wide interventions to the smallest level of exhibit details, helping forge an integrated and seamless visitor experience by evoking an overarching direction and spirit that permeate the whole of a project.

2. The Power of the Cliffs

For the **Joggins Fossil Cliffs Centre**, the proposed master concept is the **Power of the Cliffs**.

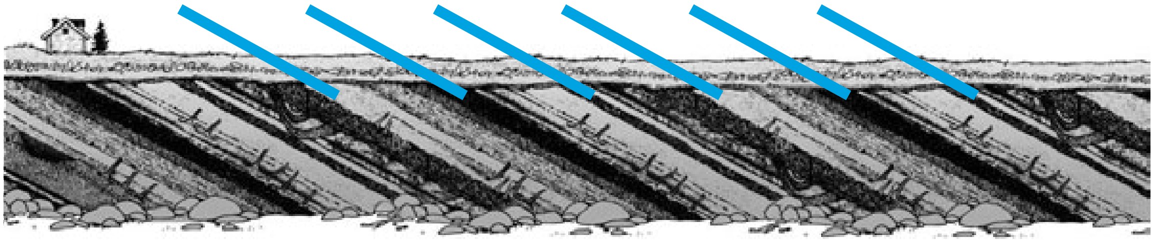
The concept is inspired by the essence of the visitor experience at Joggins: the human encounter with the cliffs, set against the dramatic backdrop of the Bay of Fundy. This encounter begins with the sheer natural beauty of the place, and continues through an ongoing process of questioning, exploration, discovery and understanding – a personal and collective journey that began with the first human habitants of the site and that continues today, as the cliffs reveal their secrets and the knowledge of times long past.

- **Joggins**: the site, building and interpretive components must all reflect the particular cultural, historical, geological and natural dimensions of the Joggins site. The universal significance of the site must be expressed through the specific character of Joggins.
- **Fossil**: the scientific and human importance of the record of Coal Age life and Carboniferous ecosystems that are found at the Joggins site is the key driver for the Fossil Cliffs Centre project, and must be reflected in the design of the Centre and the site.
- **Cliffs**: the design process must be inspired by the natural beauty of the site, including Joggins' position within the Bay of Fundy ecosystem as well as the powerful forces of nature that created the cliffs and that continue to shape them today.

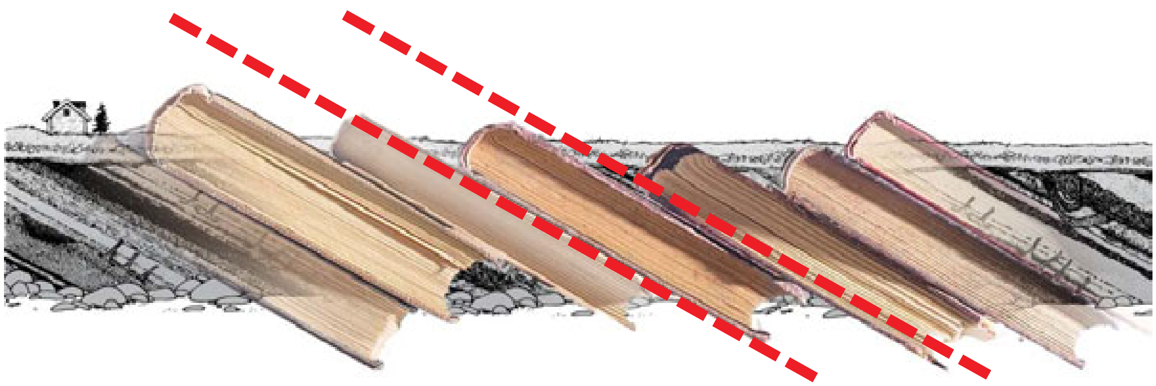


The concept of the **Power of the Cliffs** is a tribute to the **power of nature**. The organic, ever-changing form of the cliffs is a dynamic testament to the natural forces that have been at work for millions of years. These forces include the cycles of wind and tide that continue to shape the cliffs today, constantly revealing the traces of millions of years of life, with ancient riverbeds and primeval forests.

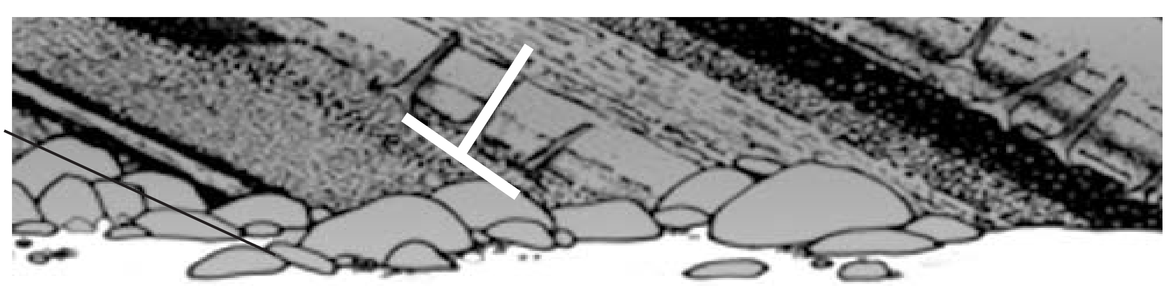
The concept also reflects the **power of life**: the fact that for all of these unimaginable spans of time, life has flourished at Joggins, both on the cliffs and in the waters. Some of the forms of life that we find today are virtually unchanged from the record preserved in the strata at Joggins, while others are new and different, forged through time by the vital and resilient power of life.



The **Power of the Cliffs** further reflects the **power of time**. A walk along the strata of the cliffs takes us on a journey that literally traverses millions of years of geological and natural history, reminding us of the fragile and mysterious place that we humans occupy when considered against the vast sweep of time. It likewise evokes a sense of wonder, as we consider that we are briefly given the chance to contemplate and strive to understand our place on the earth and in the universe.

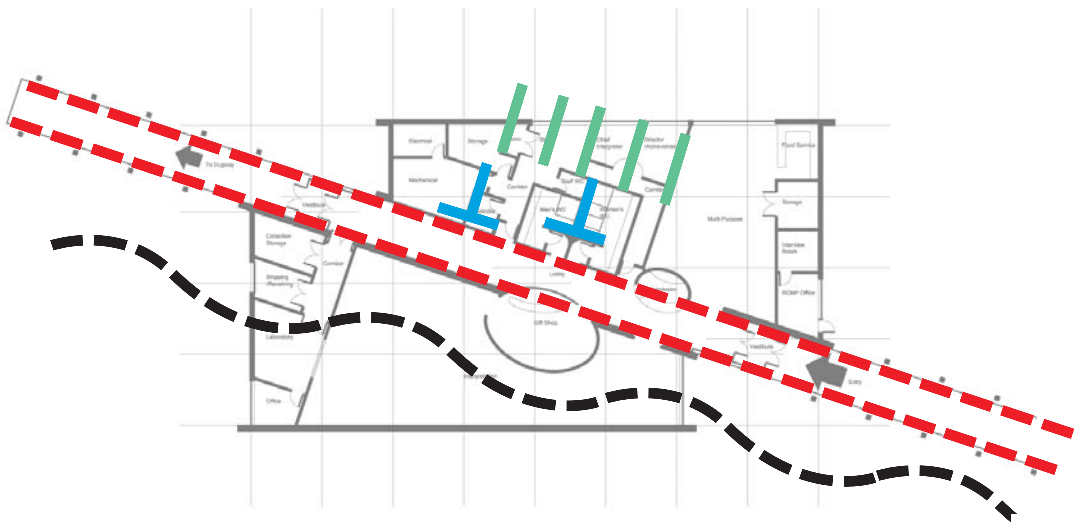


The **Power of the Cliffs** is also a reference to the **power of knowledge**, and to the important role that the Joggins Fossil Cliffs have played in furthering our understanding of the history of life on earth. From the debates over evolution to the knowledge of the first forms of terrestrial life, the cliffs have played a vital part in furthering the human comprehension of times long past.



3. The Master Concept

Through the development of the **Master Concept**, the themes of nature and life, time and knowledge have inspired the development of a formal vocabulary that can now serve as a basis for integrating the design of the site, building, interpretive components and graphic elements, composing with the tensions and harmonies between organic curves and rectilinear forms.



Through these, the concept of the **Power of the Cliffs** reflects the human experience of the site in its many dimensions. Through personal and shared experience, through scientific analysis and natural beauty, through the force of nature and across spans of time that defy the imagination, the **Power of the Cliffs** is a reflection of what draws us to Joggins.

Finally, it is important to remember that a master concept is an inspiration, not a limit. It is not expressed literally, through reproduction, but rather metaphorically, through layers of analogy and symbol. The **Power of the Cliffs** may inform architectural gestures, just as it will anchor exhibits in terms of both formal structure and symbolic meaning. But throughout, what is most important in a master concept is not only its visual form, but the role it plays in structuring and unifying the whole of the visitor experience.

CONCLUSION

The completion of a Visioning Study brings a number of benefits, some applicable in the short term and others that will become more important as the project advances further. From the identification of key challenges that will inform subsequent design decisions to the development of a compelling Master Concept that serves as a source of inspiration for everyone involved in the project, a Visioning Study initiates the process of giving a coherent form to the whole of a project.

The process also provides the important benefit of creating consensus among key stakeholders and representatives of the different teams involved in the process. People's participation in the process contributes to a shared understanding of the stakes and issues, which helps to ensure that people will work together as the project continues to advance. Everyone's questions, comments and concerns have been taken into consideration in the formulation of this Visioning Study.

The Study, like the Master Concept, serves as a basis for inspiration, a creative spark that helps bring the project to life. Throughout the upcoming development of the Joggins Fossil Cliffs Centre, the Spiral of Life will help to structure the whole of the visitor experience, from marketing and branding to experience planning and site development. It does not define a strict formal structure, but rather helps to reveal key elements, issues, questions and concerns, and to provide a common understanding of the project centered on a clear image and a strong, coherent form.

Code: **1.0**	Location: Exterior – Interpretation centre	

Central theme:

Approach and Main Entrance

Subthemes:	Objectives:
N/A	• *Welcome and orient the visitor to the Centre* • *Establish identity* • *Communicate global significance of Joggins site*

Key message:

Joggins is a site of global significance that visitors can experience first-hand.

General media description:

The sign and gate at the head of the access road leading to the Centre will provide visitors with initial orientation and a welcome message.

From the parking area, visitors will see the primary identity signage on the low wall that runs along the pathway leading to the main entrance.

Before arriving at the entrance, weather-resistant graphic and interpretive signage (see 13—Site Interventions) will introduce the site, present the Statement of Universal Value and communicate key stewardship messages. A map of the site will help visitors orient themselves. Flags of Nova Scotia and Canada will welcome visitors; provision will be made for the possible inclusion of a UNESCO flag if the nomination proves successful.

Outside the main entrance, applied to the exterior fenestration of the exhibit gallery, visitors will see historical images and memorable quotes of famous scientists whose work is related to the Joggins site (see also datasheet 4.2 – People and Quotes).

Signage on the entrance doors will provide operational information (opening hours, admissions fees, etc.) for the Centre.

Code: **2.0**	Location: Entrance – Interior – Interpretation centre	

Central theme:

Lobby / Reception Hall

Subthemes:	Objectives:
N/A	• *Communicate a sense of quality and authenticity* • *Ensure access to key visitor services (washrooms, telephone, gift shop, food services) in non-paying area of Centre* • *Orient visitors to the various points of interest in the Centre, on the site, and in the Joggins area* • *Ensure that visitors understand key issues of stewardship, including the collecting policy* • *Present tourist information on the whole Bay of Fundy area, with a focus on Route 209.*

Key message:

The interpretive centre provides a richer understanding of the site, which will enhance the experience of a visit to Joggins, the Fossil Cliffs, and the Bay of Fundy area.

General media description:

A visit to the Centre will typically begin at the reception / admissions desk. In addition to providing admission to the exhibit area, this area will provide visitor information including safety, tides, stewardship and the fossil collecting policy. A community bulletin board, located near the main entrance, will provide a space for posting information of interest to local community members and to the general public.

Throughout public spaces in the Centre, the choice of materials and the overall design approach will contribute to theming the public spaces, including the gift shop, food service area, washrooms and the exterior deck leading to the Dugway access. Quotes and images of scientists associated with Joggins (see 4.2 – People and Quotes) will be used as a leitmotif. In these public areas, the emphasis will be on creating an atmosphere rather than on presenting specific, detailed content.

A site map or model, located between the gift shop and food service areas, will give visitors a better understanding of the site as a whole. A staffed regional tourist information area will provide information on additional attractions and services available in Joggins and in the Bay of Fundy area. Finally, graphic and text panels link the green design of the building to the larger issues of climate change, and to the coal for which Joggins is famous.

Code: **3.0**	Location: Interior – Interpretation centre	

Central theme:

Exhibit Hall

Subthemes:	Objectives:
4.0 Introduction to Joggins 5.0 The Place in Recent Times 6.0 The Power of the Bay of Fundy 7.0 The Changing Earth 8.0 Big Ideas 9.0 Stewardship 10.0 Coal Age Ecosystem at Joggins	• *Create a powerful first impression* • *Reinforce the Master Concept—give people a sense of the Power of the Cliffs*

Key message:

Studying the past helps us to better understand how both life and the Earth itself have evolved and changed to form the world in which we live today. This knowledge helps us to both understand the present and imagine the future.

The unique cliffs of Joggins played a key role in this process in the past and continue to do so today. Understanding the many dimensions of the Joggins Fossil Cliffs, as a geological site, a home for many different peoples, a part of a natural ecosystem and a focal point for scientific activity, helps people to better appreciate the Power of the Cliffs.

General media description:

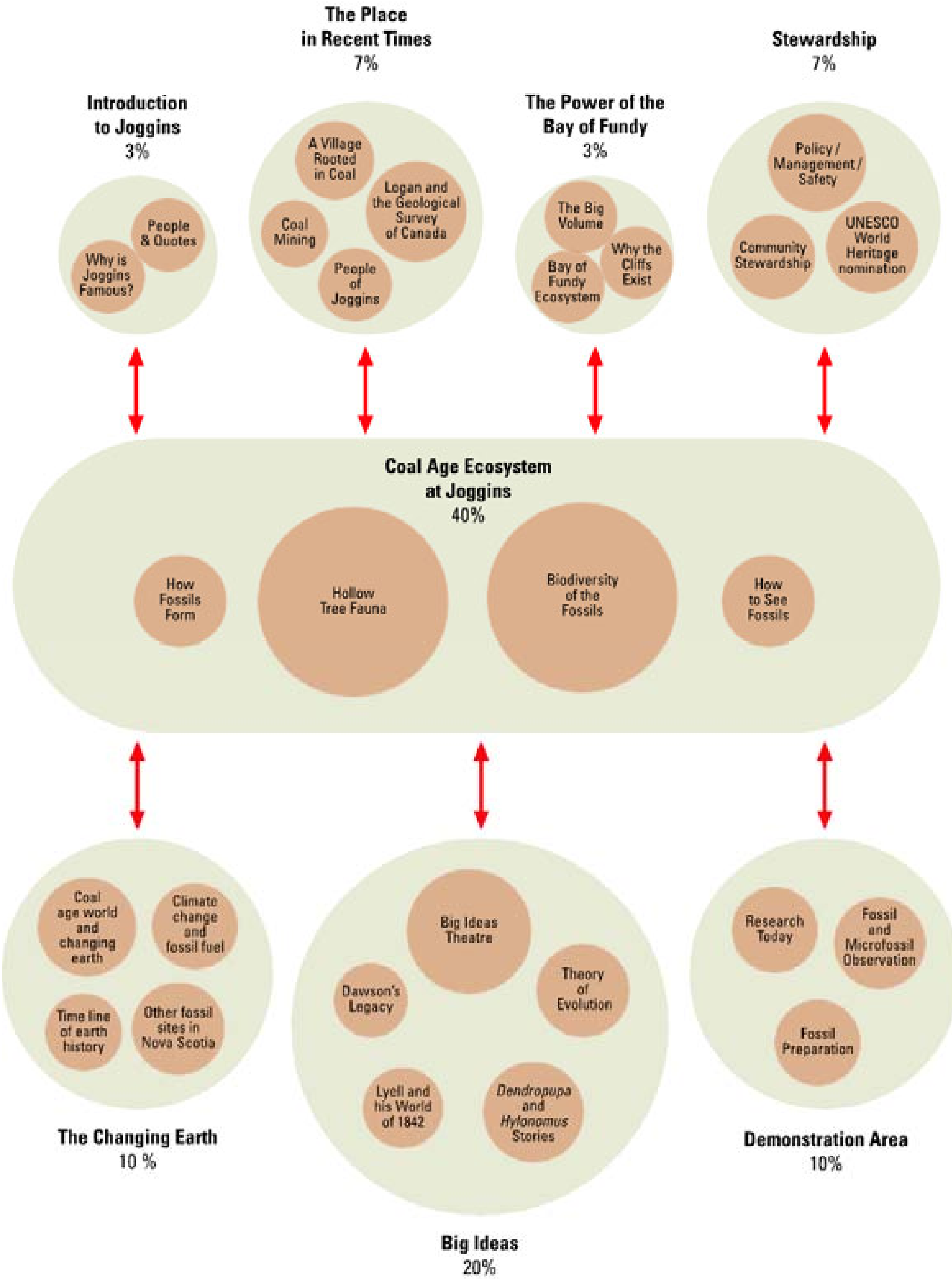
Upon entering the exhibit hall, visitors will first see a large, visually striking representation of the cliffs. This will create a powerful initial impression that will reinforce the Master Concept – the Power of the Cliffs.

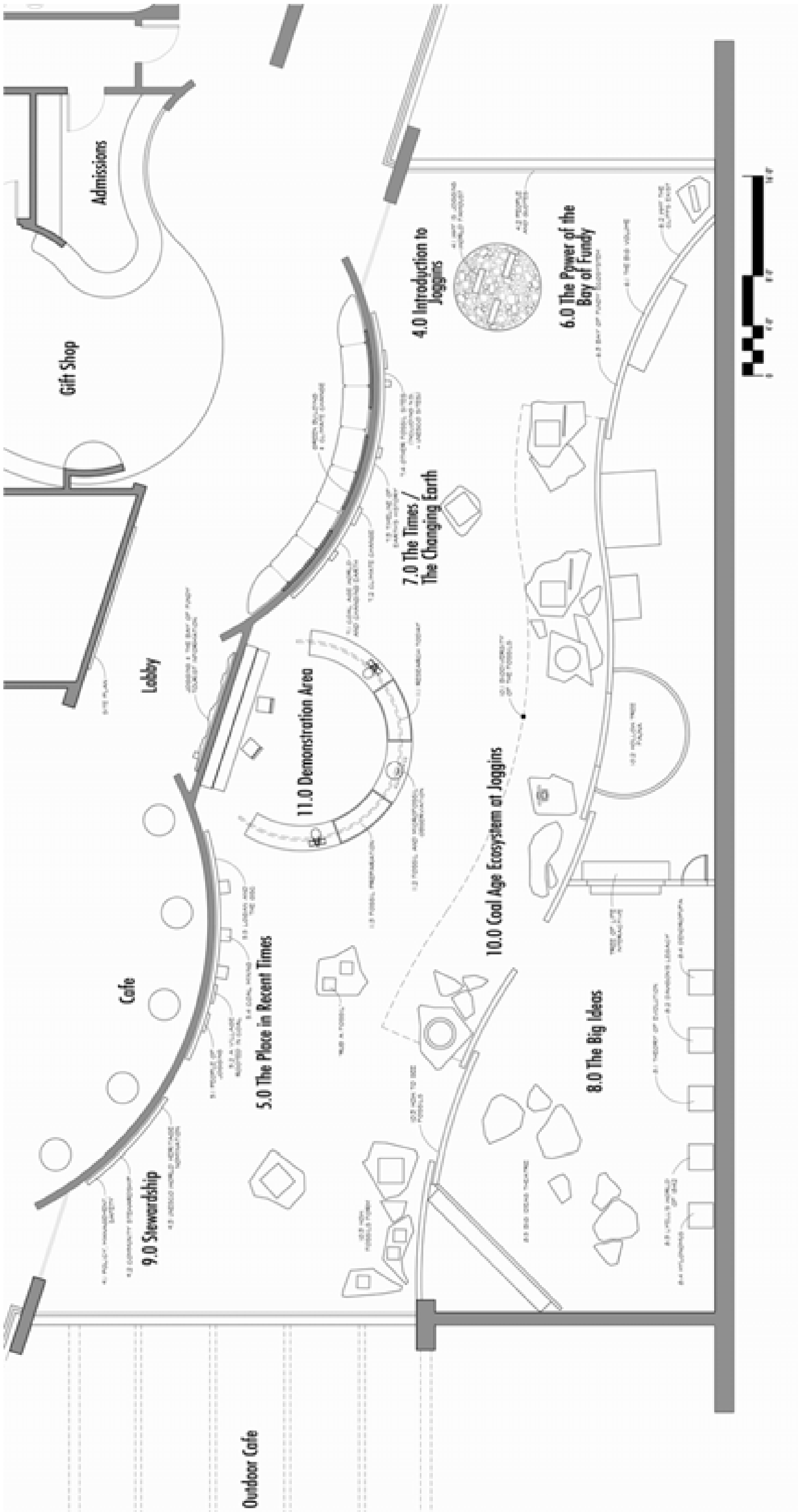
The “cliff” in the exhibit hall will not be a realistic reproduction of the actual rock formations of Joggins. Instead, it will be an interpretation, a collage of many different media and various representations of the cliffs, including photography, painting, drawings and engravings, inspired by different historical periods.

Within the hall, the detailed interpretation program will unfold through a series of evocative, engaging and entertaining thematic settings and media. The exhibit hall will help visitors to better appreciate the significance of the site and the power of the natural forces that have shaped it through time.

A diverse range of media will be used to effectively communicate the messages. Media will be selected so as to engage a diverse range of learning styles and appeal to a wide range of interests.

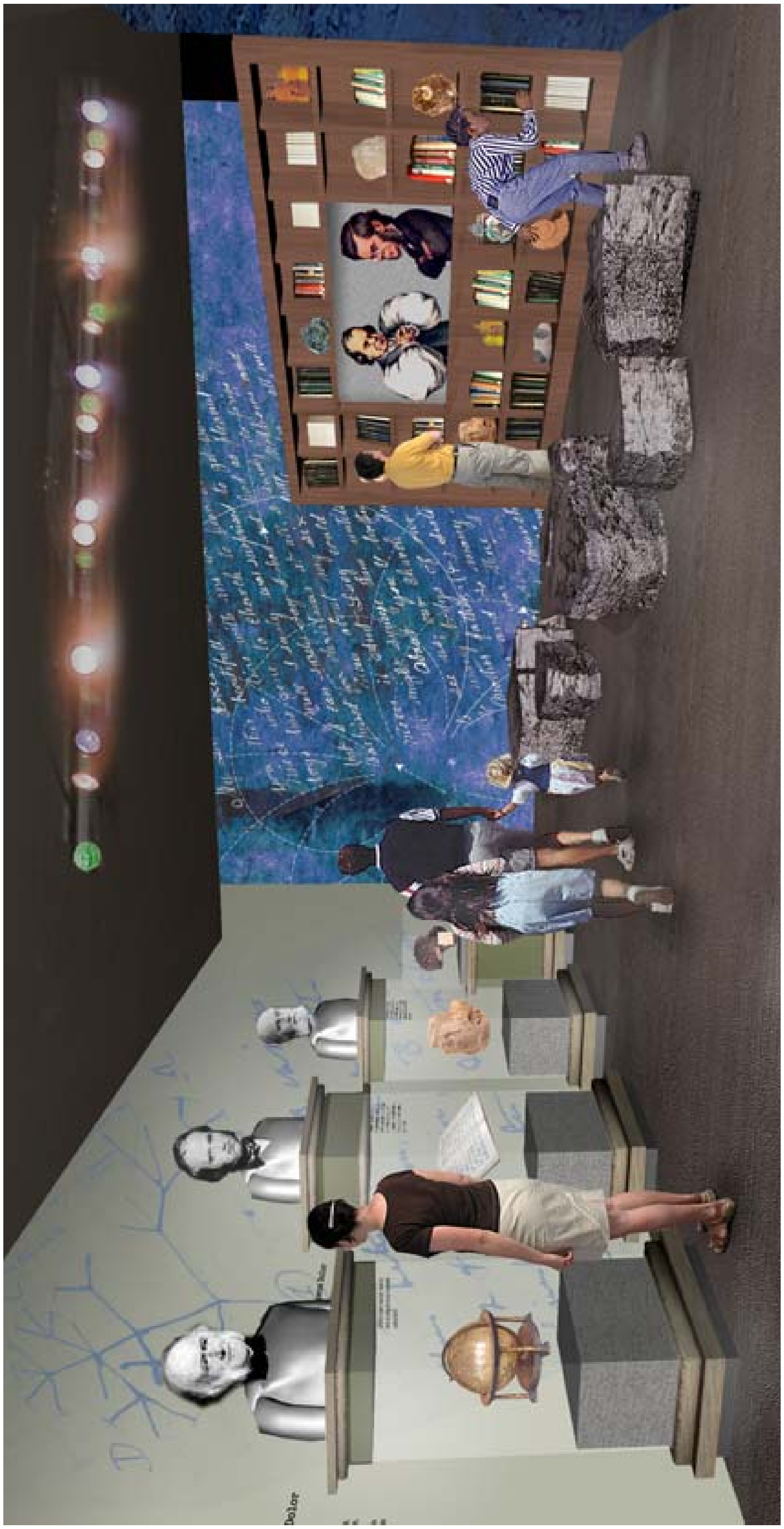
Thematic organizational diagram



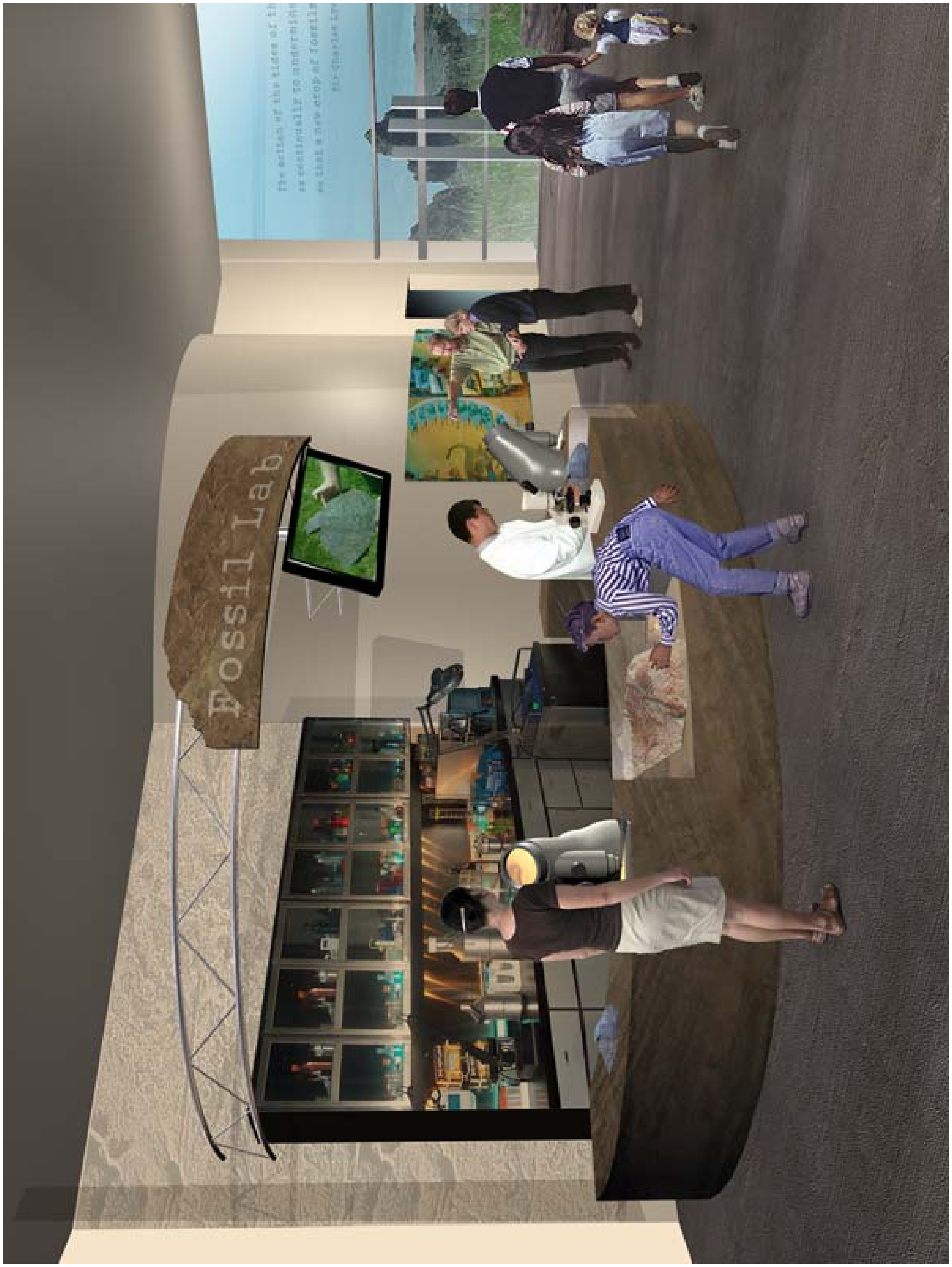


Plan of exhibit hall

Rendering of exhibit hall



Rendering of Big Ideas theatre



Rendering of demonstration area

Code:	Location:	Value:
4.0	Exterior, lobby + exhibit hall	3%

Central theme:

Introduction to Joggins

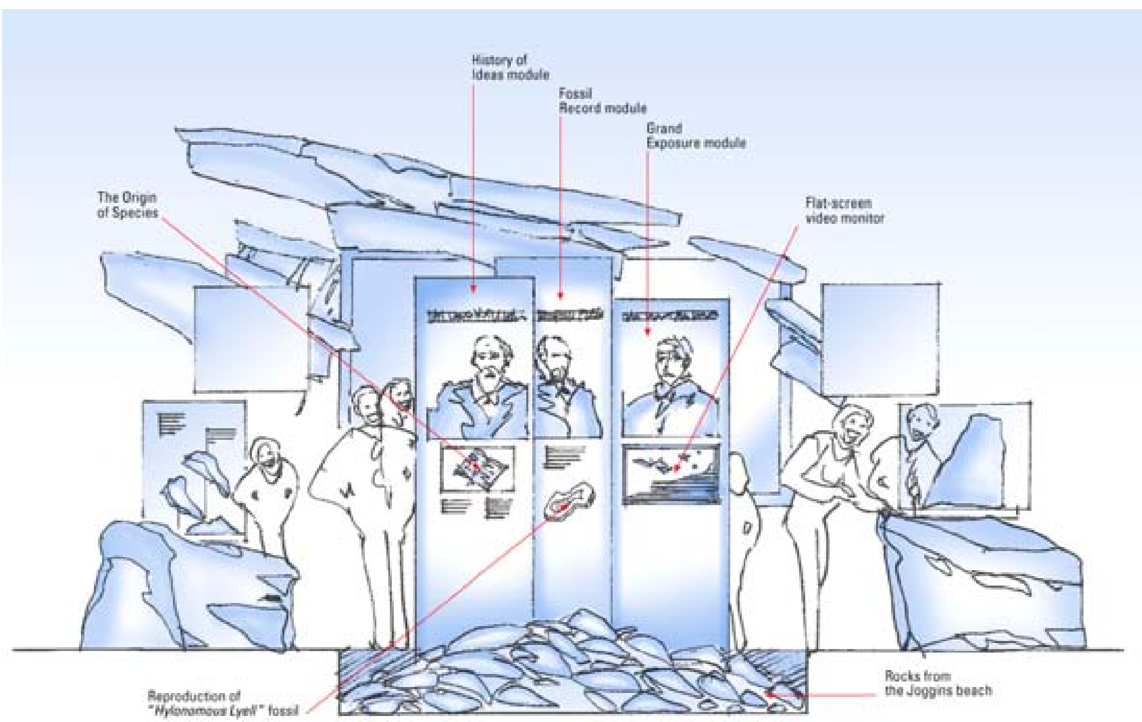
Subthemes:	Objectives:
4.1. Why is Joggins World Famous? 4.2. People and Quotes	• *Trigger curiosity* • *Establish authority and authenticity* • *Introduce global significance of site*

Key message:

At the fossil cliffs of Joggins, the power of the Fundy tides exposes evidence of life in the Coal Age so amazing that it has changed our understanding of the history of life on Earth.

General media description:

- Against the backdrop of the cliffs, three interpretive modules introduce the three key factors responsible for Joggins' fame



Code: 4.1	Central theme: *Introduction to Joggins*	

Subtheme:

Why is Joggins World Famous?

Objectives:

- *Introduce the three key factors in Joggins' fame*
- *Ensure that important ideas are presented in an accessible way*

Key message:

Three main factors have contributed to Joggins' global fame.

Storyline – Content:

Joggins owes its lasting fame amongst scientists and public to three things:

1.Its grand exposure on the shores of the Bay of Fundy, where its fossil record is continuously hewn and replenished by the action of the world's highest tides. The site is robust (even wild) and there is an ever present chance of discovery for the visitor (Learn more in "The Power of the Bay of Fundy")

2. The fossil record found at Joggins allows us to reconstruct the 'Coal Age' world here better than anywhere else on Earth. At Joggins one finds rare fossils that show a wide diversity of life forms, including unique terrestrial life, and because many of the fossils are preserved 'in situ', in the place where they lived, they provide us with evocative details of their life and environment that are found nowhere else. As an example, Joggins not only preserves the oldest known reptile fossils, but reveals to us that they lived in hollow trees scarred by wildfire. (Learn more in "Coal Age Ecosystem at Joggins" and "The Changing Earth")

3. The role that it played in the developing ideas of some of the greatest scientific thinkers of the 19th century, including Lyell and Darwin, coupled with their written commendation of Joggins as the most outstanding 'Coal Age' exposure in the world. (Learn more in "Big Ideas")

Resources:

- Images of the Bay of Fundy, fossil cliffs, fossils, and famous scientists.
- Original drawings and sketches, or reproductions
- Books by Lyell, Dawson, Darwin and contemporaries
- Fossils collected by Lyell and Dawson, or reproductions

Media approach:

To present this introductory information, three interpretation modules will be created, against the backdrop of the cliff and the "Power of the Bay of Fundy" content. The modules will be standalone elements incorporating text, graphics, fossil specimens,

Code: 4.1	Central theme: *Introduction to Joggins*	

Subtheme:

Why is Joggins World Famous?

props and A/V equipment. The floor treatment around the base of each of the three modules will evoke the Joggins beach.

Each of the three modules will present one of the key ideas listed above, together with a quote by a famous scientist associated with Joggins. A showcase for each module will present an iconic object that supports the idea.

For example, the “Grand Exposure” module will feature a quote such as:
“The finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia,” from Sir Charles Lyell’s *Students Elements of Geology*, 1871. A small flat-screen monitor, integrated into a showcase, will present an aerial view of the grand exposure.

The “Fossil Record” and “History of Ideas” modules will follow the same principle, the former supported by an iconic Joggins fossil and the latter by a significant publication (like Darwin’s “Origin of Species”) opened to a page that references Joggins.

Code: 4.2	Central theme: *Introduction to Joggins*	

Subtheme:

People and quotes

Objectives:

- *Link Joggins to the global scientific community*
- *Show the role of Joggins in the evolution of scientific thought*

Key message:

Joggins has been a site of global scientific significance since the 19th century.

Storyline – Content:

The words of Sir Charles Lyell

"But the finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia."
Students Elements of Geology, 1871

"I was particularly desirous, before I left England, of examining the numerous fossil trees alluded to by Dr. Gesner as imbedded in an upright posture at many levels in the cliffs of the South Joggins, near Minudie.

The first allusion to the trees which I have met with, is that published in 1829 by Mr. Richard Brown, in Halyburton's Nova Scotia, and he attributed their fossilization to the inundation of the ground on which the forests stood. I felt convinced that, if I could verify the accounts of which I had read, of the superposition of so many different tiers of trees, each representing forests which grew in succession on the same area, one above the other; and if I could prove at the same time their connexion with seams of coal, it would go farther than any facts yet recorded to confirm the theory that coal in general is derived from vegetables produced on the spots where the carbonaceous matter is now stored up in the earth."
Travels in America (1845) pp. 177-8

"...the action of the tides of the Bay of Fundy being so destructive as continually to undermine and sweep away the whole face of the cliffs, so that a new crop of fossils is laid open to view every three or four years."
Travels in America (1845) p. 187

"I never travelled in any country where my scientific pursuits seemed to be better understood, or were more zealously forwarded, than in Nova Scotia..."
Travels in America (1845), pp. 229-230.

"Dr. Gesner, however, has not abandoned the opinion at which he had previously arrived on this point, having recently, in a letter to the President of the Geological Society, and read May, 1845, declared his belief that the true order of super position is

Code: 4.2	Central theme: *Introduction to Joggins*	

Subtheme:
People and quotes

not as I have represented it, and that other geologists have been misled by me."
Travels in America (1845) pp. 207-8

The Words of Sir Charles Darwin

'In other cases we have the plainest evidence in great fossilized trees, still standing upright as they grew, of many long intervals of time and changes of level during the process of deposition, which would never have been suspected, had not the trees chanced to be preserved: thus, Messrs. Lyell and Dawson found carboniferous beds 1400 feet thick in Nova Scotia, with ancient root-bearing strata, one above the other, at no less than sixty-eight different levels. Hence, when the same species occur at the bottom, middle, and top of a formation, the probability is that they lived on the same spot during the whole period of deposition, but have disappeared and reappeared, perhaps many times, during the same geological period. So that if such species were to undergo a considerable amount of modification during any one geological period, a section would not probably include all the fine intermediary gradations which must on my theory have existed between them, but abrupt, though perhaps very slight, changes of form.'
The Origin of Species by Means of Natural Selection, or Preservation of Favoured Races in the Struggle for Life. Ch. IX, *Imperfection of the Geological Record*, (1859) p. 296.

The words of Sir William Dawson
On his first visit to Joggins ~

"We [with Hon. Daniel MacFarlane] travelled for the most part by night, or in the evening and early morning, to avoid the heat of the day. From Amherst, I set off early for the ferry at the estuary of the Herbert River, crossing the pleasant Amherst marsh-lands, through clover-scented fields. On arriving at the ferry, the tide being low, I had an hour or two to wait. (The great tides of the Bay of Fundy extend into all its branches and estuaries, and restrict navigation to the time of high water.) I reached Minudie, a village some miles from the Joggins shore, only to find that there was no conveyance or practicable road, except for walking. So, armed with my hammer and a basket for specimens, I set out for the shore by a mere track through the woods. After a warm walk, I came out on the coast at the grindstone quarries of Lower Cove, where as it was now evening, I was glad to find supper and a bed in the rough building occupied by the quarrymen ...

"The tide being low in the afternoon, I rose early next morning, and taking some luncheon in my basket, walked along the shore to the south-westward for several miles. I was amazed at the grand succession of stratified beds exposed as plainly as in a pictured section, and was interested beyond measure in the beds of coal, with all their accompaniments, exposed in the cliffs and along the beach, the erect trees (*Sigillaria*) represented by sandstone casts, and the numerous fossil plants displayed in the beds. The tide favoured my expedition, and the day was fine, though small banks of fog drifted

Code: 4.2	Central theme: *Introduction to Joggins*	

Subtheme:
People and quotes

up the bay from time to time, dissolving as they touched the cliffs, warmed by the sun. I returned in the evening to the quarrymen's shanty, thoroughly fatigued, but loaded with fossils, delighted with the knowledge I had acquired, and with my enthusiasm for geology raised to a higher point than ever before. Such was my first visit to the celebrated coast-section of the Joggins, on which I have spent so many pleasant and profitable days."
from '*Fifty Years of Work in Canada*'

On the discovery, with Lyell, of the earliest 'reptiles' at Joggins ~
"I well remember how, after we had disinterred the bones of *Dendrerpeton* from the interior of a large tree on the Joggins shore, his thoughts ran rapidly over all the strange circumstances of the burial of the animal, its geological age, and its possible relations to reptiles and other animals, and he enlarged enthusiastically on these points, till, suddenly observing the astonishment of a man who accompanied us, he abruptly turned to me and whispered, 'The man will think us mad if I run on in this way.'
from '*Fifty Years of Work in Canada*'

On the ancient environment of Joggins and the Coal Age ~
" ... these beds carry our thoughts back to a period when the district was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades, or the Delta of the Mississippi." *Acadian Geology*, p.182, 1855

On field studies of palaeoecology ~
[better to study] '... plants as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum.' ~ from a letter to Lyell, 13 August, 1868

The words of Abraham Gesner
'The place where the delicate foliage of a strange, extinct vegetation lies transmuted into stone.' [Check] 1836

The words of Donald Baird
'My opinion would be to strike "Eosaurus acadianus" from the list. In my opinion the type specimen is a couple of ichthyosaur centra from Lyme Regis, England, that were palmed off on young Professor Marsh of Yale by one of his shipmates. I suspect that O.C. had made himself rather insufferable on the trip and thus set himself up for the hoax. Or am I just judging others by myself? The temptation must have been strong! And how he fell for it!' ~ Baird, in a letter to Calder, 25 July, 1994

The words of Bishop Wilberforce ('On Darwin's 'Origin of Species')
"The rare land shell found by Sir C. Lyell and Dr. Dawson in North America affords a conclusive proof that in the carboniferous period such animals were most rare, and only the earliest of that sort created. For the carboniferous strata of North America,

Code: 4.2	Central theme: *Introduction to Joggins*	

Subtheme:

People and quotes

stretching over tracts as large as the British Isles, and containing innumerable plants and other terrestrial things, must have been equally depressed and elevated, since the very flowers and fruits of the period have been preserved; and if terrestrial animals abounded, why do we not see more of their remain than this miserable little *Dendropupa* about a quarter of an inch long?"

Samuel Wilberforce, 1860. On 'The Origin of Species'. Quarterly Review, 225-264. [page 244]

Resources:

Works from the scientific literature, including those featured in the above list.

Media approach:

Appropriate excerpts from selected quotes will be used in several different areas of the Centre, including the lobby, exterior and themed public spaces.

Code: 5.0	Location: Exhibit hall	Value: 7%

Central theme:

The Place in Recent Times

Subthemes	Objectives:
5.1. People of Joggins 5.2. A Village Rooted in Coal 5.3. Coal Mining at Joggins 5.4. Logan and the GSC	• *Link cultural history with natural history* • *Show the roots of the village of Joggins* • *Explain importance of coal in the history of Joggins*

Key message:

Known to the First Nations as *Chegoggin*, "The Joggins" and its coal deposits first attracted European explorers and settlers more than four hundred years ago.

General media description:

In this area, photocollages, showcases, postcards, graphics (including historical photos and artworks) and text are used to tell the story of Joggins, its peoples and the essential role played by coal.

A section is dedicated to explaining coal and coal mining. Maps and photos from the Joggins mines recount the story of mining. Finally, a showcase (supported by text and graphics) presents a small setting that shows Logan's work for the GSC and links his story to the story of a village rooted in coal.

Code: 5.1	Central theme: *The Place in Recent Times*	

Subtheme:

People of Joggins

Objectives:

- *Explain the human history of Joggins*

Key message:

People have been coming to Joggins for a very long time.

Storyline – Content:

Long ago, the Mi'kmaq people of Atlantic Canada named this place Chegoggin ~ 'the Place of Weirs', a testament to the biological richness of the Bay of Fundy, invaded annually by vast numbers of migrating shad and alewives.

Like many other First Nation place names, it became misconstrued as The Joggins, and later, in the time of the earliest geological visitors, to The South Joggins (The North Joggins being across Chignecto Bay at Cape Maringouin, New Brunswick, the split names likely coming from the quarrymen working both shores for grindstones).

Descendants of the early French at Acadia ~ the Hebert, Legere, Melanson and other families ~ continue to reside in the Joggins area in spite of expulsion and political turmoil in the eighteenth century....

New Englanders were also here in the 1700s, gathering coal.

The mines provided work in the mines, on the dock, on ships, on the railway, and for suppliers of pit timber, merchants, and farmers.

Resources:

Petroglyph: hunters in a canoe, with a musket shooting a porpoise	Nova Scotia Museum http://museum.gov.ns.ca/images/petroglyphs/21466_W.jpg
Portrait of a young Mi'kmaq by Dawson	Woodblock etching in *Acadian Geology*
1735 map "of a Peninsula Situate in ye Bay of Fundy…"	Map 5.2 in *Mapmaker's Eye* by Joan Dawson. Nimbus and the Nova Scotia Museum, 1988. Crown Copyright photo. UK Public Records Office, Kew Maps, MPG 972.
Haying on the Tantramar	*Picturesque Canada*
"View in the Bay of Fundy", a watercolour sketch by John Elliott Woolford, 1817	Nova Scotia Museum History Collection. 78.45.107. Digital file: 31141.tif TIFF Format, colour. 300 dpi. 15.50 Mb Landscape (13.6 x 09.1 in)

Code: 5.1	Central theme: *The Place in Recent Times*	

Subtheme:
People of Joggins

Rockport and its grindstones:	From a sketch by K. Blatch in *Canadian Illustrated News*, Feb. 10, 1872. Library and Archives Canada. Record 2471. http://www.collectionscanada.ca
McCarron's River Bridge, Joggin Mines, Jan 1907: showing bridge and carriages crossing, logging	Postcard, colour photomechanical reproduction NSM History Collection. 89.81.46. http://museum.gov.ns.ca/images/html/41017.html Tiff format, 300dpi 14.00Mb 12.5 x 08.0 inches
Citizens' band	Photo in personal collection of Dara Legere, Joggins as posted on website www.greencrow.ca
Photos	Cumberland County Museum collection

Media approach:

Chronologically structured photocollage, including early drawings and sketches as well as postcards, newspaper clippings, paintings and period photographs.

Code: 5.2	Central theme: *The Place in Recent Times*	

Subtheme:

A Village Rooted in Coal

Objectives:

- *Show the importance of coal for the village of Joggins*

Key message:

The history of the modern community of Joggins is intimately linked with the history of the coal mining industry.

Storyline – Content:

The population of Joggins has ebbed and flowed much like the tides of the bay. By the 1940s, the population of the community reached 5000, swelled by the influx of miners and their families. Today the village of Joggins numbers less than 500.

In 1876, the Intercolonial Railway permitted the Springhill-Maccan area to take advantage of a huge market for coal.

On Dec 31, 1928, the Joggins streetscape changed dramatically when fire destroyed the school, the theatre, two hotels, and many shops. The town never completely recovered.

Resources:

Colour Postcards of Main Street and B&W photos of churches, schools, movie theatres etc.	Personal collection of Dara Legere, Joggins (902-667-9754) as posted on website www.Greencrow.ca Dara is happy to make this collection available for reproduction and use to the JFC project.
The parade down Main Street, Joggins, July 1, 1920.	In Roger David Brown, *Historic Cumberland County South*, p. 19. Nimbus, 2002. Collection of John Reid, Joggins.
Lower Main Street, Joggins Mines.	Colour postcard in Postcard Album 93 # 77, p. 115. NS Archives and Records Management, Halifax. Same image in Legere collection
Photos etc.	Cumberland County Museum

Media approach:

Photocollage based on postcards (fronts and backs) recounting the ebb and flow of Joggins in the late 19th and early 20th centuries. A small video monitor presents a slide show of photos and postcards from the period.

Code: 5.3	Central theme: *The Place in Recent Times*	

Subtheme:

Coal Mining at Joggins

Objectives:

- *Explain the formation and nature of coal*
- *Link coal and the Coal Age that made Joggins famous*
- *Recount the history of coal mining at Joggins*

Key message:

Coal deposits put Joggins on the map long before the site's value as a geological and paleontological site was discovered.

Storyline – Content:

Coal is fossilized plant material. It consists mainly of carbon, derived from the Carboniferous atmosphere by the leaves of plants. After millions of years of being buried without oxygen, the decayed plants form peat. Heat from the earth causes chemical changes that produce coal. The higher the earth temperatures, the greater the amount of carbon that is fossilized and the greater the amount of energy that is released when the coal is burned using oxygen. (*Encyclopaedia Britannica*)

The village of Joggins grew out of the coal produced from the decayed plants of the Coal Age swamps. Mining began with the earliest European settlement in the region. Long before any written reference to its geology in the English language, coal was mined from the cliffs of Joggins by the French.

Archaeological investigations at Port Royal, some hundred kilometres farther down the Bay of Fundy, suggest that the first forges of the New World in North America were fuelled by the coal beds of Joggins in the earliest years of the 1600s.

Over a century later, the fires of the French garrison at Fort Beauséjour at the head of the Bay were stoked by coal worked from the Joggins cliffs. New England entrepreneurs were also mining Joggins coal and selling it in Massachusetts during the 1700s.

From 1847 until 1980, 83 official mines followed the coal beds. The entire coal field stretches inland from the cliffs of Joggins for about 30 km. Records of coal production, kept since 1848, document the extraction of 6 million tonnes, hard wrought from the narrow seams known as the Fundy, the Forty Brine, the Kimberly, the Joggins, and the Hard Scrabble.

About one hundred lives were lost, mostly in three major disasters in 1930, 1931, and 1932. The last underground colliery in the Joggins-Chignecto coalfield closed in 1980 at River Hebert.

Code: 5.3	Central theme: *The Place in Recent Times*	

Subtheme:

Coal Mining at Joggins

Resources:

Calder, Gillis, MacNeil, Naylor and Campbell. One of the Greatest Treasures: The Geology and History of Coal in Nova Scotia. NS Dept of Natural Resources. Info Circular No. 25. 1993.

The old Joggins wharf in the 1950s	In Roger David Brown, *Historic Cumberland County South*,. Nimbus, 2002. Same image in Legere collection
Photos of coal-loading wharf, showing changes over time, and at low and high tide	Personal collection of Dara Legere, Joggins 902 667-9754 as posted on website www.Greencrow.ca
Joggins 1894, tug and vessels by wharf	In Roger David Brown, *Historic Cumberland County South*.
Loading coal below Joggins Mine No. 7	In Roger David Brown, *Historic Cumberland County South*.
The Terminal, Joggins. Roundhouse + locomotives, around 1945.	In Roger David Brown, *Historic Cumberland County South*, Collection: Bud Johnston, Heritage Models River Hebert.
Miners going to the pit, 1930	Personal collection of Dara Legere
Mine manager's house	Personal collection of Dara Legere
Letterhead (and letter text) for Phoenix Coal Company Limited, 1888	RG28, Vol. 16a. Joggins NS Archives and Records Management, Halifax.
Letterhead (and letter text) for Joggins Railway, 1888.	RG28, Vol. 16a. Joggins NS Archives and Records Management, Halifax.
Joggins Railway PLAN of Railway and Coal Areas. 25 x 30 cms. Original drawn on a very fine fabric, coloured lines now faded.	RG28, Vol. 16a. Joggins NS Archives and Records Management, Halifax.
Chignecto Mine buildings. Photo	Calder. SBI
View on the Joggins Shore, c. 1830.	Calder. SBI
To be identified. Potential: pictures of miners who currently live in the village	River Hebert Mining Museum Cumberland County Museum and Archives

Code: 5.3	Central theme: *The Place in Recent Times*	

Subtheme:
Coal Mining at Joggins

Specimens:
- Potential for coal mining memorabilia from River Hebert Miners Museum, community donors
- Samples of coal
- Fossils found in the mines

If any miners are still in the community, there may be the potential to collect stories from them, with a particular focus on fossil occurrences in the mines.

Media approach:
- Showcase with samples of coal and coal mining equipment. Graphic panels and texts explain the process of the formation of coal.
- Map of the Joggins mines and other mines of the area.
- Small model of a section of a colliery, showing wagons and workers descending into the mine.
- Photocollage of the mines and miners of Joggins.

Code: 5.4	Central theme: *The Place in Recent Times*	

Subtheme:

Logan and the GSC

Objectives:

- *Show the importance of Logan's work*

Key message:

Logan's pioneering work for the GSC set the standard for all future studies of the cliffs at Joggins.

Storyline – Content:

Industry and economics drove the first field project of the new Geological Survey of Canada in 1843 when Sir William Logan undertook a monumental, layer-by-layer measurement of the completely exposed coal-bearing rock sequence of the Joggins cliffs in the hope of discovering deposits of coal close to Lower and Upper Canada. Coal was the vital fuel of the Industrial Revolution, in a world before oil.

Logan's detailed measurement of the sedimentary beds in the cliffs totalled 14,570 feet 11 inches, and carried him 15 kilometres from Minudie south to Ragged Reef. Incredibly, Logan undertook this feat, working around the high tides, in just five days. The artistic sketches in his notebooks seem all the more remarkable given the time frame under which he was working. His detailed log has stood as the reference description of the section for 150 years, having been updated only recently ~ and only in part ~ by an international team taking considerably longer than five days!

The Logan project was commemorated in 1992 by a monument and plaque situated in front of the Joggins Fossil Centre.

Resources:

A younger Sir William Logan seated with specimens	Library and Archives Canada C-007606 (copy neg #) http://www.collectionscanada.ca/logan
Portrait of Sir William Logan by Notman, 1869. No. 68772	Calder, SBI Geological Survey of Canada. Logan Collection http://www.collectionscanada.ca/logan
Sketch of the Joggins section, 1843	Calder SBI, Logan sketch 8
Sketch of tree in cliff	Calder SBI, Logan notebook 1
Sketch of "My Tent" in Logan's journal, July 18, 1843	National Library, Wales http://www.llgc.org.uk/drych/

Code: 5.4	Central theme: *The Place in Recent Times*	

Subtheme:
Logan and the GSC

Media approach:

Small setting in showcase, incorporating 3D paper figurine of Logan sketching the cliffs (based on historical photos). Text and graphics – including reproductions of Logan's sketches – tell the story of his surveying work and link to the theme of coal mining at Joggins.

Code:	Location:	Value:
6.0	Exhibit hall Site interpretation stations	7%

Central theme:

The Power of the Bay of Fundy

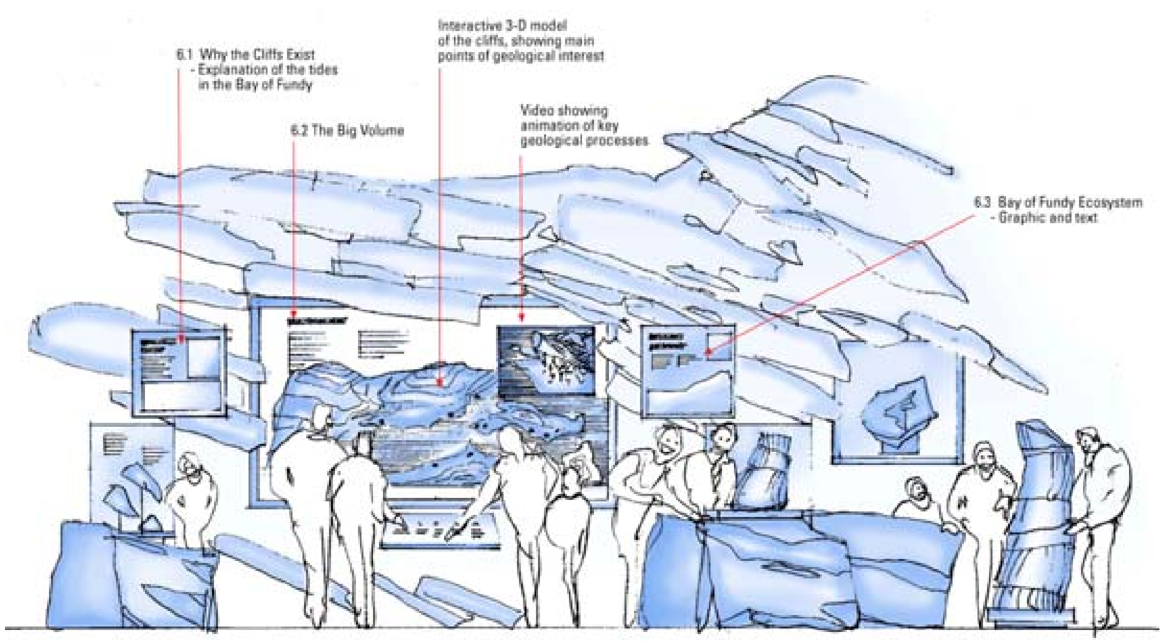
Subthemes	Objectives:
6.1. The Big Volume 6.2. Why the Cliffs Exist 6.3. Bay of Fundy Ecosystem	• *Understand the geological history of the Joggins cliffs* • *Understand the effects of the tides, and how they shape the cliffs* • *Appreciate the Bay of Fundy ecosystem*

Key message:

Today, the Joggins Fossil Cliffs are part of the Bay of Fundy ecosystem. Powerful natural forces, including the world's highest tides, have shaped both the Bay and the cliffs.

General media description:

This area introduces the Joggins cliffs and briefly explains how the cliffs came to be and their place in the Bay of Fundy ecosystem. A combination of graphic panels and audiovisual media helps to explain the complex convergence of geological processes and tidal flows that created and revealed the fossil cliffs at Joggins.



Code: 6.1	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

The Big Volume

Objectives:

- *Appreciate how geologists read the cliffs at Joggins to reconstruct the past*

Key message:

For geologists, the cliffs at Joggins are like books that tell the story of the Coal Age.

Storyline – Content:

Background: Although Joggins is being nominated to the World Heritage Committee as representative of the Pennsylvanian Period, the section designated extends well back into geologic time to include much of the earlier Carboniferous, or Mississippian Period as well.

A layer, or bed, of sediment that is laid down on top of another layer is slightly (and sometimes a lot) younger than the one below. Because the sequence of layers exposed in the cliff face have been tilted millions of years later, the layers of rock become older and older (deeper and deeper in the original layers of sediment) as we follow the cliffs north.

In the far north of the section that is being proposed as a World Heritage Site, at Downing Cove, the rocks are approximately 325 million years old, and become progressively younger, layer by layer, bed by bed, as we follow the cliffs south past Joggins to Ragged Reef. Here, the age of the rocks is approximately 310 million years, meaning that we have passed through approximately 15 million years of earth history.

During that walk, and in that interval of Earth history, is recorded a marked shift in the rock record, the most fundamental of the entire Carboniferous Period. This break, or shift, in the character of the rocks defines the boundary between the older Mississippian Period and the succeeding Pennsylvanian Period. The break is of global significance. This boundary is exposed across the Appalachian Basin in the eastern and southern United States. Scientists have attributed the so-called ‘Miss-Penn unconformity’ to a sudden drop in global sea level as the polar ice cap over southern Gondwana quickly developed. Other scientists favour an explanation that more directly involves continental drift and plate tectonics. As the African coast of Gondwana collided with North America, the buckling continental crust formed the Appalachian mountain chain of eastern North America. Rivers whose headwaters were sourced in the mountains flowed northeasterly

Code: 6.1	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

The Big Volume

across the lowlands of eastern Canada, including the Cumberland Basin and Joggins, towards Europe. The sandy deposits of these huge rivers form the thick, well-sorted sandstones exposed at Boss Point, which can be viewed from Little River as the buff coloured headland in the northern distance. Swept along in these rivers were huge trees eroded from the uplands and river banks, and now preserved in the sandstone beds of Boss Point as huge fossilized trunks (sometimes called petrified wood, although the term 'permineralized' is more correct). These woody trees are called Cordaites, and were early, seed-bearing conifers that contrast with the pithy, spore trees of the 'coal swamps'.

The 'Miss-Penn' boundary also records a marked change in climate. Mississippian age rocks record hot, arid conditions, whereas the rocks of the Pennsylvanian record a shift to a wetter, humid climate that favoured the lush forest swamps and their peat deposits that gave the Pennsylvanian its nickname: the 'Coal Age'. (It is likely that the rising Appalachian mountains created a rainshadow or even altered global weather patterns.)

The Joggins cliffs show that this change was not as sudden as generally thought, however. The section of low bluffs at Lower Cove, which succeed the Boss Point sandstones and precede the classic coal-bearing rocks of Joggins, record drylands with seasonal rains and flash floods, that slowly gave way to wetter conditions. Even after the first thin bed of coal appears in the rock record at the resumption of the cliffs south of Little River, conditions were still seasonally dry, with narrow, deep streams criss-crossing the landscape much as in the Channel Country of the Australian outback.

Eventually, waterlogged conditions persisted, allowing thicker peat to form, resulting in layers of coal that were thick enough to be mined by humankind millions of years later. Wooden pit props and beams of the old mines are exposed in the cliffs at this spot, while fossil trees stand like great pillars in the cliffs, both marking the spot where coal formed. From Little River to MacCarrons Creek, more than 67 individual beds or seams of coal are exposed in the cliffs, and at least 60 horizons of fossil forests. It is these coal-bearing rocks that best record life in the 'Coal Age' forest swamps.

South of MacCarrons Creek, the nature of the rocks changes yet again, recording the dynamic landscape. Global tectonic forces began to squeeze the basin in which the Joggins forest swamps lay, and alluvial fans of coarse boulders tumbled from the rising highlands of southern New Brunswick.

Resources:

- Lyell's section
- Map of the designated cliff section.
- Photographs from the cliffs.

Code: 6.1	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

The Big Volume

- Map showing the rising Appalachian mountains and rivers coursing through Joggins towards Europe.
- An artist's reconstruction of the landscape would be an asset.
- Specimen of permineralized wood of Cordaites from Boss Point.

Media approach:

- Interactive 3-D model of the cliffs, showing main points of geological interest
- Video showing animation of key geological processes (how and when did the strata at Joggins get deposited, and how and when were they tilted?)

Code: **6.2**	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

Why the Cliffs Exist

Objectives:

- *Explain the recent events that have shaped the cliffs*

Key message:

Show how, together, the last Ice Age and the tides of the Bay of Fundy exposed the cliffs at Joggins.

Storyline – Content:

If it were not for the sweeping cliffs at Joggins, we would not know of the fossil record preserved there, nor would it have played a pivotal role in the history of science. The Joggins cliffs exist because of two rather recent developments in Earth history. The first is the end of the last 'Ice Age', just over 10,000 years ago. The second is the development of extreme tides in the Bay of Fundy.

During the Quaternary period, a continental ice cap covered most of Canada, including Nova Scotia. The ice cover waxed and waned over a 100,000-year period, and melted for the last (?) time about 10,500 years ago. In geological terms, the thick cover of glacial ice vanished remarkably quickly, and the Earth's crust rebounded upward with the release of the weight (much as a foam cushion would rebound after you depress it with your hand). As the crust rose upward rapidly, the former shoreline at Joggins rose as well, becoming 'stranded' high above the present day shoreline. The ancient shore forms the flat surface at the top of the rock cliffs. Overlying this surface, which stretches all along the cliffs, is a thick layer of clay, strewn chaotically with boulders. This material, which washes down over the Coal Age rocks during rainstorms and paints them brick red, was unceremoniously dumped by the last glacial ice cover as it melted: it is properly called glacial till. The ancient wave cut platform and glacial till are nearly as famous to geologists who study the most recent period of earth history, the Quaternary, as the rocks and fossils below!

As the continental ice cover worldwide continues to melt, global sea levels have risen dramatically. The upper reaches of the Bay of Fundy, including the arm at Joggins known as Chignecto Bay, flooded, drowning forests along the shore, as at nearby Aulac and West Amherst. The shape of the Bay and the volume of water that it contains is a perfect fit for the timing of the Earth's tides at this latitude: every 6 1/2 hours, the tides flood the Bay and then withdraw again, in perfect harmony with the pull of the moon. The vertical rise and fall of the tides in the bay – 44 feet – is the greatest found anywhere in the world.

Code: 6.2	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

Why the Cliffs Exist

[The Bay of Fundy] has long been of great economic, ecological and scientific significance, largely because of its renowned tides that can exceed 16 meters in height. Twice daily, water equal to the flow of 2,000 St Lawrence Rivers surges into the Bay. Its funnel shape and gradual shallowing causes a piling up of the inrushing water. Because the Bay of Fundy and the Gulf of Maine form a large single basin, the moving seawater also sloshes back and forth like a wave in a tub. This aptly named "bathtub effect", being nearly in unison with the bay's tidal cycle, gives the water the extra push needed for the world record heights. - Fundy Marine Ecosystem Science Project. *Fundy Issues*, No. 1, Spring 1999

The waves pound the cliffs relentlessly during the highest tides. Rocks topple from above, sometimes in 'terrible landslips' in the words of Dawson. Each falling rock brings with it the possibility of revealing a pressing of fossil life from the pages of this 'marvellous chapter of the Big Volume', as Lyell so aptly described Joggins.

Resources:

- Photo of cliff clearly showing glacial till overlying the ancient "stranded" shoreline. (example: Rob Fensome Images: file JogginsProject - #3)
- Maps showing the extent of the ice cap (*Last Billion Years,* Pg 190)
- A small interactive to represent the effect of land rebounding after the weight of the ice cap was removed. (a piece of foam to compress; or when a block of "ice" is removed a spring loaded cliff emerges)
- Commissioned photos of the tide in and out and half way at Joggins.
- Specimens of rocks from the beach that have been transported by glaciers with a suggestion of how far they have been transported
- Photo of the drowned forest at Amherst Marsh.(National Resources Canada, Collection of Earth Sciences Information Centre (#2002-053
- Commissioned photo of shore in winter covered with blocks of ice
- Atlantic Geoscience Society. The Recent Ice Age Video Guide. AGS Special Publication 13. Contains many photos and drawings.

Media approach:

Graphic and text panels:

- Explanation of the tides in the Bay of Fundy; images of Joggins at high and low tides
- Ice Age map of Joggins

Code: 6.3	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

Bay of Fundy Ecosystem

Objectives:

- *Show that the Bay of Fundy is home to a diverse range of life forms today, very different from the ancient life forms revealed in the cliffs*

Key message:

Today, the world's highest tides create environments for a unique range of marine life that includes whales and sea birds.

Storyline – Content:

The world's highest tides present extraordinary tidal landscapes while the upwelling of deep ocean water generated by the tides creates ideal environments for marine life including whales and sea birds.

"The Bay of Fundy is 'a system with a biological pump at both ends'. In the lower Bay, the strong tides pump nutrients from the seafloor up into the light, or photic zone, which sets in motion the marine food chain: phytoplankton, copepods, herring, seabird and whales. In the shallower upper Bay of Fundy, huge expanses of mud flat and salt marsh are the biological factories. Slicks of single-celled algae, each a tiny solar greenhouse, flourish at ebb tide on the mud flats, and lush ribbons of salt marsh supply carbon-based food to the marine environment, which is then churned by the action of the tides into a nutrient soup for a variety of bottom dwellers, fish, and birds." (Thurston. *Tidal Life: A Natural History of the Bay of Fundy*)

The Bay of Fundy, linking New Brunswick and Nova Scotia, is a 270-kilometer extension of the productive Gulf of Maine ecosystem. The Bay's 1,300 kilometer coastine randges from rugged headlands flanking its mouth to broad mudflats and lush salt marshes at its inner reaches. …

…the ceaseless tidal turbulence stirs the waters of the Bay, raising dissolved nutrients from its darkest depths to its sunlit surface. … This endless abundance of natural fertiliser stimulates the production of marine plants and the animals that feed on them. These in turn support large populations of fish, seabirds, whales and seals. … The restless tidal circulation also stirs up the fine sediments eroded from the soft rocks surrounding the upper Bay and over time has shaped them into the productive salt marshes and mudflats that fringe Minas Basin, Chignecto Bay, and other estuaries. … Large tracts of the upper bay are now protected areas for shorebirds and waterfowl…. The Bay of Fundy is clearly a dynamic, highly productive and ecologically diverse ecosystem.
- Fundy Marine Ecosystem Science Project. *Fundy Issues*, No. 1, Spring 1999

Code: 6.3	Central theme: *The Power of the Bay of Fundy*	

Subtheme:

Bay of Fundy Ecosystem

Resources:

Layers in the saltmarsh mud, Fort Beausejour	No. 2002-056. Earth Sciences Info Centre (ESS) keyword:Bay of Fundy
Tidal marsh encroaching on forest	No. 2002-053 . Earth Sciences Info Centre (ESS) http://geoscan.ess.nrcan.gc.ca keyword:Bay of Fundy
Glacial-age shore platform, Cape Chignecto	No. 2002-055 . Earth Sciences Info Centre (ESS) http://geoscan.ess.nrcan.gc.ca keyword:Bay of Fundy
Images showing work of the tide, like that by Stephen Homer	Pages 17, 21, 22, 38 Harry Thurston, *Tidal Life: A Natural History of the Bay of Fundy,* Camden House Publishing, 1990.
Weir fishing	Photo by Stephen Homer, p.31 in Harry Thurston, *Tidal Life: A Natural History of the Bay of Fundy,* Camden House Publishing, 1990.
Marshes of the inner bays, winter ice and summer lushness	To be commissioned from a photographer like Stephen Scott Patterson, www.stephenpatterson.com www.gathering-of-artists.ca/photography/stephenpatterson/gallery www.parks.gov.ns.ca/posters.htm
Images of the outer Bay: whales feeding	
Sardine Fishing in the Bay of Fundy, Black's Harbour NB	National Museum of Science and Technology Image no. CN0003362 CSTMC/CN Collection
	Rob Fensome GSC/BIO and the Colour Photographic Guild of NS may have suitable images
The Fundy Basin: a map showing paleogeography about 200 mya:	P.127 in Atlantic Geoscience Society. *The Last Billion Years*. Nimbus, 2001.

Media approach:

- Graphic and text panels

This theme is also addressed in the lobby and outdoor interpretation.

Code:	Location:	Value:
7.0	Exhibit hall	10%

Central theme:

The Changing Earth

Subthemes	Objectives:
7.1. Coal Age World and Changing Earth 7.2. Climate Change 7.3. Timeline of Earth's History 7.4. Other fossil sites, including Nova Scotia and UNESCO sites	• *Situate the Joggins Fossil Cliffs in the geological timescale* • *Show the evolution of the Earth's continents and climate over time* • *Help visitors understand that the Earth continues to change today*

Key message:

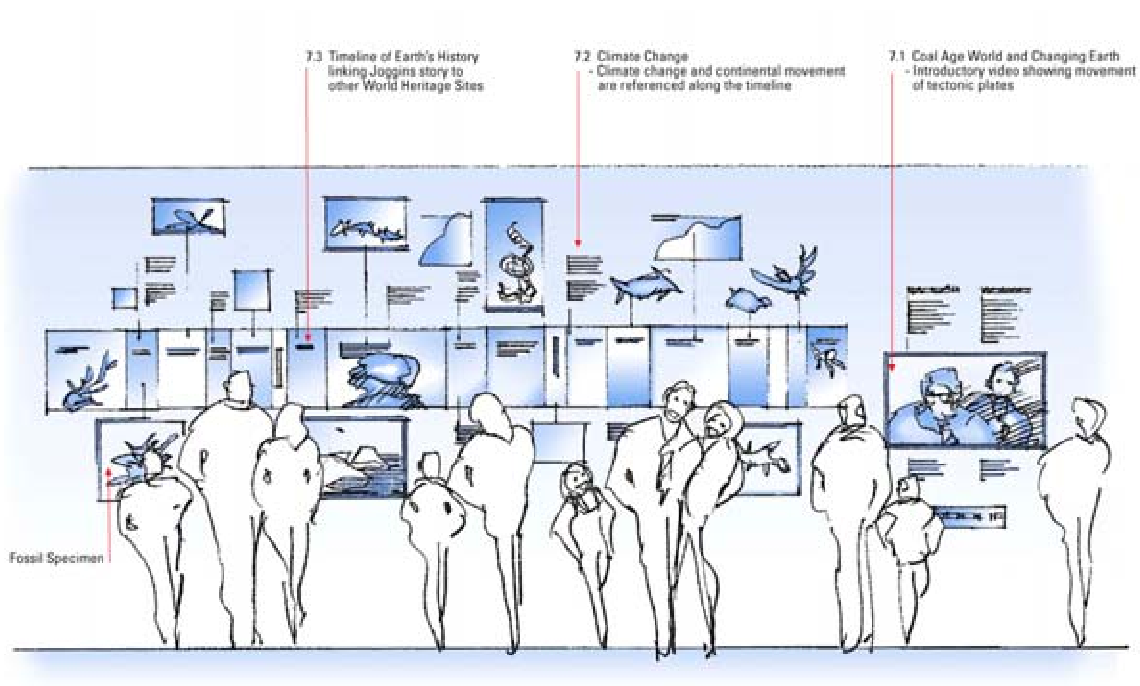
The cliffs at Joggins are a legacy of the Carboniferous period about 300 million years ago, when vast coal reserves were formed. The climate and geography of the earth were very different at that time, and continue to change today.

General media approach:

In this area, a 'History of Life & Earth' timeline links the Joggins story to other World Heritage Sites, as well as to some other sites of particular geological interest in Nova Scotia and the Bay of Fundy area. The timeline incorporates representative fossils from different periods in Earth's history, including the periods covered at each of the other UNESCO fossil sites.

The timeline also shows the cycles of global climate change. A video presentation at the beginning of the timeline explains the movement of Earth's tectonic plates through time, showing how Joggins has moved over the past 300 million years (and even before).

Code: 7.0	Location: Exhibit hall	Value: 10%



Code: 7.1	Central theme: The Times *The Changing Earth*	

Subtheme:
Coal Age World and Changing Earth

Objectives:
Understand

Key message:
The Earth's surface has always changed and moved and continues to do so today.

Storyline - Content:

The 'Coal Age' world was very unlike the world of today in many respects, but in others, was more similar to the modern world than at any time in the past. If one were to observe the Coal Age Earth from space, the most obvious difference from today would be the shape and position of continents and oceans. When looking at a globe or map today, most people think of the physical world as a constant, and consider changes only in terms of political borders or country names. The position of the continents, however, is constantly changing, like a slow waltz (or perhaps more aptly, slow motion bumper cars). For instance, Europe and North America today are steadily drifting apart at about the rate that one's fingernails grow, while India pushes into Asia, giving rise to the Himalaya Mountains.

In the Coal Age, the continents were assembling into a super-continent that geologists have named *Pangaea* (Greek for 'one Earth'). Much of that land mass was situated at the south pole, but it extended north to straddle the equator. While the equator was humid and 'tropical', the land at the south pole[1] was covered by a huge icecap, much like today's world. For this reason, both the Coal Age and recent times have been described as an 'Icehouse world'. The time between when the world was ice-free included the entire 'Dinosaur Era', and is known as a 'Greenhouse world'.

Joggins was at the geographical centre of the Coal Age World.

Resources:

- Map/globe of the 'Coal Age' world, as reconstructed by Chris Scotese (www.scotese.com/earth.htm) or by Ron Blakey (http://jan.ucc.nau.edu/~rcb7/Penn.jpg)

[1] These southern lands of Pangea, known as *Gondwana*, included present-day South America, Africa, India, Australia and Antarctica.

Code:	Central theme:	
7.1	The Times *The Changing Earth*	

Subtheme:

Coal Age World and Changing Earth

Map showing the global extent of the Carboniferous environment best witnessed at Joggins.	Calder: "Figure derives from Alfred Wegener who came up with the theory of continental drift and Pangea in 1925. It's very much derived, and one shouldn't worry about copyright if it's redrawn."
Upper Paleozoic floral provinces	Calder SBI, Coal Age file
Map of *Pangea,* 300mya	Calder, SBI, Coal Age file
Map of late Carboniferous/Pennsylvanian	Calder, SBI, Coal Age file
Aerial photos + image of cliffs today to reinforce the progression and layering that occurred throughout the Pennsylvanian and Mississippian	Aerial photos purchased from NS dept of environment and forwarded to D+C

Media approach:

- Introductory video showing movement of tectonic plates over time, highlighting the movement of Joggins
- The message is reinforced with small graphic and text elements located at key points along the timeline, such as period boundaries (see section 7.3)

Code:	Central theme:	
7.2	The Times *The Changing Earth*	

Subtheme:

Climate Change

Objectives:

- *Demonstrate that climate change is a natural phenomenon, though the role played by humans should not be discounted in present-day climate change*

Key message:

The global climate has changed, often drastically, throughout Earth's history.

Storyline – Content

It may come as a surprise to learn that the steamy tropical 'Coal Age' forests flourished at a time when the south pole was under ice, but today's world is much the same: consider the Amazon rainforest vs. Antarctica. During such Icehouse times, the climate and temperature differ dramatically from the equator to the polar regions, more so than during Greenhouse times when global climate was evenly warm. (For instance, at the end of the last Greenhouse period some 50 million years ago, the polar regions of the Arctic and Antarctica were covered in lush, temperate forests.)

The rich plant life of the Coal Age removed carbon dioxide from the Earth's atmosphere. The carbon, used as a building block by plants, was stored beneath the tropical forest swamps in vast deposits of peat (which would later turn to coal). As carbon dioxide was removed, oxygen in the atmosphere rose to its highest level ever, about 50% higher than today. Some scientists speculate that the oxygen-rich atmosphere may have helped to coax life from the waters onto land, and may also have contributed to the huge size of some 'Coal Age' invertebrates like the giant millipede-like Arthropleura. Lightning strikes would have caused instant conflagrations, and evidence of these wildfires is found in charred trees at Joggins.

Fossil fuels: Oil and coal are known as fossil fuels because they originate from ancient organisms, mainly plants. When we burn them, we release the energy in the form of heat and light, which was originally captured by the living plants during photosynthesis millions of years ago. Fossil fuels are extracted in huge quantities from the Earth. ...They are also used in the manufacture of many synthetic materials. Taylor, Paul. Eyewitness FOSSIL. P. 40

Coal is fossilized plant material. It consists mainly of carbon, derived from the Carboniferous atmosphere by the leaves of plants. After millions of years of being buried without oxygen, the decayed plants form peat. Heat from the earth causes chemical changes that produce coal. The higher the earth temperatures, the greater the amount of carbon that is fossilized and the greater the amount of energy that is released when the coal is burned using oxygen. (paraphrased from Encyclopedia Britannica).

Code: 7.2	Central theme: The Times *The Changing Earth*	

Subtheme:
Climate Change

To be developed: release of carbon, creation of greenhouse gases

Resources:
Maps/globes of the modern world, and 'Greenhouse' world of the Dinosaur era (www.scotese.com/earth.htm), showing comparison

Media approach:
- Cycles of climate change will be referenced in the introductory video (see section 7.1) and will be graphically represented along the timeline (see section 7.3)
- Climate change will also be referenced in terms of "green building" and contemporary human-generated climate change (including the coal for which Joggins is famous) in the lobby area.

Code: 7.3	Central theme: *The Times*	

Subtheme:

Timeline of Earth's History

Objectives:

- *Show the vast sweep of time recorded in the rocks of the Earth's surface*

Key message:

The fossil record and the geological record both attest to the vast sweep of the Earth's past history.

Storyline – Content:

Milestones in the Earth's History

-4.6 billion years ago: birth of the Earth
-4 billion years ago: oldest rocks on Earth
-3.5 billion years ago: oldest evidence of life: stromatolites built by cyanobacteria (blue-green algae) as today at Shark Bay, Australia
-2.5 billion years ago: oxygen builds in the atmosphere (evidence in banded iron formations)
-670 million years ago: earliest multicellular life (Ediacaran fauna of Australia, China and at about 565 mya, Newfoundland's Mistaken Point)
TL Mistaken Point, Canada (Ediacaran: ~ 560 million years ago) *earliest multicellular community*
-550 million years ago: 'Cambrian Explosion' of multicellular lifeforms
- Burgess Shale, Canada (Cambrian: ~ 550 million years ago) *'explosion' of multicellular life*

-460 million years ago: first fish
-425 million years ago: first land plants, terrestrial ecosystems
-375 million years ago: first trees & forests
- Miguasha, Canada (Devonian: ~ 375 mya) *'Age of Fish' & evolution of limbs, preparing for life on land*

-350 million years ago: first steps on land: amphibians
- 315 million years ago: first reptiles: the 'portable pond, Joggins, Canada (Pensylvanian: ~ 315 mya) *'Coal Age' swamps & first reptiles*

-250 million years ago: supercontinent Pangea finally assembles; greatest extinction event
-220 million years ago: first dinosaurs
- Monte San Giorgio (Triassic: ~ 240 mya) *marine reptiles*
- Dorset Coast, UK (Jurassic: ~175 mya) *marine life & geology of the 'Dinosaur Era'*

-100 million years ago: first flowering plants
- Drumheller, Canada (Cretaceous: ~ 100 mya) *acme of the Dinosaurs*

-65 million years ago: dinosaurs fall, mammals rise
-50 million years ago: first grasslands

Code: 7.3	Central theme: *The Times*	

Subtheme:

Timeline of Earth's History

- Messel, Germany (Eocene: ~ 50 mya) *Tertiary mammals, exceptionally preserved*
- 3-5 million years ago: first hominids
- Fossil hominid sites, South Africa (Quaternary: 3.3 mya) *Australopithecus discovery site*; Lake Turkana, Kenya *early hominid sites*
- Narcoorte Caves, Australia (Quaternary: ~1 mya) *Australian marsupials*
- 14,000 years ago: first art of 'modern' humans
- Altamira Cave, Spain (Quaternary: 13,500 yr) *early cave art of modern humans*

-10,500 years ago: last glacial period ends; 11,000 - 9,000 years ago: the Paleo-Indian period in Atlantic Canada (Tuck)

-7000 years ago: Formation of the present day Bay of Fundy

- The fossil record as we know it represents only the last 10% of earth history (JC)

Resources:

- www.unesco.org
- Time spiral (Calder, SBI, Coal Age file)

Media approach:

- "History of Life & Earth" timeline linking Joggins story to other World Heritage Sites; ideally including representative fossil from each of the other UNESCO fossil sites
- Timeline shows vast sweep of geological time ("Deep Time") and positions Joggins and the Carboniferous within a bigger picture
- Identify the Pennsylvanian and Mississippian progression within the Carboniferous section
- Timeline also includes fossils from other key NS geological sites
- As mentioned above, climate change and continental movement are referenced along the timeline (see sections 7.1 and 7.2)

Code: 7.4	Central theme: *The Times*	

Subtheme:

Other Fossil Sites in Nova Scotia

Objectives:

- *Link to related Nova Scotia experiences*

Key message:

Joggins and its Fossil Cliffs are a "gateway" to other fossil, geological, and mining experiences in the Cumberland Region and in the rest of Nova Scotia.

Storyline – Content:

For more fossil, geological, and mining experiences, here are places with stories related to Joggins to visit in Nova Scotia

- the 'Coal Age' story locally in Cumberland County:
  River Hebert Miners Museum, River Hebert
  Springhill Miners Museum, Springhill
- King Seaman Schoolhouse Museum, Minudie (grindstone quarries at Lower Cove)
- Cape Chignecto Provincial Park

The 'Coal Age' story regionally

- Museum of Industry, Stellarton (coal mining)
- Glace Bay Miners Museum, Cape Breton
- Sydney Mines Fossil Centre, Cape Breton

The times just before and just after the Coal Age

- Blue Beach Museum and Research Centre at Horton Bluffs, Hantsport (earliest Carboniferous)
- Brule Fossil Centre, Brule, Pictou County (end of Carboniferous-early Permian)

Further back in time to the Silurian 'Age of Fishes'

- Arisaig Provincial Park, Antigonish County

Coal Age and ahead to the 'Era of Dinosaurs'

- Parrsboro Rock and Mineral Shop
- Five Islands Provincial Park

Major Centres

- Fundy Geological Museum, Parrsboro
- Nova Scotia Museum of Natural History, Halifax

Resources:

- To be identified: Maps, photos from Department of Tourism, Culture and Heritage, photos from CREDA

Code: 7.4	Central theme: *The Times*	

Subtheme:
Other Fossil Sites in Nova Scotia

- Photos from Atlantic Geoscience Society as in brochure "Nova Scotia Rocks"

Media approach:

- When appropriate, fossils from Nova Scotia sites will be used to illustrate key periods in the timeline (see section 7.3)

The regional tourist information area in the lobby (see section 2.0) will have additional information (brochures and maps) about these destinations.

Code: **8.0**	Location: Exhibit hall	Value: 20%

Central theme:

Big Ideas

Subthemes	Objectives:
8.1. Theory of Evolution 8.2. Dawson's Legacy 8.3. Lyell's World of 1842 8.4. *Dendropupa* and *Hylonomous* 8.5. Big Ideas Theatre	• *Help people understand that Joggins played a major role in the scientific debate on the evolution of life on Earth* • *Help visitors to develop their understanding of evolution so as to be able to take an informed position*

Key message:

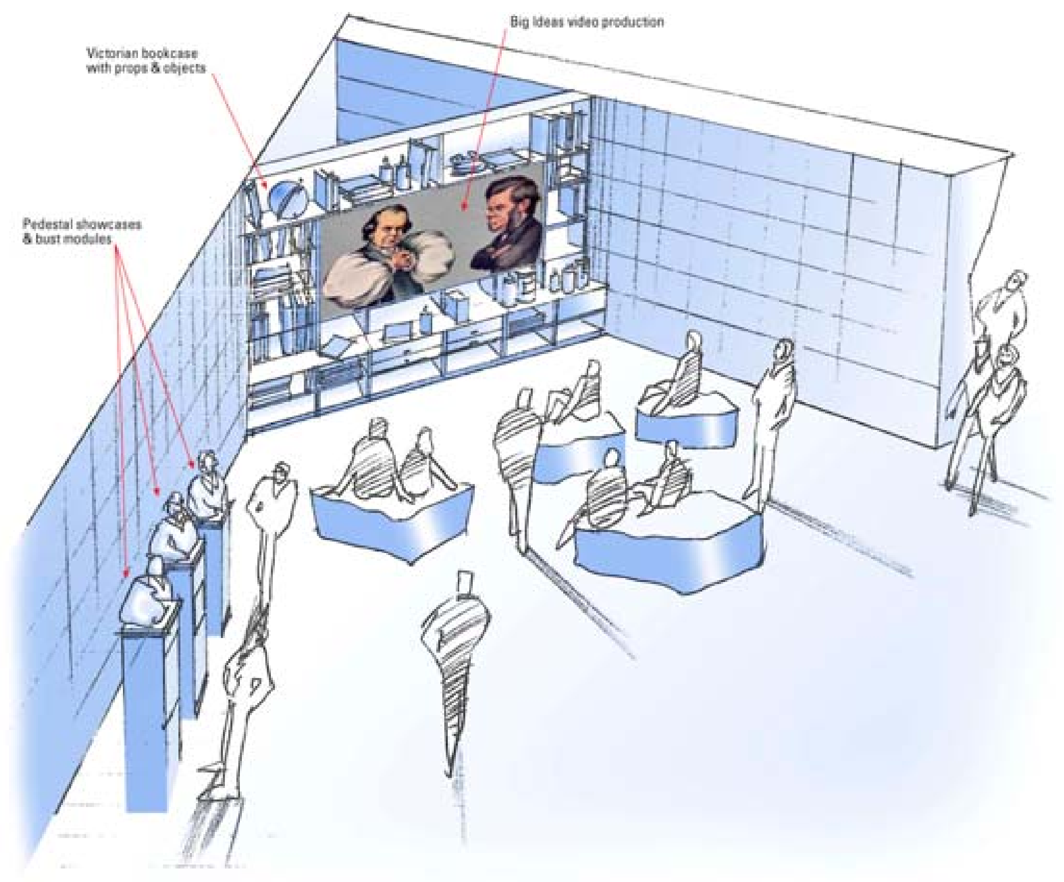
The record of the Coal Age preserved in the cliffs at Joggins has figured prominently in scientific debates about the evolution of life on Earth.

General media approach:

Visitors move freely through this open area, which offers thematic content presented in display cases and graphic panels as well as a short A/V production dealing with Joggins' role in the debates on evolution. The production complements and enriches the themes presented in the dramatically lit display areas.

The overall flavour of the zone is inspired by the Victorian era – expressed through the treatment of the theatre as well as the use of historical images, prints and caricatures, archival documents, images and artefacts. At the same time, much of the information that is presented – like the tree of evolution or tree of life – is extremely modern.

Code: 8.0	Location: Exhibit hall	Value: 20%



Code: 8.1	Central theme: *Big Ideas*	

Subtheme:
Theory of Evolution

Objectives:
- *Provide historical and social context for the theory of evolution*
- *Show the role of Joggins in the debates around evolution*

Key message:

Evolution is the scientific idea, derived from preserved physical evidence as well as inference based upon observable processes, that life forms have been changing and adapting over a very long time.

Storyline – Content:

There are as many ideas about the origin of life and of the earth as there are cultures. Creation stories abound, including the Mi'kmaw creation story featuring Grandfather Sun and Grandmother Rock. The Book of Genesis in the Bible is another account of the origin of the earth and life on the earth, suggesting that the earth is about 6000 years old.

An amateur Scottish geologist, James Hutton, concluded that the Earth was far older than the Bible had allowed. He published his *Theory of the Earth* in 1795, in which he proposed that the earth had its own history of great and ancient changes, which, like diseases of the body, left their visible mark on its surface through fossil remains and sedimentary rock deposits.

Stephen Jay Gould. *Hens' Teeth and Horse's Toes*
p. 122 Science must identify processes that yield observed results. The results of history lie strewn about us but we cannot, in principle, directly observe the processes that produced them. How can we be scientific about the past?
P. 123 As a general answer, we must develop criteria for inferring the processes we cannot see from results that have been preserved. This is the quintessential problem of evolutionary theory: How do we use the anatomy, physiology, behaviour, variation, and geographic distribution of modern organisms, and the fossil remains in our geological record, to infer the pathways of history?

Darwin's worm book is ... an exploration of how we can approach history in a scientific way.

Resources:

- Gould, Stephen Jay. "Evolution as Fact and Theory" in *Hen's Teeth and Horse's Toes*. Norton, 1983.

Code: 8.1	Central theme: *Big Ideas*	

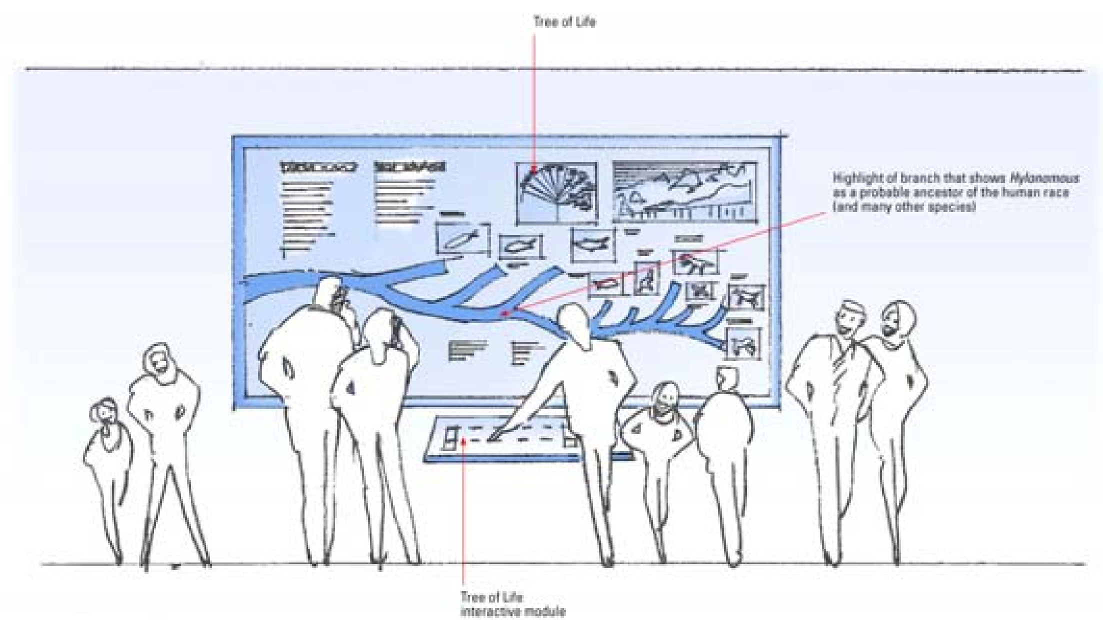
Subtheme:

Theory of Evolution

- Quammen, David. “Darwin’s Big Idea” in National Geographic. Vol. 206, No.5, November 2004.
- Herman, Arthur. *How the Scots Invented the Modern World and Everything In It*. NY, Three Rivers Press, 2001.
- Stein, Sara. *The Evolution Book*. NY, Workman Publishing, 1986.
- Webster, Stephen. *The Kingfisher Book of Evolution*. NY Larousse Kingfisher Chambers Inc, 2000.
- Tree of life (*Lepidodendron* as a model) highlighting the position of *Hylonomous* and *Dendropupa*. John Calder can identify examples of existing “trees of life” to use as guides. Example of tree form: SBI Ecosystem / lycopsid trees
- Title page of Origin of Species (SBI Lyell World / Origin of Species)
- Caricatures (Vanity Fair and similar)

Media approach:

- Large-scale image of the tree of life, highlighting the branch that shows *Hylonomous* as a probable ancestor of the human race (and many other species)
- Pedestal showcase of antique books (or reproductions of books) from the period of early debate about evolution. A bust of Charles Darwin, with a striking and modern visual treatment, sits atop the showcase.



Code: 8.2	Central theme: *Big Ideas*	

Subtheme:

Dawson's Legacy

Objectives:

- *Introduce and present Sir William Dawson*
- *Explain Dawson's role in making Joggins world-famous*

Key message:

Dawson demonstrated that interpreting the Joggins fossils in their original environmental context could provide new insights into the Carboniferous ecosystem.

Storyline – Content:

What we know of the fossil record of this special place we owe almost exclusively to the insight and labour of love of one man: Sir William Dawson. Born in 1820 in Nova Scotia, Dawson would become Canada's most internationally recognized palaeontologist and educator of the nineteenth century. Serendipity brought both Charles Lyell and William Logan to the young William's doorstep in his home port of Pictou while home on a forced sabbatical from his university studies at Edinburgh due to family misfortune. Lyell and Logan, both 20 years senior to young William, would draw on Dawson's insights of the geology of the 'Coal Measures' and the red sandstones of Pictou and Prince Edward Island with which young William was so familiar. But it was Joggins that cemented Dawson and Lyell's lifelong relationship, both professionally and as friends.

Dawson had an approach to studying fossils that was unorthodox for his day, and well ahead of his time. It can be best summed up in a quote from a letter of 13 August, 1868 to his mentor Lyell, in which he mused about the odd and frustrating conclusions drawn by many of the leading palaeontologists of the day, most of whom were affiliated with the 'ivory tower institutions' of London. Dawson wrote that it is better to study '... plants as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum.' It was precisely this approach that led Dawson to so many discoveries at Joggins, exemplified with his success with the hollow tree fauna that has been unmatched by efforts of all later palaeontologists combined. Joggins is the one place best suited to placing fossil life of the 'Coal Age' in its environmental context, and Dawson was the person best suited to the task.

Dawson published over 40 books and learned papers on Joggins, most in the Journal of the Geological Society of London. Most of his research and fossil discoveries are summarized in his opus *Acadian Geology*, published in four editions between 1855 and 1892. Dawson's discoveries made their way to colleagues at leading institutions in the United States and Britain, including Yale, Harvard and the British (Natural History) Museum, and when he took on the role of principal of McGill University in Montreal, his collection became the foundation of the Redpath Museum (built by the sugar baron of the same name expressly to convince Dawson to stay at McGill). He remained at McGill as

Code: 8.2	Central theme: *Big Ideas*	

Subtheme:

Dawson's Legacy

its principal for 40 years, where he could be seen calling in on sick students with his trademark basket of soup and bread on his arm: an honest-to-goodness gentleman and scholar. A devoutly religious man, Dawson may well be the least understood scientist of his day, as many later historians have superficially written off his scientific objections to aspects of Darwinian evolution as the intransigence of religious dogma.

"*The tide being low in the afternoon, I rose early next morning, and taking some luncheon in my basket, walked along the shore to the south-westward for several miles. I was amazed at the grand succession of stratified beds exposed as plainly as in a pictured section, and was interested beyond measure in the beds of coal, with all their accompaniments, exposed in the cliffs and along the beach, the erect trees (Sigillaria) represented by sandstone casts, and the numerous fossil plants displayed in the beds. The tide favoured my expedition, and the day was fine, though small banks of fog drifted up the bay from time to time, dissolving as they touched the cliffs, warmed by the sun. I returned in the evening to the quarrymen's shanty, thoroughly fatigued, but loaded with fossils, delighted with the knowledge I had acquired, and with my enthusiasm for geology raised to a higher point than ever before. Such was my first visit to the celebrated coast-section of the Joggins, on which I have spent so many pleasant and profitable days*."
-- Sir William Dawson, *Fifty Years*

Resources

- *Acadian Geology*
- Dawson letters at the Natural History Museum

Portrait of Dawson	SBI Dawson / Dawson young
Standing photo portrait of Dawson age 39 wearing a fur collared coat	Redpath Museum, seen in Dawson exhibit case.
Dr. Dawson's study	Canadian Illustrated News, Aug 26, 1882 http://www.collectionscanada.ca/cin/026019-119.01-e.php?uid=77309&uidc=Negative1 or http://www.collectionscanada.ca/cin/026019-119.01-e.php?uid=77307&uidc=Negative1
Dawson signature	SBI Dawson / Dawson signature
Map of low tide beach off Coal Mine Point	SBI Dawson / Dawson CMPt map
Foliage from the Coal formation	SBI Dawson / carbbqt
"Airbreathers" illustration	SBI Dawson / airbreathers

Code: 8.2	Central theme: *Big Ideas*	

Subtheme:

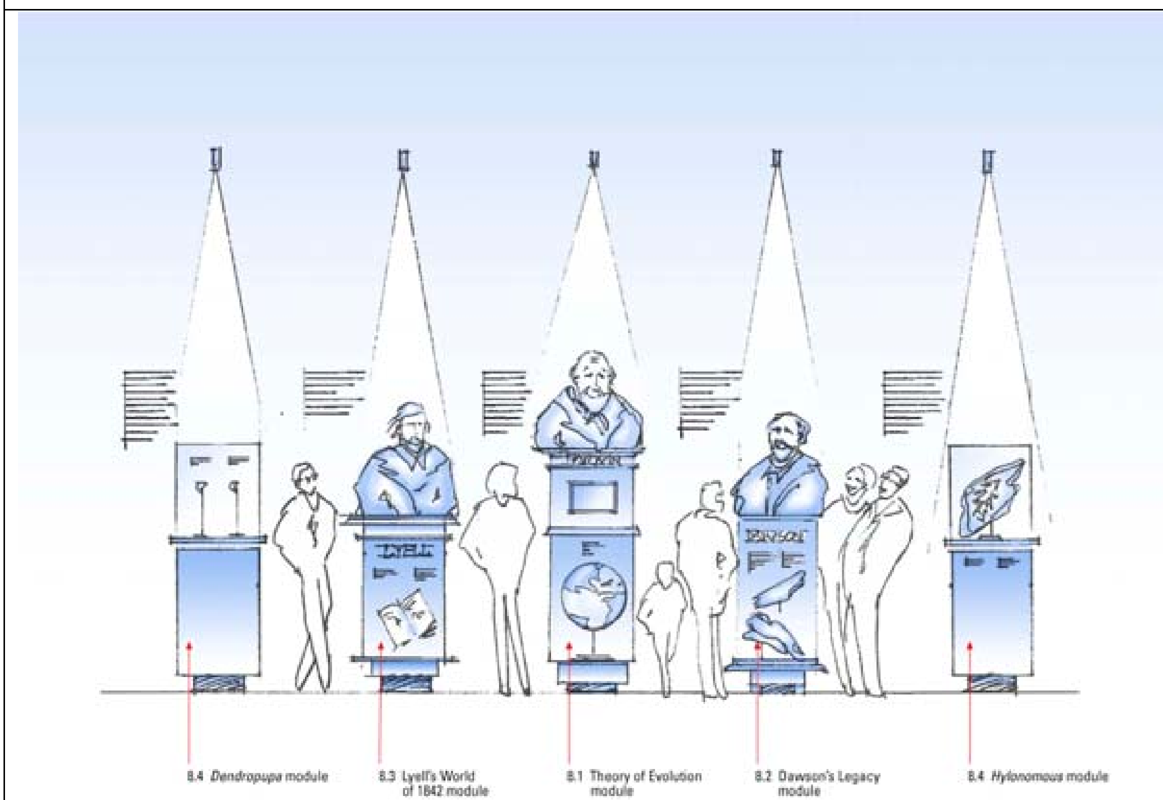
Dawson's Legacy

Portrait of George Frederic Matthew	William F. Ganong Collection, New Brunswick Museum.
Tetrapod footprints figured by Matthews (1903)	SBI Biodiversity / asperipes

Media approach:

A Dawson module in the Big Ideas area will incorporate:

- Portrait of Dawson
- Interpreted bust of Dawson
- Victorian "curio cabinet" in pedestal showcase containing Dawson's sketches, books, images, fossils with identification tags (in Victorian script)
- Graphic / text panels explaining Dawson's role in recording and interpreting the Joggins fossil record



Code: 8.3	Central theme: *Big Ideas*	

Subtheme:

Lyell's World of 1842

Objectives:

- *Provide a backdrop that will allow visitors to better appreciate Lyell's work*
- *Reinforce the significance of Joggins in the 19th century debates around geology and evolution*

Key message:

Lyell and his work at Joggins were instrumental in the establishment of 'Deep Time' – the idea that prehistory or geologic time must be considered in terms of millions (or even billions) of years.

Storyline – Content:

"*I was particularly desirous, before I left England, of examining the numerous fossil trees alluded to by Dr. Gesner as imbedded in an upright posture at many levels in the cliffs of the South Joggins, near Minudie.*

The first allusion to the trees which I have met with, is that published in 1829 by Mr. Richard Brown, in Halyburton's Nova Scotia, and he attributed their fossilization to the inundation of the ground on which the forests stood. I felt convinced that, if I could verify the accounts of which I had read, of the superposition of so many different tiers of trees, each representing forests which grew in succession on the same area, one above the other; and if I could prove at the same time their connexion with seams of coal, it would go farther than any facts yet recorded to confirm the theory that coal in general is derived from vegetables produced on the spots where the carbonaceous matter is now stored up in the earth." Sir Charles Lyell, *Travels in America* (1845) pp. 177-8

The year that Charles Lyell first set foot on the shore at Joggins, in July of 1842, the public was agog at the news of a startling scientific discovery: the world was once home to a race of dragon-like beasts.

Sir Richard Owen, first curator of the British Museum in London, had just the year before proclaimed them to be the *Dinosauria* ~ 'terrible lizards'. Until that time, most people had little reason to consider the antiquity of the Earth beyond that related in the Bible, which Archbishop Ussher of Ireland had calculated to be 4004 BC. The dinosaurs, and the questions they posed, changed all that. So great was the public appetite for 'breaking news' of discovery and ideas that up to 3,000 souls would pay to hear the likes of Sir Charles Lyell speak at the Lowell lectures in Boston, his next stop after Joggins.

On the eve of Lyell's return to Joggins in 1852, and his famous discovery with Dawson of the tree fauna, a group of luminaries took their seats at a table in the partially constructed life size model of *Iguanodon* at London's Crystal Palace. Seating himself at the head of the table was the unscrupulous Owen, who in true character would soon

Code: 8.3	Central theme: *Big Ideas*	

Subtheme:

Lyell's World of 1842

steal Lyell and Dawson's thunder.

.... and *evolution*? For scientists of the day, the fundamental debate of catastrophism vs. gradualism was fanned into flames. The cornerstone of catastrophism was the recognition of major extinction events (catastrophes) that Georges Cuvier had long ago used to define the three eras of the Paleozoic (ancient life), Mesozoic (middle life) and Cenozoic (recent life). Gradualism, whose first prophet had been James Hutton and was now Lyell, proclaimed that 'the present is the key to the past'. In other words, everything that helped to shape the earth in the past operates in full view today, or as Lyell himself admonished the catastrophists: 'We are not authorized to invoke the supernatural'. Lyell felt that extinction was more a matter of appearance than reality, due to the fragmentary nature of the fossil record.

For gradual processes to be possible in explaining the features of the earth, the antiquity of the earth had to be vast. Scientists began to think of 'Deep Time', and of prehistory or geologic time in terms of millions of years. It was on this canvas of deep time and with the pen of gradual change that Darwin would sketch out his theory of progressive change of living species: evolution.

Here we come face to face with Lyell's conundrum: his belief that the discovery of higher life forms in the fossil record would prove catastrophists wrong also put him at odds with the developing theory of one of his followers, Charles Darwin. The embattled Darwin never received from Lyell the blessing he so badly needed and desired, and Dawson (who has been described as more Lyellian than Lyell himself), would never reconcile evolution with the conflicting views of his beloved mentor, Lyell. Dawson would find ammunition for opponents to Darwinian evolution in the fossil record of Joggins, requiring Darwin to deal specifically with Joggins in *The Origin of Species*.

Resources:

Portrait of Lyell	SBI Lyell world / Lyell
Title page of Elements of Geology	SBI Lyell world / Elements of Geology
Lyell section	SBI Marv Chapter / Lyell section
Lyell signature	SBI Lyell world / signature
Portrait of Abraham Gesner	John Calder
Sir Richard Owen portrait	John Calder
Sir Richard Owen caricature	SBI Lyell world / Owen on dino
Charles Darwin portrait	John Calder

Code: **8.3**	Central theme: *Big Ideas*	

Subtheme:

Lyell's World of 1842

Media approach:

A Lyell module in the Big Ideas area will incorporate:

- Portrait of Lyell
- Interpreted bust of Lyell
- Pedestal showcase; Victorian "curio cabinet" containing Lyell's sketches, books, images, fossils with identification tags (in Victorian script)
- Graphic / text panels explaining Lyell's role in developing the concept of "Deep Time"
- Graphic / text panel explaining Lyell's relationship to Charles Darwin and the theory of evolution

Code: 8.4	Central theme: *Big Ideas*	

Subtheme:

Dendropupa and *Hylonomus* Stories

Objectives:

- *Show how tiny fossils help to establish big ideas*
- *Show the role of two key Joggins fossils in the debates around evolution*

Key message:

Two Joggins fossils have played particularly important roles in the debates on evolution – *Hylonomus*, the oldest, first, and earliest *known* example of the reptiles, and the "miserable little *Dendropupa*."

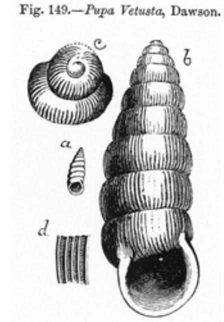
Storyline – Content:

The first land snail *Dendropupa* known from the fossil record excites invertebrate palaeontologists who study these creatures.

Dawson was the first to hold up the problematic little snail to Darwin, challenging him to explain how his theory of progressive evolution ~ his 'transmutation of species'~ could explain the persistence of a 'conservative' life form for millions of years ~ until today ~ with almost no evolutionary change.

(Critics of Dawson have wrongly ascribed Dawson's criticism to his religious beliefs. Rather, Dawson saw over a century before others, the phenomenon we now call 'stasis' in the fossil record (long periods with little evolutionary change) which underpins the now widely accepted theory of Stephen Jay Gould and Niles Eldredge known as 'punctuated equilibrium'.)

Fig. 149.—*Pupa Vetusta*, Dawson.



In the great evolution debate of 1860, the 'no' side hauled out Bishop Samuel Wilberforce, known as 'Soapy Sam' due to his debating prowess, to take on Darwin's 'bulldog', Thomas Huxley. Wilberforce gleefully raised this thorny problem, chiding his opponent with 'this miserable little Dendropupa'.

Origin of Coal. Darwin struggled with an explanation for the vast deposits of coal of Europe and North America that were the fuel for the Industrial Revolution. He could only explain their vast extent by invoking a marine origin (although his closest friend, Joseph Hooker at Kew Botanical Gardens, sharply disagreed). Darwin even mused out of frustration in correspondence to Hooker "I suppose coal was rained down to puzzle we mortals!' It was the discovery by Lyell and Dawson of land snails in the once hollow trees at Joggins that finally convinced Darwin that Dawson was right, and he was wrong. Coal was in essence 'fossil peat' formed in vast 'coal swamps'.

Of all the fossils found at Joggins, none carries greater weight than the diminutive, 20

Code: 8.4	Central theme: *Big Ideas*	

Subtheme:
Dendropupa **and** ***Hylonomus*** **Stories**

cm long reptile first named by Sir William Dawson in 1860: *Hylonomus lyelli*, meaning ‘forest dweller’.
Dawson returned to Coal Mine Point to search for more tetrapod-bearing trees, and in 1860 it was he who found a tree that bore the bones of a creature that he would name *Hylonomus lyelli* in honour of his mentor. Interestingly, bones of other tetrapods were also there in Lyell and Dawson’s tree of 1852, and one of these would later be recognized by Dawson as *Hylonomus*.

Hylonomus is figured in countless textbooks on the history of life, dinosaurs, and vertebrate paleontology. Not only is *Hylonomus* the oldest, first, and earliest *known* example of the reptiles, its pedigree goes farther: it is the first known amniote, a group that includes reptiles (and dinosaurs), birds and mammals (including humans). *Hylonomus lyelli* is the first known reptile, but is it the first to have evolved from amphibians? Probably not. Paleontologists have recognized various types of reptile: a) a primitive lineage that may have been an evolutionary dead end; b) a lineage leading to snakes, crocodiles, dinosaurs and birds; and c) a third lineage leading to mammal-like reptiles and to mammals themselves. Apart from being the oldest reptile fossil yet found, *Hylonomus* may well be the very first of one of the most primitive of these lineages. But! There should be a common ancestor to all these lineages, earlier in the fossil record. Such an ancestor has been reluctant to show itself, the closest contender having come from East Kirkton, Scotland. *Westlothiana lizziae*, nicknamed ‘Lizzie’ by its discoverer Stan Wood, was for a time in the late 1980's thought to be an earlier reptile, but more rigorous study has shown it to be lacking all the features of a reptile. It is now considered to be a ‘stem amniote’, or more primitive ancestor of the first reptile. Somewhere between Lizzie and *Hylonomus*, the very first reptile lies in wait to be unearthed. Whether or not it ever will be, only time will tell. In the meantime, *Hylonomus* continues its 150 year old reign as the oldest known reptile and amniote.

In 2002, *Hylonomus lyelli* was proclaimed the official fossil of the Province of Nova Scotia.

Who actually discovered *Hylonomus*?

The tetrapod (a usefully vague term that encompasses both reptiles and amphibians) discovered by Lyell and Dawson in 1852 was not *Hylonomus*, but rather the terrestrial amphibian *Dendrerpeton*, which has turned out to be the most abundant tetrapod of the hollow tree fauna at Joggins. Although it was originally referred to as a reptile, this was not an error. At that time in the mid-Nineteenth Century, the term ‘reptile’ was used much as we use tetrapod today to include both ‘true’ reptiles and to ‘batrachian reptiles’ or amphibians.

Code: 8.4	Central theme: *Big Ideas*	

Subtheme:
Dendropupa and *Hylonomus* Stories

Resources:
Images, Text
- etching from *Acadian Geology*
- 'Miserable little *Dendropupa*' quote by Wilberforce
- 'What a fact about the coal land snails!' quote by Darwin
- Specimen
- Brian Hebert *Dendropupa* specimen isolated by spot, magnifying glass

Images:
- fossil of *Hylonomus lyelli* at the Natural History Museum, London
- Reconstructions of *Hylonomus* from various sources:
- line drawing from Carroll, 1970.
- painting by John Sibbick in Czerkas & Czerkas' *Dinosaurs: A Global View* (1995)
- drawing by Doug Henderson, in David Norman's *Prehistoric Life* (1994).

'Imperfection of the Fossil Record' chapter in Darwin
-

Dendropupa engraving	SBI Dendropupa / dendropupa
Dendropupa specimen	BH Collection http://collections.ic.gc.ca/fundycoast/photopg4.htm
Caricature of Bishop Wilberforce	SBI Dendropupa / Wilberforce
Caricature of William Huxley	
Hylonomus photo of British museum specimen	SBI Hylonomus / Hylonomus fossil
Hylonomus line drawing and illustrations and stamp	SBI Hylonomus and Hollow Tree Fauna
Hylonomus engravings of bone "hash"	*Acadian Geology*, Dawson

Media approach:

The Dendropupa & Hylonomus modules in the Big Ideas area will include:
- Pedestal showcases topped by dramatically lit reproductions / fossils of Dendropupa and Hylonomus
- The showcases contain "curiosity cabinet" presentations of images, photos and fossils that explain the role of these two creatures in the scientific debates on evolution

Code: **8.5**	Central theme: *Big Ideas*	

Subtheme:

Big Ideas Theatre

Objectives:

- *Bring to life the big ideas associated with Joggins*
- *Reinforce and synthesize the other elements presented in the Big Ideas section*

Key message:

The record of the Coal Age preserved in the cliffs at Joggins has figured prominently in scientific debates about the evolution of life on Earth.

Storyline – Content:

See sections 8.1-8.4

Resources:

See sections 8.1-8.4

Media approach:

The Big Ideas Theatre is home to a 5-7 minute audiovisual presentation with a Victorian flavour. The presentation deals with serious scientific and historical ideas in an engaging and humorous way, integrating period illustrations (like the Vanity Fair caricatures of Wilberforce and Huxley), engravings and the like.

The theatre has something of the feel of a Victorian shadow theatre, with spectators seated on rocks as if they were on the Joggins beach. From the “miserable little Dendropupa” debate to the Joggins references in Darwin’s work, the Big Ideas Theatre reinforces and gives greater weight to the concepts, debates and scientific discoveries presented in the Big Ideas area.

Code:	Location:	Value:
9.0	Near exit to cliffs (lobby/corridor)	7%

Central theme:

Stewardship

Subthemes	Objectives:
9.1. Policy, Management, Safety 9.2. Community Stewardship 9.3. UNESCO World Heritage Nomination	• *Underscore the importance of preserving and respecting the site* • *Honour the ongoing role played by community members in preserving and promoting Joggins*

Key message:

The local community in collaboration with partners at all levels of government continue to preserve and promote the outstanding natural heritage of the Joggins Cliffs for all the peoples of the world.

General media approach:

This area will present essential information about the Joggins site, both in terms of respect for the site and the collecting policy and in terms of personal safety and security on the beach.

The area will also pay tribute to people from the community who have been involved in preserving and promoting the cliffs; this tribute will include short biographies, brief testimonials, group photos, stories and anecdotes.

Code: 9.1	Central theme: *Stewardship*	

Subtheme:

Policy, Management, Safety

Objectives:

- *Ensure public safety*
- *Ensure that the collections policy and the site are respected*

Key message:

Joggins is a special place that must be respected. The powerful natural forces at Joggins require care and attention on the part of visitors.

Storyline – Content:

Rules for fossil collecting:
All fossils are the property of the Province of Nova Scotia and are protected by the Special Places Protection Act.

Safety:
Explore at your own risk and use common sense. Cliffs can be high and steep and may have overhangs - rock falls can kill you. Stay at least the same distance from a cliff, as the cliff is high. Rocks and sea weed are often extremely slippery. Tread carefully and never explore without a friend.

The Bay of Fundy has extremely high tides. Check tide times so that you always begin trips on a falling tide and ensure that you have time to return to access points before the tide cuts off at headlands. Note that conditions can differ depending on date, weather and locality so it is wise to check locally.
Source: Nova Scotia Rocks: Explore Our Geology map

Resources:

Joggins Operational Policies	
Photos of “First Responders”	
Photos or illustrations of dangers	

Media approach:

Graphic panels with text and photos.

This message is reinforced on brochures and site-wide interpretive signage.

Code: 9.2	Central theme: *Stewardship*	

Subtheme:

Community Stewardship

Objectives:

- *Celebrate the work of the community in preserving and promoting the cliffs*

Key message:

Members of the local community continue to be actively engaged in preserving the Joggins site today, just as they have been in the past.

Storyline – Content:

Joggins-area residents have been working alongside researchers since the first geologists visited the cliffs.

In the 1840s, William Logan was accompanied in his surveys by a Mi'kmaq guide who also taught him to live off the land and to savour such delicacies as porcupine.

Sir William Dawson routinely sought the assistance of the coal mining companies in supplying gunpowder and men, some of whom volunteered for seemingly hair-raising detail extracting trees from the cliff face. Albert J. Hill of the Joggins Mines was one of the coal company men who organized such efforts for Dawson.

In the 1890s, Dawson had a local man, P.W. McNaughton, presumably of the Joggins coal mines, to keep watch for newly exposed tetrapod-bearing trees.

In the mid-Twentieth Century, resident Harry Bourque maintained a fossil shop in the barn at his home, to which the likes of Donald Baird of Princeton paid visits.

In the 1980s, Donald Reid opened the doors of his fossil display on Mitchell Street to the public, and conducted guided tours of the cliffs. In 1992, with the support of his family, Mr. Reid opened the doors of the Joggins Fossil Centre on Main Street. His collection at the Joggins Fossil Centre represents a census 60 years in the making of fossils from the ancient Joggins ecosystem.

In recent years, following the example of Mr. Reid, several young people from Joggins and surrounding area have taken up formal study of the fossils of Joggins, and have made significant discoveries and contributions to scientific research. Notable among these is Brian Hebert, of Lower Cove.

Resources:

Photo of Don Reid	SBI Keepers / Don Reid by tree
Engraving of man / tree/ cliff	SBI Keepers / dadoxylon tree
John Calder	SBI Visitors / DSCF0030
Brian Hebert	http://collections.ic.gc.ca/fundycoast/credits.htm

Media approach:

Graphic panels with text and photos.

Code: 9.3	Central theme: *Stewardship*	

Subtheme:

UNESCO World Heritage Nomination

Objectives:

- *Support the Joggins nomination for World Heritage Site status*

Key message:

The Joggins site is of outstanding value to humanity.

Storyline – Content:

World Heritage

Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritages are both irreplaceable sources of life and inspiration. Places as unique and diverse as the wilds of East Africa's Serengeti, the Pyramids of Egypt, the Great Barrier Reef in Australia and the Baroque cathedrals of Latin America make up our world's heritage.

Heritage sites belong to all the peoples of the world, irrespective of the territory on which they are located.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) encourages the identification, protection and preservation of cultural and natural heritage around the world considered to be of outstanding value to humanity.

The Joggins Nomination

The Pennsylvanian Coal Age was a highly significant episode in the history of life witnessing both the rise of the first rainforests and the appearance of reptiles. The classic fossil site at the Joggins Cliffs represents the finest example in the world of a Pennsylvanian-aged ecosystem, which makes it a strong candidate for World Heritage designation. Work is proceeding to have Joggins included on Canada's list of potential World Heritage Sites as a step towards consideration of the site by UNESCO.

The case for Joggins:
1) The richness of the biodiversity of the site and its evolutionary significance.
2) The preservation of an unrivalled record of fossil ecosystems that show a dynamic response to millions of years of global change.
3) The extraordinary natural laboratory from which many fundamental geological principles and insights have emerged, beginning in the early nineteenth century and continuing at an accelerated pace today.

Code: 9.3	Central theme: *Stewardship*	

Subtheme:
UNESCO World Heritage Nomination

Resources:

- *Images of Joggins and other World Heritage Sites*
-

Media approach:

Graphic panels with text and images.

Note that all interpretive signage – and other relevant aspects of the interpretive program – will be designed so that the UNESCO logo and accompanying text could easily be integrated should the nomination move forward.

Code: **10.0**	Location: Exhibit hall	Value: 50%

Central theme:

Coal Age Ecosystem at Joggins

Subthemes	Objectives:
10.1. Biodiversity of the Fossils 10.2. Hollow Tree Fauna 10.3. How Fossils Formed at Joggins 10.4. How to see Fossils	• *Take people back in time to the Coal Age ecosystem* • *Showcase the range of fossils found at Joggins* • *Demonstrate that Joggins is the best site on Earth for observing fossils* in situ *that illustrate life in the Carboniferous*

Key message:

Joggins is the best place on Earth to reconstruct a Carboniferous ecosystem. Careful scientific interpretation of the fossils found in the Joggins cliffs provides unparalleled insights into life on earth during the Coal Age.

General media approach:

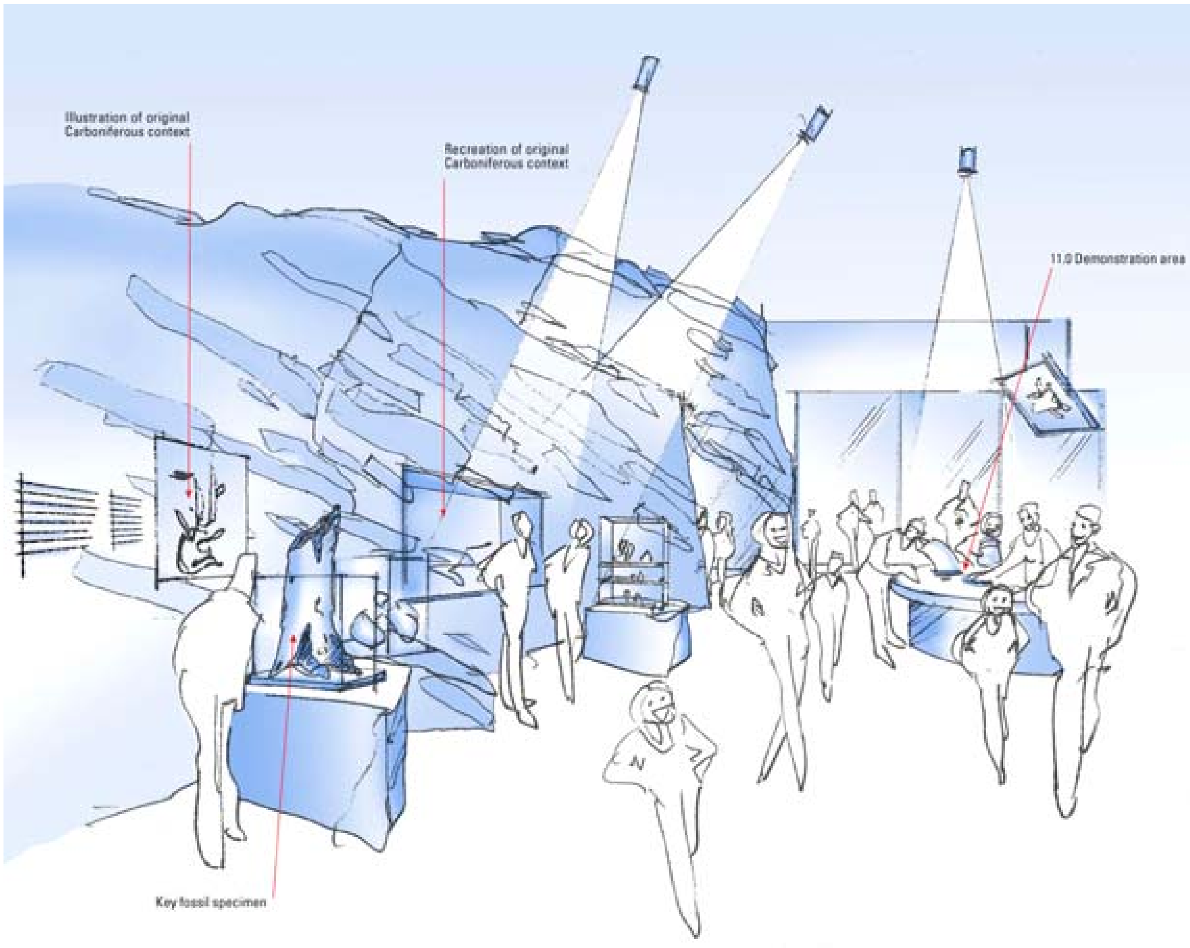
This area is the centrepiece of the exhibits, where key fossil specimens from the Joggins cliffs are presented. A variety of 2D and 3D media are used to enhance the visitor experience by showing samples of the original flora and fauna in a recreated Carboniferous context. Visitors also learn about how scientists use fossils (and other traces) to recreate the past, in terms of climate and environmental context. Models and graphics also explain the process of fossil formation, and show where fossils are likely to be found in the Joggins cliffs.

Special attention is given to fossils that played a particularly central role in the history of Joggins, such as Hylonomus. However, the focus in this area is on the diversity and number of fossils found at the site, together with the fact that the fossils have been preserved in their original context, a fact that provides us with valuable insights regarding what life was like during the Carboniferous era. Together, these allow us to better understand the evolution of the Coal Age ecosystem at Joggins.

Code: 10.0	Location: Exhibit hall	Value: 50%

Central theme:

Coal Age Ecosystem at Joggins



Code: 10.1	**Central theme:** *Coal Age Ecosystem at Joggins*	

Subtheme:
Biodiversity of the Fossils

Objectives:
- *Illustrate the diversity of fossils found at Joggins*
- *Give a sense of the Coal Age ecosystem at Joggins*
- *Show how scientists use fossils to recreate the past*

Key message:

The diversity and quantity of fossils from Carboniferous era terrestrial life found in the cliffs at Joggins are, as far as we know, unparalleled anywhere on the Earth's surface. They provide unmatched insight into the evolution of their original Coal Age ecosystem.

Storyline – Content:

During this era life moved on to the land. The earliest known land-dwelling creature was a Joggins reptile

The ecosystems preserved in the rock record at Joggins evolved from seasonal drylands to forested wetlands, but it is the latter that forms the iconic archetype for the 'coal swamps' of this time. An adventurous dragonfly high in the air would have witnessed a landscape quite like that of the bayous of the Mississippi, with glints of silver here and there through the trees betraying the presence of water. As it descended to light upon one of the tallest trees, however, differences with modern forest swamps would become readily apparent. Beautiful, ornate geometric designs patterned the upper trunks of the trees, which had curious crowns, some looking like two-headed palm trees with cones dangling from their upper trunks, others with eucalyptus-like crowns with needle-like leaves 30 cm long high atop slender trunks.

Here and there further down, groves of 'seed ferns' with graceful, drooping fronds form a scattered understorey perhaps 10 m above the swamp floor. Grasses are nowhere to be seen, and would not appear until almost 250 years later. Instead, delicate ferns and other graceful plants grow at the base of the towering lycopsids. At the edge of the swamp forest, a lush green thicket of the giant horsetail *Calamites* pokes up through the sand and mud laid down by floodwaters that recently overtopped the network of many dividing streams.

There are no howling monkeys or calling birds, but only the sound of the wind whistling through long lycopsid leaves or stirring leathery fronds of seed ferns, the faint whirring of insects, and in the distance, the faint roll of thunder. On the dank floor of the swamp forest, a metre long *Arthropleura* slowly pushes through the litter of branches, cones and

Code: 10.1	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:
Biodiversity of the Fossils

leaves, startling a small, lizard-like reptile to scurry nimbly to safety inside a fire-scarred tree.

The framework of this ecosystem is provided by the towering lycopsid trees, which reached heights of over 30m. Fossilized trunks of these trees stand in the cliffs like great Grecian pillars. The two most commonly encountered genera of these trees at Joggins are *Sigillaria* and *Lepidodendron*.

All elements of the trophic system or 'food web' of the 'Coal Age' ecosystem are represented at Joggins: the trees were 'primary producers', the decaying remains of which were fed upon by invertebrate detritivores, which on land ranged from diminutive land snails to gargantuan millipede-like *Arthropleura*. These detrivores in turn were fed upon by carnivorous tetrapods (reptiles and amphibians ranging from 20cm long reptiles to lumbering, crocodile-like amphibious predators).

Flying dragonfly-like insects and predatory arachnids such as scorpions and huge whip spiders were interlopers of this simple food chain. At times when the forest swamps were flooded, the food chain in the dark waters was similar, with tiny crustaceans cleaning up the decaying plant matter, various arthropods from shrimp to horseshoe crabs scavenging the bottom, and a whole array of fish from small paleoniscids through lurking coelacanths to small but swift xenacanth sharks and fearsome, 2m-long rhipidistian predators, whose distant cousins had emerged from the waters as amphibians.

A lesser known aspect of the fossil record that has helped to define Coal Age paleontology is the record at Joggins of trackways and trails of crawling invertebrates and footprints of reptiles and amphibians. Whether it be the looping, bulldozer-like trails of the gargantuan *Arthropleura* browsing the floodplain, or the trail of two horseshoe crabs caught in the act of mating on a Coal Age sand bar, the trackways of creatures great and small paint an evocative picture of life in the 'Coal Age'. The footprint record of tetrapods (reptiles and amphibians) is as rich as it is varied. Names were first applied to Joggins specimens for many of the footprints of Carboniferous tetrapods, once agian giving Joggins a special place in paleontology.

From tiny, tree frog-like microsaurs to the footprints of an obviously heavy footed baphetid amphibian prowling the muddy shores for its next meal, with the twisting motion of its feet recorded as it extricated its feet from the sucking - and certainly stinky - mud of the Joggins swamps.

Code: 10.1	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:
Biodiversity of the Fossils

Resources:

Subdivison xv, drawn by Dawson	Figure 34 in *Acadian Geology* Note: *Acadian Geology* is now public domain, so there are no copyright issues
Sections etc. of the South Joggins Coal Formation, drawn by Dawson	Fig 35 in *Acadian Geology*
Subdivision XXVII by Dawson	Fig. 41 in *Acadian Geology*
Beds overlying Joggins Main Coal by Dawson	Fig 40 in *Acadian Geology*
Fossils drawn by Dawson	Fig 31 in *Acadian Geology*
Denderpetron Acadianum drawn by Dawson	Fig 142 in *Acadian Geology*
Denderpetron Oweni drawn by Dawson	Fig. 143 in *Acadian Geology*
Dawson's etching of 'Airbreathers'	Fig. 16 *Acadian Geology*
Dawson drawings of plants: *Lepidodendron*, Tree ferns, Ferns of the Middle Coal Formation, *Calamites*, *Sigilaria*, *Cordaites*, etc.	Figures 30, 37/38,161, 163, 166, 167, 168, 169, 170, 171, 172 in *Acadian Geology*
"Joggins Fossil Specimens", a list of land-dwelling invertebrates, flying insects, water-dwelling invertebrates, fishes, amphibians and reptiles, and plants, compiled by John Calder – see below.	As found in the collections of Don Reid, Brian Hebert, John Calder, the Nova Scotia Museum, the Redpath Museum, Fundy Geological Museum. Illustrations may be found on NSM Fossils website (www.museum.gov.ns.ca/fossils/sites/joggins and the Fossils of the Fundy Coast website: http://collections.ic.gc.ca/fundycoast/col.htm

Fossil resources for potential acquisition

Land-dwelling invertebrates

land snail	*Dendropupa vetusta*	BH collection
'whip spider'	*Graeophonus carbonarius*	DR collection
millipedes	*Xyloiulus sigillariae*	BH collection
	Archiulus xylobioides	DR collection
Arthropleura trail	*Diplichnites*	DR collection?

Code: 10.1	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

Biodiversity of the Fossils

flying insects

'dragonfly-like'	Megasecoptera	DR collection
	compound eye of someone's dinner in hollow tree, & SEM photo	Redpath

water-dwelling invertebrates

'shrimp'	*Pygocephalus dubius*	DR or BH collections
'horseshoe crab'.	*Belinurus sp*	FGM specimen
'clam coal'	*Naiadites*	sp. from beach
mega clam	*Archanodon westoni*	BH collection
nematode-like trail	*Cochlichnus*	DR collection
horseshoe crab trail	*Kouphichnium*	DR collection

Fishes

'shark' spine	*Gyracanthus duplicatus*	BH collection (at JFC)
'ray' teeth	*Ctenoptychius cristatus*	DR or BH collection
top predatory fish	*Megalichthys sp.*	DR collection
lung fish	*Sagenodus cristatus*	DR collection

amphibians & reptiles

jaw of largest predator	*'Baphetes minor'*	Redpath or BH collection
amphibian	*Dendrerpeton acadianum*	NSM collection
reptile-like amphibian	*Calligenethlon watsoni*	Redpath collection
amphibian tracks	*Limnopus mcnaughtoni*	DR collection
reptile-like footprints	*Matthewichnus velox*	BH collection
reptile-like footprints	*Asperipes flexilis*	DR collection
footprints of top predator	*Pseudobradypus 'rex'*	DR/BH collection

Plants

leaves	*Cordaites principalis*	
cordaite wood	*Cordiaxylon*	*polished sample for viewing cell structure under microspcopic & SEM photo (F-L)*
enigmatic fern-like	*Pseudadiantites rhomboideus*	DR or JC collection
seed fern foliage	*Neuralethopteris schlehanii*	DR collection
seed fern foliage	*Alethopteris discrepans*	DR collection
seed fern foliage	*Alethopteris decurrens*	DR collection
seeds	*Trigonocarpus* seeds	DR collection
fern-like plants	*Eusphenopteris obtusiloba*	DR or JC collection
	Senftenbergia plumosa	DR collection
	Renaultia crepinii	JC collection
'horsetail' stems	*Calamites* sp.	

Code: **10.1**	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:
Biodiversity of the Fossils

‘horsetail’ leaves	*Annularia* cf. *stellata*	
‘horsetail’ leaves	*Asterophyllites equisetiformis*	
‘framework’ lycopsid tree	*Lepidodendron aculeatum*	
framework’ lycopsid tree cones	*Lepidostrobus*	DR collection
‘framework’ lycopsid tree roots	*Stigmaria*	
lycopsid tree	*Lepidophloios laricinus*	
deciduous branch scars (‘knots’)	ulodendroid branch scar	
lycopsid tree	*Sigillaria mamillaris*	DR collection
lycopsid tree	*Sigillaria scutellata*	DR or JC collection
cones	*Sigillariostrobus*	DR collection

= only known or exceptional specimen
To be evaluated:
icthyosaur hoax "*Eosaurus acadiensis*" Yale Peapody collection
actual icthyosaur vertebrae Lyme Regis or eBay

Media approach:

The biodiversity of Coal Age life at Joggins, plants and animals both common and rare, will be presented through carefully chosen fossils that represent key elements from the collection. Many of these fossils will be displayed in showcases whose form and placement evoke rocks that have fallen from the cliff. Other key specimens will be integrated directly into the cliff itself, while certain fossils (like tree bark) will be accessible for visitors to touch and feel. Throughout the exhibit, real rocks will be placed in front of the cliffs, recreating the experience of the Joggins cliffs. At key points in the exhibit, these rocks will also contain specimens, highlighted with lighting and captions. Interactive activities – like “Rub a fossil,” where visitors rub traces of fossil tracks and other fossil reliefs, will appeal to younger visitors.

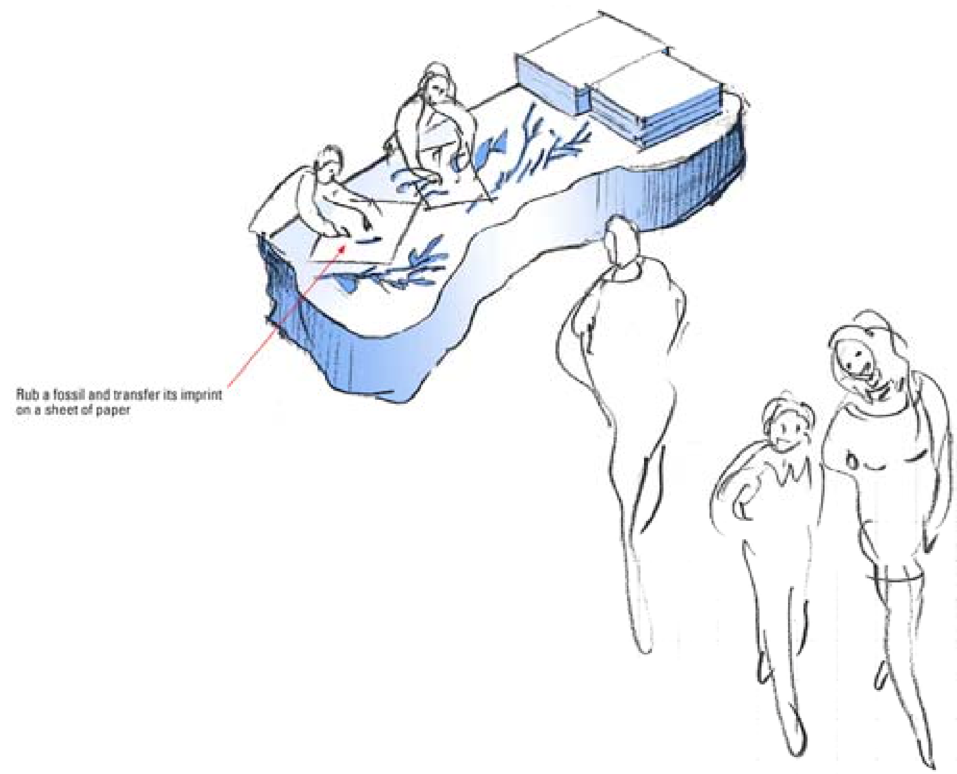
The fossils displayed in the showcases will be presented in a way that evokes their original Carboniferous context; for example, a fossilized fish scale might be accompanied by a drawing or rendering of the original animal in its environment, or by a life-size model of the original animal. Throughout this section, a variety of representations – 2D and 3D, modern and historical – will be used to show the diverse flora and fauna of Joggins during the Carboniferous era, and to explain how scientists are now able to understand the evolution of this Coal Age ecosystem.

Careful lighting design will help to show the fossils to best effect; this will be especially important in the case of fossil tracks and traces, which are often visible only under certain lighting conditions.

Code: 10.1	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

Biodiversity of the Fossils



Code: 10.2	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

Hollow Tree Fauna

Objectives:

- *Tell the story of the earliest known reptile,* hylonomus*.*
- *Illustrate* hylonomus' *original environmental context.*
- *Engage visitors in the project of understanding the hollow tree fauna.*

Key message:

The earliest known examples of lineages in the fossil record, including the earliest reptiles and amniotes, are found only in the hollow trees at Joggins. The hollow trees of Joggins provide us with an unusually high level of detail about what life on Earth was like for the first known reptiles.

Storyline– Content:

The discovery in 1852 by Lyell and Dawson of tetrapod bones in the interior of a fossil tree recently fallen from the cliffs at Coal Mine Point is one of the most famous of all fossil discoveries, recalled by Sir William Dawson late in his life in his memoirs *Fifty Years:*

> "*I well remember how, after we had disinterred the bones of* Dendrerpeton *from the interior of a large tree on the Joggins shore, his thoughts ran rapidly over all the strange circumstances of the burial of the animal, its geological age, and its possible relations to reptiles and other animals, and he enlarged enthusiastically on these points, till, suddenly observing the astonishment of a man who accompanied us, he abruptly turned to me and whispered, 'The man will think us mad if I run on in this way.'*'"

Lyell's reaction on the beach and in his later correspondence reveals that this was more than just the discovery of an interesting specimen. To Lyell, it supported his contention that sooner or later, higher life forms would be found throughout geologic time, setting to rest the notion of evolution, which he felt was more apparent than real. Unfortunately for Charles Darwin, this discovery at Joggins did nothing to help him win the public endorsement of his developing theory of evolution that he so badly wanted from his mentor Lyell.

For the next several decades, Dawson continued the search at Joggins for more creatures entombed within the standing trees. He would focus most of his attention on the fossil forest from where their 1852 discovery came, entombed in the 'lesser reef of Coal Mine Point'. In 1859, Dawson would discover a tetrapod whose significance would continue to grow even after he had passed away: the earliest known reptile, *Hylonomus lyelli*.

In 1878, armed with gunpowder from the mining company purchased with a fifty pound grant from the Royal Society, Dawson would detonate the sandstone reef that entombed the fossil forest, uncovering a total of 25 trees. Amazingly, over half (15 to be exact), contained the skeletons of reptiles and amphibians. This extraordinary cache yielded Dawson well over 100 individual reptiles and amphibians and to this day constitutes the world's richest collection of terrestrial tetrapods of the 'Coal Age'.

Code: 10.2	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:
Hollow Tree Fauna

Just how the tree fauna came to be entombed within the standing trees has captivated the imagination of scientists and public alike. Originally, in their discovery paper of 1853 read before the Geological Society in London, Lyell and Dawson offered three possible explanations: the creatures may have blundered into the once hollow trees once they became partially buried, much like falling through an open manhole, where they were doomed to die and driven to eat one another out of desperation; they may have been washed in by floods; or they may have crept in though some crevice and used the hollow trees as dens. Over the years, Dawson came to favour the first scenario, now known as the pitfall theory, and it has been depicted in countless artistic renditions in popular and scientific books.

Recent research by Calder advances an alternate hypothesis to the 'pitfall': that the creatures used the trees as dens, accessing the hollow trees by fire scars at the base of the trunks. The hypothesis has a wealth of support from modern analogues: nine-banded armadillos in bald cypress in the bayous of the Mississippi, racoons in the boreal forests of Nova Scotia, monitor lizards in eucalyptus trees of Australia, and countless others. As such, the Joggins tree fauna represent the first example in the fossil record of the hollow tree guild ('way of life'), and shows that animals and plants were already delicately intertwined ecologically soon after the first forests and terrestrial vertebrates evolved. This contrasts with the view that the first tetrapods were hapless victims of their environment, which was perhaps a human-centred view that pervaded Victorian times. And what of the role of fire? Fire, generated most probably by lightning, is prevalent in seasonally dry ecosystems, which Joggins is likely to have been. We can say with certainty that repeated passage of wildfire created the fire scars and openings for terrestrial creatures. The reasons why tetrapods may have used the openings are more conjectural, but the habits of modern tree hollow creatures provide some possibilities: the seasonal dryness, or perhaps oppressive heat, would have made the damp tree interiors a haven for tetrapods and eggs of the earliest reptiles alike. Predators may have dragged their unwilling dinner guests inside, while still others may have sought temporary refuge from the flames.

My dear Sir, - I have very good news to tell you. Agassiz only conjectures that the hollow-tree Joggins animal is a coelacanth fish ... you will be delighted to hear that in the same stone Wyman has worked out part of a vertebral column ... belonging to a distinct creature, and which he at once pronounced a salamander from the articulating surface of the ball-and-socket joints, &c. Afterwards, when it was shown to Agassiz, he exclaimed, - This is more reptilian than anything I ever saw in the coal! ....
<u>Latest intelligence.</u> - Dr. Wyman has just been here with great news. The first bone which we found is clearly not the hyoid bone of a fish, but the iliac bone of a reptile. Do not say anything about it, as every hour he is advancing...... So we have two reptiles according to this, and as only four individuals were previously known in the coal of the whole world, I hope we have added 33 1/4 per cent. at one stroke to the reptilian palaeontology of that era. Believe me, my dear sir, ever truly yours, Charles Lyell
-- in a letter of 9 November, 1852 to his young colleague, J.W. Dawson

The tree fauna present an opportunity for the visitor to be engaged with the process of developing a scientific hypothesis that best explains the various facts ('Ockham's Razor'!). They could either passively witness the very scenarios re-enacted, or could be

Code: 10.2	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:
Hollow Tree Fauna

challenged with putting together their own hypothesis, step by step. The salient points regarding the hollow tree fauna (there are many more 'details') are these:

1. the trees were clearly once hollow *This opens the possibilities ....*
2. the creatures lie at the bottom of the tree interiors, having arrived there before any sediment had begun to wash in.*This presents a problem for falling in and being washed in: why did they only fall or wash in before the trunks began to be infilled intermittently?*
3. every skeleton has been picked apart, or disarticulated. *Likely they were someone's dinner: if they were meals of desperate tetrapods (a 'Coal Age' sitcom), where is the articulated skeleton of the ultimate survivor?*
4. every skeleton is found together with fossil charcoal. *Fire played a role, always.*
5. fossil 'poo' (coprolite matter) is sometimes in abundance. *They were alive in the trees for some time.*
6. the tetrapods are found together with millipedes and land snails. *These creatures are happy feeders of rotting plant material, and have long been considered to be at home in the tree hollows: why not the tetrapods?*

To these can be added points that have come to light in recent years, which may strengthen (or lead them to change) their chosen scenario:
1. In 1995, a tetrapod-bearing tree was found at Joggins that had a charred, notched base representing a 'fire scar'.*Thus presenting another way other than by pitfall*.
2. Many animals today, (including amphibians, reptiles, mammals and birds), in every forest environment or biome, use tree hollows as dens. Many access the hollow trees via fire scars. *Modern analogues show that the Denning theory works.*

Resources:

Depictions of the pitfall scenario: - *Hylonomus* painting by John Sibbick in Czerkas & Czerkas' '*Dinosaurs: A Global View*' (1995) - line drawing in Carroll's 1970 paper - step-by-step pitfall in Laing Ferguson's Joggins booklet	Calder SBI Tree Fauna file
Dens in modern fire-scarred trees: - tree of southern cypress swamps, home of a nine-banded armadillo - boreal forest tree, home of a porcupine	Calder SBI Tree Fauna file

Code: 10.2	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

Hollow Tree Fauna

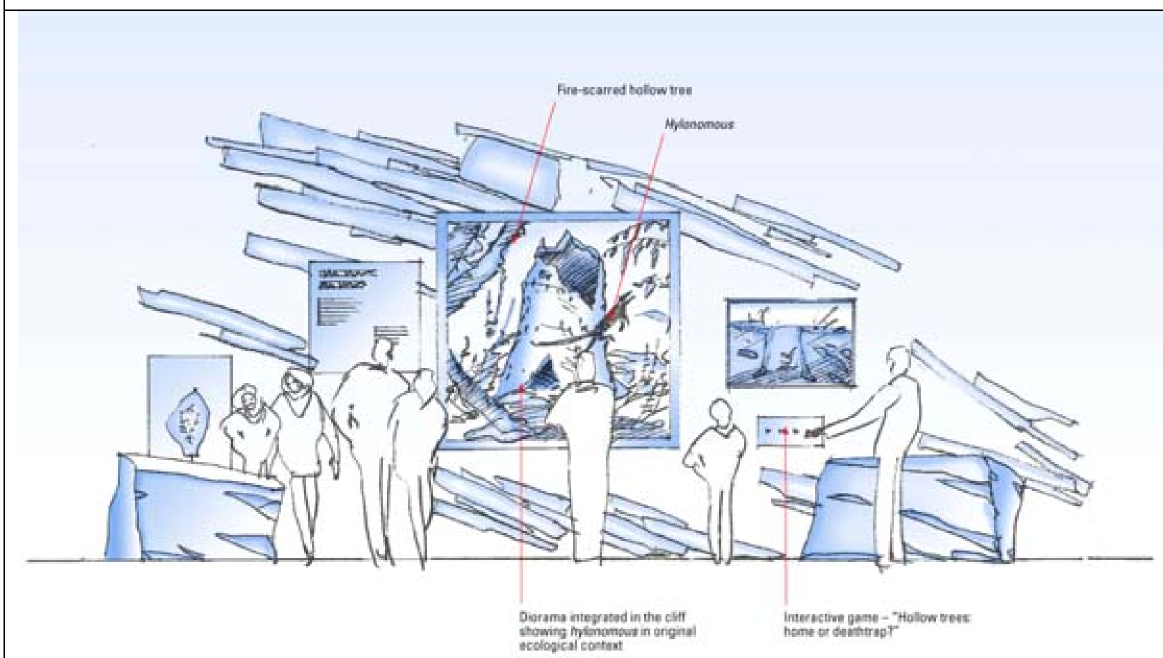
Depictions of the Denning scenario: - Steve Greb's rendition	Calder SBI Tree Fauna file
Tree section drawn by Dawson	Calder SBI Tree Fauna file
Charred tree fossil *in situ*	Calder SBI Tree Fauna file

Media approach:

Several elements will contribute to the visitor experience:

- Dramatic, carefully lit diorama integrated in the cliff, based on Doug Henderson's rendering of *Hylonomus* and showing the original ecological context of this first known terrestrial reptile. The diorama will also show a fire-scarred hollow tree, with *Hylonomus'* head poking out. Text and graphics will enrich the story and provide context allowing visitors to better understand the significance of this reptile.
- Interactive game – "Hollow trees: home or deathtrap?" – where visitors test their scientific skills by interpreting the evidence from the hollow trees to determine how it is that, 310 million years later, we find *Hylonomus* in the hollow trees at Joggins.

This complements the Hylonomus *fossils and interpretive content found in the Big Ideas section (see 8.4).*



Code: 10.3	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

How Fossils Formed at Joggins

Objectives:

- *Show how fossils are formed*
- *Explain the unusual conditions at Joggins that led to the formation of terrestrial fossils*

Key message:

There are different kinds of fossils (as well as other traces), each of which forms under different conditions.

Storyline – Content:

There are two main types of fossils: body fossils and trace fossils. Body fossils include any part of the actual animal or plant. Things like bones, teeth, shells, and leaves are considered body fossils. Trace fossils give us proof of animal life from the past. Trace fossils include things like footprints, burrows, and coprolites (fossilized poop).

How Does Something Become a Fossil? Live. Die. Get buried.
But it's not quite that simple. . Most plants and animals will not become fossils They decay very quickly or get eaten by other creatures. If a plant, an animal, or a trace is going to become a fossil, it has to be buried rapidly by sediment (like mud).Generally speaking, conditions on land don’t make for good fossilizing conditons. So what were the underlying conditions at Joggins that made for such good preservation?

At Joggins plants and animals were buried during times of heavy rain, when the streams overflowed their banks and flooded lowlands. There were also times when the area was covered by shallow water environments and then parts of fish and other aquatic life became buried in the bottom of the lake or lagoon. Over time, many layers of sediment built up and eventually turned to rock.

Trace fossils provide palaeontologists with evidence of the activities of ancient animals - something body fossils simply can't do. Trace fossils are formed in place and can therefore tell us about the ancient environment in which the animal lived. One single animal can make thousands and thousands of traces in its lifetime, but it will only leave behind one body when it dies. Because of this, trace fossils are much more common than body fossils.
Source: NS Museum of Natural History

Not really Fossils
Some of the most obvious evidence of the ancient environments at Joggins are technically not fossils. These are features such as ripple marks, impressions of rain drops and mud cracks all of which were formed at the time that sediments were deposited or soon afterward. You can see exactly the same forms today when you visit a sandy beach or walk along the banks of a muddy river.

Current ripples form by the actions of water or wind over mud or sand. They may be symmetrical

Code: 10.3	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

How Fossils Formed at Joggins

with sharp crests and fairly equal slopes on either side of the crest. These indicate a back and forth motion in the environment. Asymmetrical ripple marks have a sloping and steep side, with the steep side facing downstream or down wind in a single current direction environment. This can be seen in a creek formed by a water or wind flowing in a single direction.

Mud flats may be created by flooding, in an inter-tidal area, or in silt/clay when a body of water like a lake dries up. The cracks form when mud shrinks, and vertical crack results. The fossilized cracks are usually filled with a different sediment, such as sand. Most mud cracks form horizontal 5 sided shapes.

Raindrops form random small, circular craters generally with raised edges.

Features like these help palaeontologists to imagine what the environment was like. What directions did the streams flow and how fast? Was a body of water shallow or deep? Was the weather dry and hot or was it rainy?

Resources:

- Specimens, diagrams or models
- Laing Ferguson's Joggins booklet
- Series of simple models showing how trees were fossilized (similar to Ferguson, pg 16 A – C), concluding with a photo of a real tree in the cliffs (use an example with a person to provide scale such as Fensome: Joggins Project #20). Specimens of Arthropleura trackway and reptile-like footprints
- Specimens of sedimentary structures: ripple marks, rain pits, mud cracks, with photos of present day examples – perhaps from the banks of River Hebert.
- Photos of infilled channel and reefs with diagram similar to Ferguson pg 35, A - E)

Media approach:

Illustrations and models that show the different kinds of fossils found at Joggins and explain how they were formed.

This complements the fossil experiences offered at the demonstration area (see section 11), where visitors can see the different microstructures of various kinds of fossils.

Code: 10.4	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

How to see Fossils at Joggins

Objectives:

- *Show where fossils are found at Joggins*
- *Help visitors prepare for a visit to the cliffs.*

Key message:

Fossils are easier to find when you know what to look for!

Storyline – Content:

How to see fossils and other features of the shore:

- People who visit the cliffs and shore line at Joggins but do not know what to look for are often disappointed. To help you appreciate the wonders of the cliffs here are some features to look for and strategies to try when you explore the shore.
- Most obvious are the layers in the cliffs, evidence of changing environments over time.
- Upright trees are uncovered regularly by erosion but also eventually fall out of the cliff. Ask a guide what can be seen at the moment.
- Near the base of the Dugway you can see a bed of shell coal, the remains of shells and other marine life.
- Also on this shoreline look for what looks like small pieces of water-washed red brick. These are really pieces of clay that formed above layers of coal that have turned to stone.
- The most commonly found fossils are bits of plants: the impression of bark, fragments of ferns, or pieces of tree root. They will often be crisp and clear when first exposed but are quickly rounded and softened by the Fundy tides
- At several locations you will see evidence of coal mines and the wharves that were used to ship the coal.
- There are fossils on the beach but to see them you need to develop your eye. Some local residents have visited the beach thousands of times and always find something new.
- Having a search image can help. By examining the fossils in the centre you will know what can be found. Sometimes it helps to concentrate on looking only for something small or something large. It takes experience to see both large and small at the same time.
- Light does help. When sunlight strikes a rock's surface at a low angle it can make fossils or traces more obvious. Hold the rock that interests you in the light and change the angle. Sometimes a faint trace will become clear and strong.
- And sometimes what you need to do is to sit down on a rock and enjoy the view. You may find more when you are not looking too hard!

Code: 10.4	Central theme: *Coal Age Ecosystem at Joggins*	

Subtheme:

How to see Fossils at Joggins

Resources:

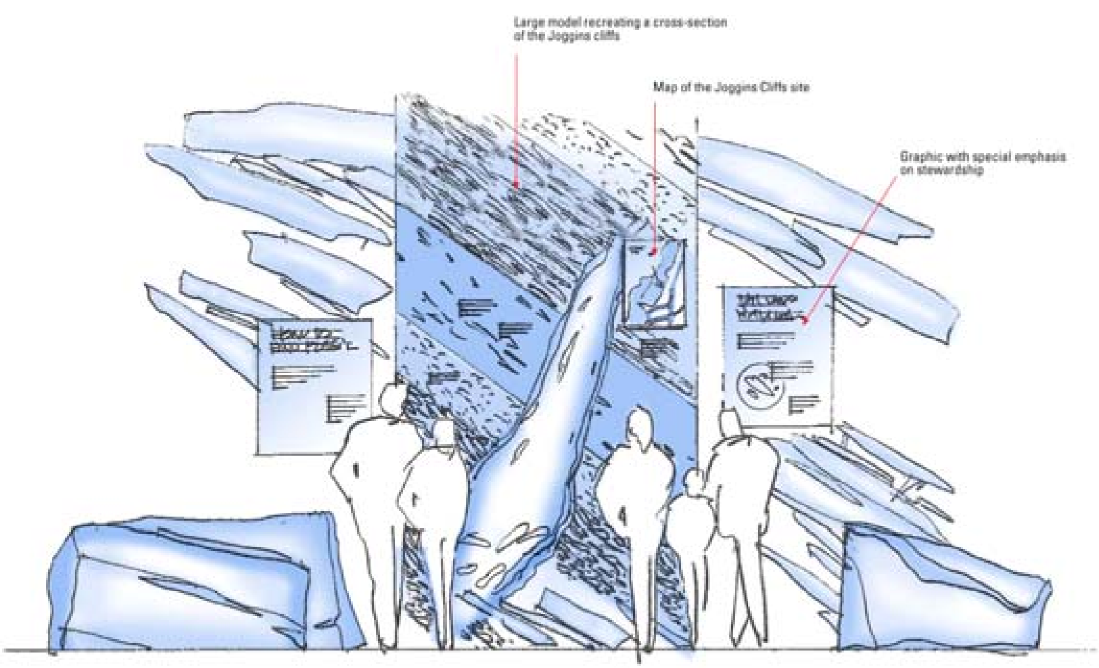
- Specimens

Media approach:

This area features several different elements:

- Large model recreating a cross-section of the Joggins cliffs, showing where fossils (as well as coal and other traces of the past) are most likely to be found.
- Map of the Joggins Cliffs site, showing the area where fossils are located and explaining which fossils are most likely to be found at different points along the way.
- Text and graphic panels, with a special emphasis on stewardship and the collection policy.

Much of this information could also be included on a brochure that visitors can take with them to the beach.



Code: 11.0	Location: Exhibit hall	

Central theme:

Demonstration Area

Subthemes	Objectives:
11.1. Research Today 11.2. Fossil and Microfossil Observation 11.3. Fossil Preparation	• *Show the scientific work being done at the JFC site* • *Let visitors play the role of a scientist and work with specialized tools* • *Display special fossils recently found by visitors*

Key message:

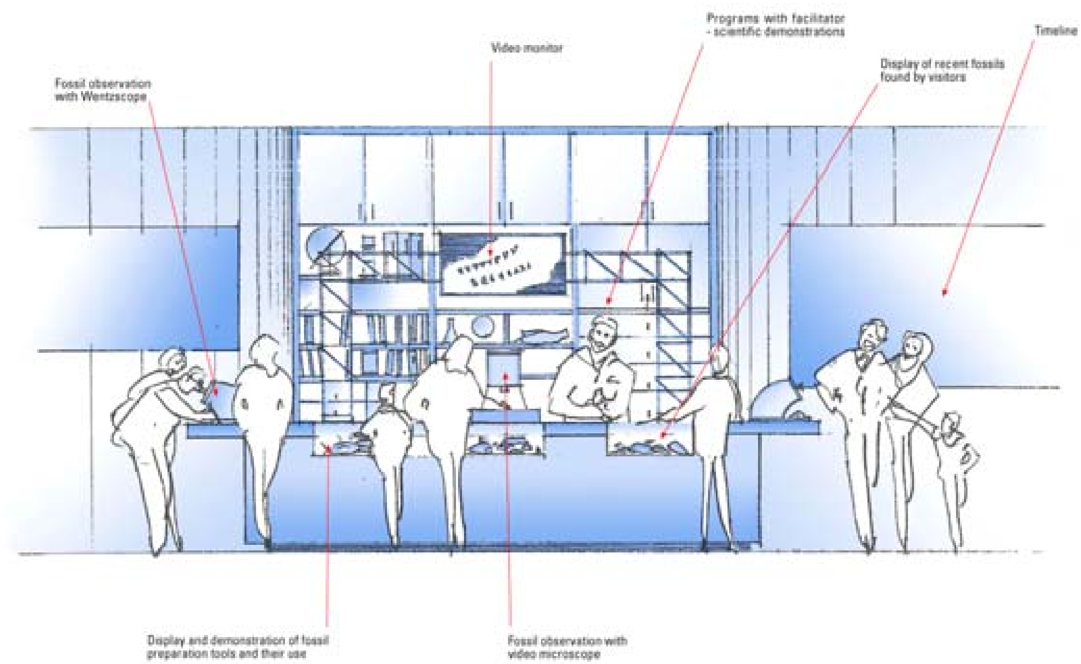
Working with a range of different tools, scientists continue to make new discoveries at the Joggins Fossil Cliffs.

General media approach:

This area is perfect for programs and guided tours, but can also function as a standalone space. Some of the elements that will be featured include:

- Fossil observation with Wentzscope or video microscope
- Programs with facilitators or guides
- Scientific demonstrations
- Current news – what is happening at Joggins today ("bulletin board")
- Display of recent fossils found by visitors and judged as being of particular scientific interest
- Display and demonstration of fossil preparation tools and their use

Code: 11.0	Location: Exhibit hall	



Code: 11.1	Central theme: *Demonstration Area*	

Subtheme:

Research Today

Objectives:

- *Show the ongoing importance of the JFC site*
- *Introduce visitors to the ongoing research being carried out onsite*

Key message:

Scientific research is ongoing at the Joggins Fossil Cliffs.

Storyline – Content:

The Joggins Fossil Cliffs are extraordinary not only because of the importance of past research but because new discoveries are still being made and will undoubtedly continue to be made in the future. Each year the relentless tides of the Bay of Fundy reveal new fossils and features that add to our knowledge of the Carboniferous. And since the fossil bearing rocks continue for about thirty miles inland, we are guaranteed endless opportunities to learn more.

Fossils alone cannot tell us everything of their environment. Each layer, or 'bed' of sediment now turned to stone provides geologists with clues as to the ancient environment of Joggins. Sedimentary rocks offer excellent clues to interpreting both the ancient climate and in reconstructing the landscape: the layers exposed in the cliffs at Joggins are such sedimentary rocks[1]. Each layer, or 'bed' of rock was once a layer of sediment that has since turned to stone over millions of years. The magnificent cliffs at Joggins excite geologists who study sedimentary rocks every bit as much as the fossils excite palaeontologists!

Scientists today are studying a number of areas. Papers are being published about the rock record and sedimentology, Dawson's work on animals, and on fossil footprints and other types of fossils.
(This is an opportunity to highlight recent finds and research and to identify if researchers are currently at the site).

[1]All rocks on Earth formed in one of three ways: 1) from molten rock that originated deep within the Earth ('igneous' rocks); 2) from 'recycled' fragments of older rocks, these fragments ranging in size from microscopic particles (clay) to sand grains, gravel and even boulders (sedimentary rocks); or 3) rocks that have been transformed from one of these two types by great heat and pressure (metamorphic rocks). Fossils are found in sedimentary rocks (and sometimes they can still be seen in metamorphic rocks that were originally sedimentary).

Code: 11.1	Central theme: *Demonstration Area*	

Subtheme:

Research Today

Resources:

Delegates to the International Geological Congress dine on the beach, 1913	SBI Visitors / Joggins 1913 lunch
North American Paleontology Convention delegates on the Beach, 2005	SBI Visitors / NAPC Group photo
List or abstracts of current research projects	John Calder

Media approach:

- Changing display showing ongoing research
- Showcase of recent scientific publications dealing with Joggins
- Multimedia station featuring 4-5 interactive interviews with scientists who continue to conduct research at Joggins

Code: 11.2	Central theme: *Demonstration Area*	

Subtheme:

Fossil and Microfossil Observation

Objectives:

- *Reveal the hidden secrets of tiny fossils*

Key message:

There is more to fossils than the naked eye can see.

Storyline – Content:

In any modern ecosystem there are many more small animals than there are large. This was also true in the Carboniferous ecosystems preserved at Joggins. The large number of individuals means that there was a better chance for small plants and animals to be preserved as fossils than larger ones. And when you are introduced to fossils such as a tiny fish tooth, a delicate amphibian jaw, ambiguous fish scales or even fossilized "poop" (coprolites) a new world of fossil discovery opens up.

Fossil hunting is all about careful observation and if you know what you are looking for you are much more likely to see it. This is what scientists call a "search image." The Demonstration Area is where visitors can hone their fossil search images or marvel at the diversity of life that has been preserved.

Resources:

Specimens, especially microfossils and fossils with interesting cell structures
(Include waterwashed specimens as well, to illustrate erosion of fossils)

Media approach:

- Wentzscopes / video microscope with samples of particularly interesting specimens that visitors can explore
- The Wentzscopes / video microscope can be used by visitors, but can also be used as part of programs or guided tours.
-

Code: **11.3**	Central theme: *Big Ideas*	

Subtheme:

Fossil Preparation

Objectives:

- *Show the tools and the work involved in preparing fossils for display*

Key message:

Preparing fossils so that they will best reveal their secrets is both an art and a science.

Storyline – Content:

A fossil destined for a public collection goes through many steps after it is discovered. Its location must be described and recorded, it may require preparation in order to be fully exposed and to be studied, it may be the subject of research (now or in the future), and must be stored with care and its documentation maintained.

People are often most fascinated by how fossils are prepared. The various types of fossils at Joggins require different methods of preparation. Plants do not need much work but the techniques for dealing with bone material are very sophisticated. Exposing tiny bones requires working with high magnification to be able to see what you are doing and miniature tools to remove bits of stone that can be smaller than a grain of sand.

Resources:

Tools used in fossil preparation (see, e.g. the demonstration area at Miguasha)

Media approach:

Display of the tools used in fossil preparation. Whenever possible, tools will be accessible by the public (though not powered!) The tools may be used by guides and interpreters as part of public programs and tours.

Code: **12.0**	Location: Various locations on site.	

Central theme:

Site-wide Interpretation

Subthemes	Objectives:
13.0 Site Interventions 14.0 Guided Tours 15.0 Hiking Trails	

Notes:

The site should own and operate a 15 passenger bus.

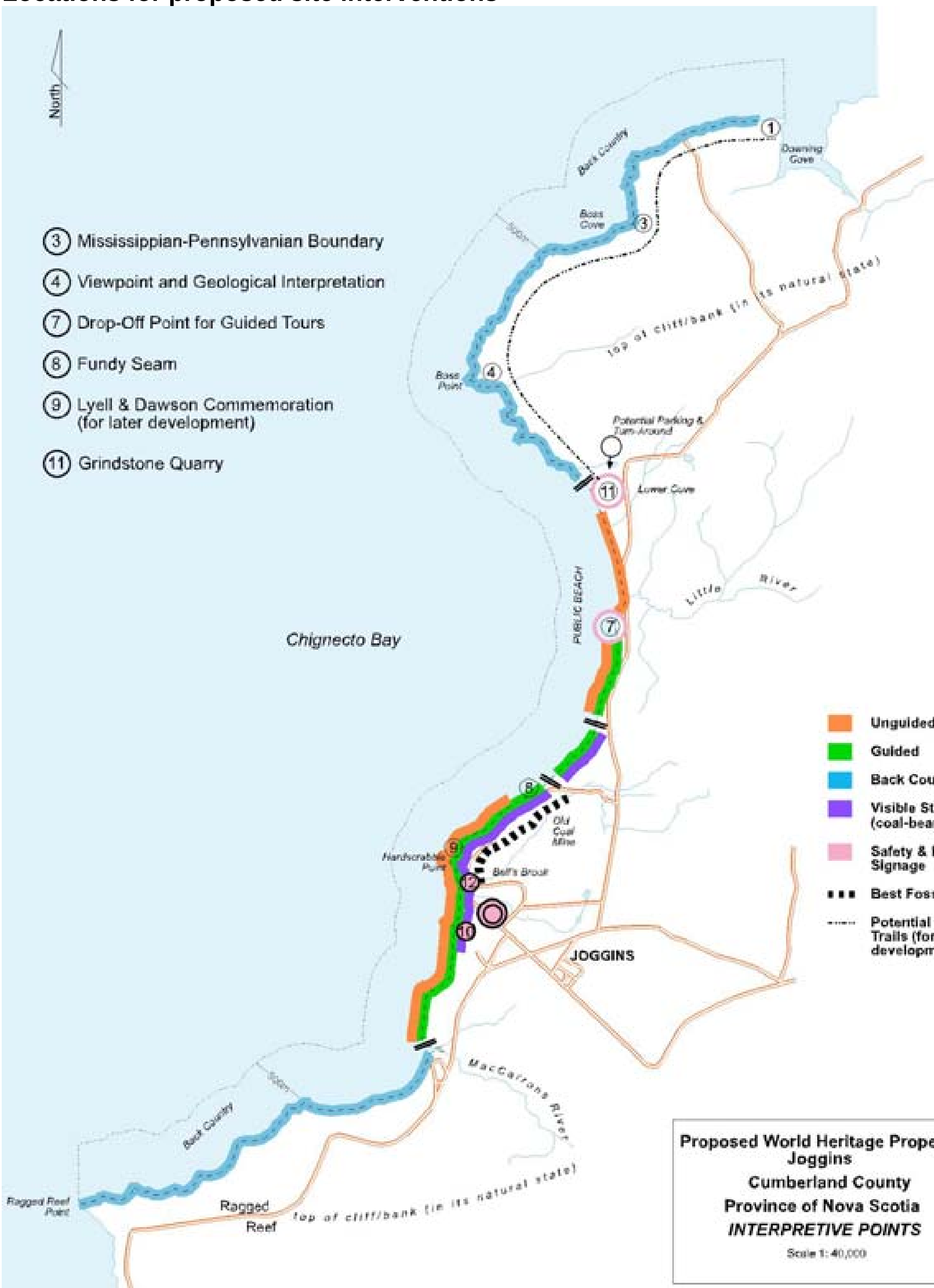
Some other site ideas mentioned:

- Carboniferous themed children's playground
- "Ten things you must see" brochure
- Various brochures for self-guided tours of the cliffs
- Carboniferous themed garden / landscaping
- Welcome signage for the site at the point when the Bay of Fundy becomes visible

Program ideas rejected by client:

- summer day camps
- sleepovers
- eco-tours

Locations for proposed site interventions



Code: 13.0	Location:	

Central theme:

Site Interventions

Numbers reference map on previous page.

Site	Shore Access	Intervention	Theme	Self Guided	Guided Group	Phase
(7) Lower Cove	Yes	Standard Sign* Interpretative Signage	Geology of the site			1
(8) Fundy Coal Seam		N/A	Fossil Trees Trip to Coal Age Mining	Yes	Yes	1
(10) Interpretation Centre / Dugway	Yes	Standard Sign* Interpretative Signage	A) Bay of Fundy B) Coal Mining	Yes	Yes	1
(11) Grindstone Quarry	Yes	Standard Sign* Interpretative Signage Kiosk & Toilets	Grindstone industry	Yes		1
(12) Bells Brook	Yes	Standard Sign*				1
(9) Coal Mine Point		Interpretative Signage Bronze Statues	Lyell & Dawson			2/3

* Standard Signs to include:

1. **Safety**
   - General safety message
   - Recommended equipment, boots, clothes for visiting the beach
   - Tides (monthly schedule)
   - Dangers of falling rocks
1. **Stewardship**
   - Collecting policy
   - Stewardship (and space for eventual UNESCO text / logo)
2. **Orientation**
   - Map - "you are here"

Code: 14.0	Location:	

Central theme:

Guided Tours

Proposed tours:

Tour	Time	Group	Guides	# of tours a day	Phase
Little River (4) to Centre (10)	4hr incl. shuttle	15	1	TBD	1
Interp Centre (10) to Fundy Coal Seam (8)	3 hr	15	1	TBD	1
Interpretation Centre (10) to Coal Mine Point (9)	1 hr	15	1	TBD	1

Code: 15.0	Location:	

Central theme:

Hiking Trails

Proposed hiking trails:

Hiking Trail from Grindstone Quarry (11) to Downing Cove (1)	N / A	N / A	N / A	N / A	2

Preliminary Building Requirements

Description	Net surface (m^2) Room	Total	Floor loading Normal load	Loading @ 700 kg/m^2	Wall structure Normal	Reinforced	Acoustic insulation Normal	Extra
Lobby		171	√		TBD	TBD	√	
Exhibit hall		321						
Main space	236			√		√	√	
Theatre	64			√		√	TBD	
Demo area	21			√		√	√	

Description	Electrical requirements Normal	Exhibit (30 W/m^2)	Lighting requirements Exhibit (50 W/m^2)	Show (100 W/m^2)	Show (200 W/m^2)	Service	Service requirements AV Conduit	Water / Plumbing
Lobby	√					√	TBD	
Exhibit hall								
Main space		√	√			√	√	
Theatre		TBD	√			√	√	
Demo area		TBD	√			√		√

Description	Communication requirements Computer network	Surveillance camera	Telephone	Comments
Lobby	√	TBD	√	
Exhibit hall				
Main space	√	TBD	TBD	
Theatre		TBD		
Demo area	√	TBD	√	Other lab requirements to be determined.

1. Joggins Fossil Cliffs Visitor Centre Site (C1)

Most visitors to the Joggins Fossil Cliffs will begin their visit at the main Fossil Cliffs Visitor Centre Building on lower Main Street in Joggins. The approach to this site is considered as part of a sequence of events leading to the building entrance and carrying through to the visitors' engagement with the interior of the facility, the staff, the program elements, interpretation exhibits and other amenities. The village itself is part of the visitor experience and it is hoped that the relationship of Centre to village will assist in general economic development and the growth of related and supporting visitor amenities throughout the community. The following narrative will describe a typical approach and visit to the Centre as a sequence of events, revealed views and encounters with site elements as proposed by the concept.

A visit to the Centre typically begins on the highway at the eastern outskirts of town where welcome signage identifies the community of Joggins and alerts visitors to the Centre located on lower Main Street Passing through the town, graphic banners on the power poles provide a colourful entry rhythm down the street and support the directional route to the Centre through town. These banners may supplement or replace existing banners with new themes or graphics that will be highlighted in the Centre itself. The Bay of Fundy is clearly visible in the distance and this water view is an important orientation marker to our approach.

Figure 1 - View to west on Main Street in Joggins

Leaving the main portion of the downtown area as we approach the Visitor Centre, Main Street takes a gentle bend to the left to enter the Centre grounds between existing trees and other natural vegetation. This provides 'main road' navigation right to the door of the Centre as the building itself is not yet clearly in view. It also removes unintended visitor traffic from the remainder of the existing Main Street alignment and the private homes fronting the street in this area. These properties have access from a turn-off road back to the remainder of old Main Street marked for local traffic only. Access to this portion of Main Street is unimpeded when the Centre gates are closed and the existing Main Street cul-de-sac continues to serve as a turnaround to local street traffic. The intersection of Hardscrabble Road is also to our right and the intersection alignment has been corrected to improve traffic safety at this location.

Figure 2 - New Entry Road will curve past pole on left

Continuing through the gates past the Centre welcome signage the water view goes briefly out of sight as the road passes beside existing and new vegetation edged to our left. Signage to the right directs buses, campers, trailers or other over-length vehicles to the dedicated pull-through parking area set back from the adjacent houses and buffered from view by vegetation. As the entry driveway continues by this parking area, we pass through flanking trees and the Centre building appears in full view silhouetted against the expanse of the Bay of Fundy beyond. The revealed view of the building at this point is the “a-ha” moment, your arrival at the Centre is confirmed and your imagination and curiosity about your visit to the site and building further stimulated. The dramatic architecture of the building is presented in its best light as the building is highlighted in a visual field of long grasses, stone, existing or naturalized vegetation groupings all set against the backdrop of the sea and the sky.

Figure 3 - Initial view of Visitor Centre site with Bay of Fundy in background

The visitor encounters a generously scaled entry plaza with a vehicle drop-off lay-by. The main entrance is directly in the line of sight and the parking area curves away to our left. This orients the visitor clearly to the entry location and parking while diminishing the visual impact of a single large parking area in front of the building. The parking and entry driveway curves away to the south and the entry driveway loops back to meet itself at the bus/trailer turn-off point initially encountered. This allows tour buses and other vehicles to initially bypass their dedicated parking area to discharge or pick-up passengers at the entry plaza first and then use the loop back road to assume a position in the bus parking area while waiting for their parties to emerge after their visit. The parking positions facing the entry doors allow bus drivers to see their groups emerging from the Centre and to move into the bus lay-by area for pick-up. It is recommended that the Centre adopt an “engines off” policy for all parked vehicles to diminish nuisance noise and fume impacts on local residents.

The parking area provides ample parking for up to 60 cars including dedicated barrier free spaces near the building main entry. The parking area and entry road can be constructed in a variety of surfaces including asphalt and/or gravel for the entry road way and any combination of asphalt, gravel and reinforced lawn for the parking areas. The parking area has been subdivided into bays of up to 12 cars each to further reduce visual impact of the parking area and to allow for surface materials changes. The final distribution of hard to soft surfaces can be determined by an analysis of budget availability, ease of maintenance and all-weather use demands. Should the Centre need year round parking, more hard surfaces may be favoured for ease of maintenance and user comfort. Summer time only use may favour mainly gravel or grass parking surfaces. Additional overflow parking can be accommodated in open grassed areas of the site or along the entry road shoulders. It is recommended that the parking bay closest to the building be fully paved to facilitate the barrier-free parking requirement and to provide a modest capacity of all-weather, all-season parking.

Returning to the entry plaza via concrete walkways from the parking area or bus lay-bys, the concrete surface narrows and the visitor encounters sweeping surface inlays of patterned sandstone paving complimentary to the stonework of the building envelope and suggestive of the waves of the Bay of Fundy. The curves draw the visitors toward the entry and converge on the front doors. The curving theme carries through the building in floor pattern, walls and general themes of the interpretive displays within.

As the visitor approaches the main entry colonnade, the building and plaza becomes edged in a stone 'beach' suggestive of the relationship between beach and cliff faces of the fossil cliffs themselves. The colonnade itself is suggestive of the forms of the mine structures that once occupied this site. A bridge passes over the cobble beach to the right and connects the main entry with a projection of the central core out into the site to the east. Passing over this bridge, the stone surface becomes irregular and disappears in the grass of this exterior display and informal picnic area.

The plaza carries on beyond the colonnade to provide an entrance address for the administration and service area of the building and the entry to the proposed RCMP satellite office. Passing through a portal flanked by the building and roof forms, the visitor accesses a path to a viewpoint opportunity north west of the building and a potential trail route beyond.

Figure 4 - View to Coal Mine (Hardscabble) Point northwest Of Visitor Centre site

The generous plaza area also provides a mustering area for the guided tours to the fossil cliffs. The Centre's bus pulls up to the nearby bus lay-by and the assembled group drives off the Centre site to the main cliffs and beach trailhead at Lower Cove and the park facilities at Grindstone Beach described below. The bus turns just outside the Centre site gates to follow Hardscrabble Road to Lower Cove providing panoramic coastline views along the way.

Visitors can also exit the building at the south end toward the Dugway to visit the observation platform or to use the integral staircase to access the Joggins Beach area for guided or self-guided tours. Once through the building the sinuous curves introduced at the north entry plaza and building interior continue down the pathway to carry the visitor along visually to the observation platform and staircase access at the Dugway. The rear entry to the building is flanked by another large stone plaza surface forming an outdoor café area. This area is furnished with casual tables and seating and is buffered from winds by the structure and nearby plantings. Return pathways nearby are available to carry visitors back to the parking area or to return back to the building to exit at the front or join a tour group.

Figure 5 - View South from Dugway overlook

In general, the area west of the building to the cliff face is not highlighted for public use due to the cliff edge and erosion hazard in this area. It is expected that the cliff edge will be vegetated in low growing hardy natural vegetation to help stabilize the top of the bank against further erosion.

2. Joggins Beach & Dugway Access (C1)

The Dugway observation platform and staircase provide the principal means of pedestrian access to the Joggins Beach area. This structure minimizes the construction intervention in the Dugway cut avoiding creating additional excavated materials that may require removal or on-site disposal and encapsulation treatment if contaminated by mining activities. The lower section of the staircase can be removed in the off-season to minimize damage from winter ice and tides. Visitors descend this staircase for out-and-back tours of the immediate area (Beach and Coal Mine point) or to return from the more extensive guided tours that may have originated at Lower Cove. Returning visitors ascend the structure after tours to return to the building for refreshments, to purchase gifts, to view further exhibits or to return to their vehicles. Local pedestrian access to the Beach can be accommodated at this structure but it is more likely that the local population will continue to use the Bells Brooks access for convenience. Vehicular access to this beach area during low tide is provided from the McCarrons River access described below.

3. Grindstone Beach Access Park & Turnaround (C1)

A key element in the development of a comprehensive approach to visiting the fossil cliffs is the necessity to get visitors from the Fossil Cliffs Visitor Centre to the beach and cliffs at Lower Cove approximately 4 km away. This is problematic in that the best access point at the Lower Cove bridge has virtually no land area to provide for parking or other amenities. Further, the access is on the west side of the road requiring visitors approaching from Joggins to turn around on the highway or in a private driveway and park on the narrow shoulder of the road to face southward. Additionally, little space is available on the preferred south side of the bridge forcing parking to the north side and pedestrians to cross the narrow bridge with no dedicated pedestrian walkway. Increasing numbers of visitors brought to the site by the new Centre would make the situation intolerably congested and inherently unsafe. An alternative site for parking and turnaround needed to be found and it is close by at the former grindstone quarry at the north end of Lower Cove Beach.

Figure 6 - Grindstone Beach park site looking south

The 'Grindstone Beach' site is ideally situated to provide a number of useful amenities. It provides a safe location to safely turn around a bus travelling from the Centre site to the cliffs. It has sufficient land area to provide for parking of private vehicles off the highway. It is a convenient beach access point with a low scarp at the water's edge that makes a ramped barrier-free access to the beach in this area possible. The site was formerly occupied by quarrying operations and is reasonably level and sheltered by existing trees. The existing long grass could be mowed and upgraded to adapt this area as a picnic park, playground, hiking trailhead, scenic look-off and/or interpretive viewpoint. Remnants of the grindstone quarrying operations are visible and there are numerous grindstone fragments littering the beach. It is recommended that the existing pit toilets and other equipment from the Bells Brook site be relocated to this site as user amenities. Higher levels of service such as running potable water and electricity could be provided as desired and as budgets and management priorities are developed. Full services such a flush toilets and showers are probably beyond the scope of currently envisioned needs at this site although the potential exists to add high level amenities in future. Some safety measures such as fencing will need to be constructed to control access to some of the water filled pits of the former quarry.

Figure 7 – Water-filled quarry pit

The attached concept site plan shows one possible pattern of development with a turnaround loop and adjacent small parking area fairly close to the shoreline. Sufficient space exists for other alternatives that could relocate either or both of the turning loop and parking area closer to the highway with a walk-in path to the main site. Gates at the highway entry point would close the site to vehicle access in off-hours or off-season. It is also recommended that local residents be engaged to provide a degree of site monitoring to protect the facility from abuse.

Figure 8 - Access road to Grindstone Beach from highway

This site is both a bus turnaround and a potential bus stop. Visitors from the main Centre site could disembark from the bus at this point and use the amenities in the vicinity and return to the Visitor Centre by scheduled bus or hike back. The use of private cars could be discouraged gently by providing regular legible bus service to this and other sites. A visitor using the site bus also has the advantage of being both a paid visitor and someone whose whereabouts can be registered with site staff for safety monitoring.

It should also be noted that the only element of the recommended 'Grindstone Beach' plan that is critical to the primary site visitor experience is the bus turnaround. Should resources not be available to develop this site as described above, a bus turning loop close to the highway at the head of the existing access road could be developed alone. This would provide the safe turning capability described above and key to the safe use of the limited Lower Cove access point approximately 1km to the south.

4. Lower Cove Bridge and Beach Access – "The Bus Stop" (C1)

The existing gravel access ramp is the only logical (and limited) option for visitor pedestrian access to the main portion of the Fossil Cliffs to the south. The very limited land base to the south of the existing bridge demands that a compact bus lay-by be developed off the highway surface in the small area south and west of the creek and bridge at the head of the gravel ramp. The lay-by must be on the west side of the highway to avoid pedestrians disembarking on the far side of the highway and crossing the road with view obscured to northbound drivers. A lay-by on the north side of the bridge is problematic similarly as this requires visitors to cross a narrow bridge with no sidewalk and with railings and curb aprons in very poor repair.

The ‘bus stop’ can be accommodated in the available space and interpretive and safety signage should be located nearby (can supplement existing as warranted). The bus stop will need to accommodate both disembarking passengers and those returning to this point from shorter “out-and-back” loop tours.

Figure 9 - 'Bus stop' at Lower Cove Bridge

It is recommended that visitor parking on the shoulder of the road be actively discouraged although some local resident parking for beach access in this area is to be expected and will make this distinction somewhat difficult. Visitors should be directed to park at Grindstone Beach 1km north or (better) to park at the Centre and take the bus and guided tour.

Hikers approaching down the beach from the north will find it difficult to cross the outwash of the creek to continue along the beach and may need to cross the bridge to continue. The Department of Transportation should be approached to evaluate upgrading this bridge for enhanced pedestrian safety for this group of users. A bridge with improved pedestrian safety would not modify our recommendation to position the ‘bus stop’ in the location noted above for the primary group of users accessing this site.

Figure 10 - Lower Cove Bridge looking north showing deteriorated condition

5. Main Fossil Cliffs, Lower Cove to Coal Mine Point (C1)

This area is the main focus of the visitor experience and has by far the richest concentration of interest to the widest variety of visitors. The interpretive program for this area and staffing/guiding requirements are described elsewhere in this report. That being said, this area would require or could tolerate few adaptations to make it suitable for visitors. The effect of tides, erosion and ice make fixed structures impractical to say nothing of their impingement upon the natural and visual environment. A tide 'clock' in one or more highly visible areas may alert visitors to the necessity to vacate the beach upon incoming tides but this would require both a reliable method of setting and display and a form legible to even the uninitiated. It is anticipated that most of the interaction between the visitor and programmed interpretation will be by way of guided tours or self-guided materials obtained at the Centre site and carried along on the beach.

6. Bells Brook Access & Parking Area (C2)

The existing stairway and parking area at Bells Brook would be retained in the proposed site concept plan as value-added amenities but would not figure prominently in the primary visitor experience. The stairway is in good condition and should be maintained for local resident access and as a secondary exit point from the Joggins Beach/Coal Mine Point area for others. The drawback to visitor use of this access is that the walkway lands people on the north side of Bells Brook requiring a stream crossing if one wishes to return to the Centre site or the Village. In the past this has resulted in visitors blundering through private backyards to get back to Main Street. If a walking tour loop is developed using the Bells Brook stair, a prefabricated pedestrian footbridge could be placed over the creek at the existing abandoned abutments. A new path back to the Visitor Centre passing from the base of Main Street to the north west of the Purdy property could be developed over an easement in this area and connecting with the Centre site

The existing parking area would be retained for local resident parking but the interpretive signage and pit toilets would be removed and relocated to the new Grindstone Beach access park. Existing No Parking signage would be maintained along the road and the head of the stair could be signed for local resident access only if desired.

Figure 11 - Bells Brook stair

7. Coal Mine Site on Hardscrabble Road above Cliffs (C3)

Hardscrabble Road between the Centre site and Lower Cove is likely to be on the route of the bus portion of the guided tours. There are spectacular views of the coastline from the height of land and appealing views back over the town site of Joggins itself. There is an existing access point from the road onto the site of the old coal mine workings at the top of the cliffs. It is strongly recommended that this site not be used for a look-off or other public access point as the tailings and till in this area are actively eroding over the shear cliff face. This area would be extremely hazardous to the public and steps should be taken to re-vegetate or otherwise stabilize the loose materials at the top of the cliffs to reduce the potential for gravel, rocks or other debris falling on visitors below. The cliffs and beach immediately below this site are of particular geological and historic interest and the active erosion hazard is of particular concern to the management of tours and visitors in the vicinity.

Figure 12 - View from eroding cliff edge Hardscrabble Road

8. Ragged Reef Point (C3)

Ragged Reef Point is at the southern end of the UNESCO designation area. The site is currently privately owned and acquisition or development is not part of the recommended program..

Although access to this site would provide visitors with panoramic views to the north and south, this opportunity would be at the discretion of the owners. The shear cliffs in this area are spectacular and the tidal action can be observed engulfing the prominent rock outcrops. This site is entirely an upland experience as beach access is not available or safe at this location. If developed, recommended facilities would probably be rudimentary i.e. pit toilets, simple walk-in trails to the site (approx 0.5 km from highway) and some interpretive signage or marker noting the UNESCO designation and other site features. Primitive camping could be provided at this location but the attractiveness to visitors would be dependent upon other resource options such as access to trails.

A small parking area would have to be provided off the highway as a trailhead but the access point from the road would have to be selected carefully as sight lines along the curved highway are only fair.

9. Uplands between Ragged Reef Point & McCarrons River Point (C3)

The upland area between Ragged Reef & McCarrons River is noted as a potential linkage between the southern extremities of the UNESCO site and the remainder of the area. All of the lands in this area are in private hands and any public access would have to be negotiated. A trail would skirt high shear cliffs and would have to be carefully located for safety. Beach access is not available throughout this zone. The trail would probably have to meet the highway at the northern end in order to gain access to the beach at McCarrons River. Trail markers and perhaps some interpretation signage could be provided in this area and any other user amenities would be at the agreement of the landowners.

10. Beach between Ragged Reef Point & McCarrons River Point (C3)

This section of the beach is not recommended for general public access. The entire beach is bordered by shear cliffs and there is very little potential to escape the beach area during rapidly incoming tides. This area should be reserved for scientific study or expert guided access under only the most controlled conditions.

Figure 13 - Shear cliffs north of Ragged Reef Point

11. McCarrons River Point Pedestrian / Bicycle Access to Beach (C2)

The existing access road to the McCarrons River boat launch would provide a pleasant walking or biking experience for the visitor and a convenient trailhead for a loop hike back northward to the Joggins Beach area and the Centre site during low tide conditions. No user amenities save for interpretive and tidal warning signage are recommended. Provision should be made to keep visitors off the high banks of existing remnant road sections bordering private property. The existing ruined bridge abutments and road approaches are hazardous and visitors should be actively discouraged from walking or climbing in this area.

Figure 14 - McCarrons River access

12. McCarrons River Point Vehicle Access (C3)

The McCarrons River access road would be the principal emergency vehicle route to the south end of the site (Lower Cove, Grindstone Beach and Downing Cove access points would serve the north). However, vehicle access by visitors to this area is not recommended due to the poor sight lines at the junction of the access road and the highway. Space for parking is limited and the potential exists that casual parking in this area could block emergency vehicle access to the beach. Current local resident use of the access road could be permitted to continue and should be signed appropriately.

Figure 15 - Poor sight lines to McCarrons River access road (near car in picture)

13. Beach from McCarrons River Point to Joggins Beach (C2)

This beach would provide an additional walking loop opportunity southward from the Centre site to McCarrons River. No facilities would be provided although visitor orientation maps would highlight leaving the beach well in advance of high tide times.

Figure 16 - Joggins Beach south to McCarrons River Point

14. Upland area from McCarrons River Point to Visitor Centre site (C3)

Although the potential exists to develop a return trail along the upland area bordering McCarrons Point to Joggins Beach, the numerous property owners along this area would make obtaining access permission problematic. Our recommendation would be that a return trail from McCarrons River follow the highway and perhaps return into the Visitor Centre site skirting the treatment plant site. This route would provide some opportunity to view the roundhouse site remains and interpret the industrial past of the site. Other considerations such as the safety of persons walking along the collapsing remains of the foundation may mitigate this opportunity.

Figure 17 - Collapsing remains of Roundhouse foundation

15. North of Grindstone Beach / Boss Point / Downings Cove (C2)

Much of the focus of secondary value-added opportunities at the site is in the area north of the recommended Grindstone Beach access park. The new park area would provide an appealing trailhead for both beach and upland trail access to the north. Beach and cliffs at Breaking Ledge, Boss Point, Boss Cove and Downing Head would provide the hiking and primitive camping enthusiast with a range of experiences, panoramic views and other opportunities much of it located on Crown (public) lands. Downing Cove marks the northerly extent of the proposed UNESCO designation area and rudimentary vehicular and trail access could be negotiated over lands in private ownership in this area. Marked trails and very rudimentary facilities could be provided in this area depending upon management resources available. The cliffs and beach throughout this northern zone also represent safety concerns that should be clearly communicated to the unsupervised public users in this area. The beach can be exited in an emergency up the cliff slope at a few intervals but this can be challenging for all but the fittest and most prepared users. Some mechanism should be put in place to register users of the trails in this area to account for their whereabouts in the event of an emergency.

Figure 18 - View northward to Boss Point

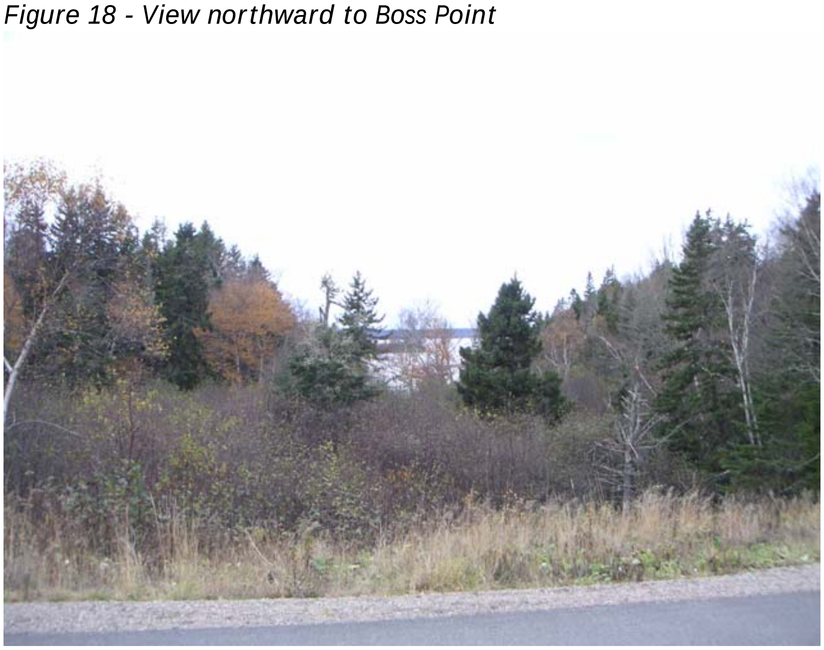


Figure 19 - Downing Cove

16. Lands east of Joggins and Lower Cove / Former Rail ROW (C2)

Long -term complimentary development opportunities of the Joggins region may also include developing trail access along the former rail right-of-way through to River Hebert and eastward or other trail connections through to Minudie in the north or south towards Advocate and Parrsboro. These facilities may be value-added amenities to the region although the impact on visitation to the Fossil Centre is only speculative. The management of an integrated series of recreation opportunities in this area of Cumberland County deserves further scrutiny beyond the scope of the current study.

Figure 20 - Numerous woodland trails intersect the study area

Content Outline

1. Introduction to Joggins

1.1. Why is Joggins World Famous?
1.2. The Fossil Record
1.3. The Grand Exposure
1.3.AVP.1 Grand Exposure Video Loop
1.4. The Big Ideas

2. The Changing Earth

2.1. The Changing Earth
- 2.1.1. The Fossil Record
- 2.1.2. Evolution and Extinction
- 2.1.3. Plate Tectonics
- 2.1.4. Earth's Changing Climate

2.2. Timeline of Earth's History

3. The Power of the Bay of Fundy

3.0. The Power of the Bay of Fundy
3.1. The Big Volume
3.1.AVP.1. Written in the Rocks
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3.3. The Bay of Fundy Ecosystem

4. Coal Age Ecosystem at Joggins

4.0. The Coal Age Ecosystem at Joggins
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4.2. Life on Land
4.3. Creatures of the Hollow Trees
4.4. Hollow Tree Interactive
4.4.AVP.1 Mystery of the Hollow Trees
4.5. Hollow Tree Experience
4.5.AVP.1 24 Carboniferous Hours
4.6. Pillars of the Coal Age Forest
- 4.6.A Seed Ferns
- 4.6.B Lepidodendron
- *4.6.C Sigillaria*
- 4.6.D Calamites

4.7. Life and Death in the Waters
4.8. Reading Tracks and Trails
4.9. Top Predator
4.10. Coal Age Tree
4.11. How Fossils Form
4.12. Finding Fossils at Joggins
note - 4.13 was eliminated at an earlier stage of the design process
4.14. Raindrops and Ripples

Content Outline

1. Introduction to Joggins

1.1. The Fossil Record

Main exhibit text:

First and foremost, Joggins is world-famous for fossils. For more than a century, scientists have recognized that the fossil record at Joggins allows a more complete reconstruction of life in the Coal Age world than any other known site on Earth.

Joggins is remarkable both for its wealth of fossils and for unique terrestrial (land-based) fossils. Furthermore, the Joggins fossils are preserved where the ancient plants and animals lived and died more than 300 million years ago.

Secondary exhibit text:

Bark from a Coal Age Tree

This fossil shows the bark texture from the lycopsid “trees” that were the pillars of the Carboniferous ecosystem and that are Joggins’ most famous fossils. They grew to 40 metres high — more than five times the height of these reconstructions. The geometric patterns are scars left by leaf formation during plant growth.

1.2. The Grand Exposure

Main exhibit text:

Joggins is known around the world for its grand exposure on the shores of the Bay of Fundy, where the fossil record is continuously revealed by the action of the world’s highest tides.

New fossils will continue to be exposed for thousands of years to come along the 14 kilometres of fossil-bearing cliffs. At Joggins, the wild, rugged beauty of the Bay of Fundy is the backdrop to a geological and paleontological treasure trove.

Secondary exhibit text:

Aerial View

From the air, the sweep of the cliffs at Joggins and the beauty of the site are clearly visible. The shoreline is constantly changing because of erosion, and storms can bring “terrible landslips,” as Sir William Dawson put it more than a century ago. Fortunately for geologists, such storms reveal new fossils and open the door to further discoveries.

1. Introduction to Joggins

1.3. The Big Ideas

Main exhibit text:

Despite its remote location on Nova Scotia's rugged coastline, Joggins played an important role in the developing ideas of some of the 19th century's greatest scientific thinkers, including Sir Charles Lyell and Charles Darwin as well as Canada's own Sir William Dawson.

Both the towering fossil forests and the discovery of the earliest known reptiles contributed to the scientific renown of Joggins in Victorian times. Today, scientists from around the world continue to study the fossils and other geological riches of this remarkable site.

Secondary exhibit text:

The Origin of Species

Joggins receives a special mention in later editions of Darwin's famous work, *On The Origin of Species*. The site at Joggins is cited as the best place on Earth to study Carboniferous fossils. But Darwin points out that, even at a site as good as Joggins, the fossil record is incomplete, and there are some questions about the ancient world that will forever remain unanswered.

1. Introduction to Joggins
1.3.AVP.1 The Grand Exposure

Location: Video monitor forming part of exhibit **1.3. The Grand Exposure**, incorporated in one of the trees at the entrance to the exhibit.

Message: Situate the site on the Bay of Fundy, and show the majestic sweep of the cliffs and the dramatic action of the tides.

Media: Video montage, in a continuous loop, to include:

- Maps situating the site (zoom-in from wide to narrow scale)
- Aerial footage of the sweep of the cliffs along the full 14 kilometres of the proposed UNESCO site,
- Shots on the shoreline at low and high tide.

Notes: This montage will include video from the upcoming CBC shoot at Joggins, including helicopter shots.

2. The Changing Earth

2.1. The Changing Earth

Main Exhibit Text:

The study of the rocks and fossils found at special sites like Joggins help us to better understand our planet's history. We have learned that the surface of the Earth has dramatically changed over billions of years, and that it continues to change today.

Powerful forces, ranging from the slow, powerful movement of tectonic plates to the explosive impacts of meteors, have shaped the Earth since the planet first cooled, forming a solid crust. These dynamic conditions, linked to constantly shifting climactic conditions, have supported different forms of life on this planet for more than four billion years.

Some changes take place so slowly that no human can see or feel their effects. Others, like earthquakes and volcanoes, are instantaneous—and can have drastic, even catastrophic results.

Secondary Exhibit Texts:

2.1.1 The Fossil Record

Traces left in stone are all that remain of many ancient species. But fossils are only created under very special conditions, so few creatures are ever preserved. What's more, only certain kinds of creatures (notably those with hard shells or bones) are likely to become fossils. The fossil record—the only catalogue of the history of life on earth—will forever remain incomplete.

The fossils included in this display are taken from special sites in Nova Scotia, in Canada and around the world. Like Joggins, these sites have contributed to our understanding of how life on Earth has evolved.

2.1.2 Evolution and Extinction

Scientists say that only one in every thousand species that have ever lived survives today; the other 99.9 percent are extinct, gone forever. For example, almost all the creatures found in the cliffs here at Joggins have long since vanished, though some of them have modern-day relatives.

The lifespan of most individual species is short by geological standards, averaging between 2 and 10 million years. But extinction serves as a springboard for life. After even the most catastrophic events, the survivors continue to evolve, giving rise to new forms of life.

2.1.3 Plate Tectonics

It may feel like the ground is solid under your feet. But in reality, the Earth's outermost layer is made of a dozen or more plates, both large and small, which are all moving relative to one another, riding atop the molten interior of the planet.

Moving at about the speed that your fingernails grow, these plates are constantly shifting and colliding, forming mountains and continents. Millions of years ago, during the Coal Age, the area we know today as Joggins was actually on the equator!

2. The Changing Earth

2.1.4. Earth's Changing Climate

Evidence found in natural recorders like ice cores, tree rings and fossils reveals that large changes in climate – including both temperature and precipitation – have taken place throughout Earth's history.

The rocks and fossils exposed in the Joggins Fossil Cliffs show both long-term and short-term variations that stretched over millions of years.

2.2 Timeline of Earth's History

Preliminary texts for timeline:

Archean Eon

During this immensely long eon, the Earth's crust cooled enough that rocks and continental plates began to form, and life first appeared on Earth. The oldest known fossils (bacterial microfossils) date from roughly 3.5 billion years ago. The atmosphere was very different from what we now breathe; at that time, it is believed to have been made of gases which would be toxic to most life on our planet today.

Proterozoic Eon

During this eon, stable continents first appeared--a long process that took about a billion years. The first abundant fossils of living organisms, mostly bacteria and archaeans, appear in rocks from this eon. By about 1.8 billion years ago, more complex cells appear as fossils.

Proterozoic rocks also show the first evidence of oxygen build-up in the atmosphere. This made possible the explosion of eukaryotic (multicellular) forms of life, including algae, and, toward the end of the Proterozoic, the first animals.

Cambrian

During the Cambrian, most of the major groups of animals first appear in the fossil record; these include shellfish and corals. The sudden abundance of life during thie period is sometimes called the "Cambrian Explosion", because of the relatively short time over which it appears.

Ordovician

During this period, most of the world's land was collected into a southern super-continent that has been named Gondwana.

The fossil record of the Ordovician includes early vertebrates, red and green algae, primitive fish, corals, crinoids, and gastropods. More recently, spores have been found, suggesting that primitive land plants may have been present.

Silurian

The Silurian was a remarkable time for the evolution of fish-- freshwater fish as well as the first fish with jaws. The first substantial evidence of life on land also appears during this period; it includes relatives of spiders and centipedes as well as the earliest fossils

2. The Changing Earth

of vascular plants.

Devonian
During the Devonian, three major continental masses were present, and the megacontinent Pangaea began to form. By the end of the Devonian, ferns, horsetails and seed plants had appeared, producing the first trees and the first forests.

Two major animal groups colonized the land. The first tetrapods (land-living vertebrates) appeared, as did the first terrestrial arthropods, including wingless insects and spiders. In the oceans, corals and ammonites were common, while many new kinds of fish appeared.

Carboniferous
Mississippian (Lower Carboniferous)
This period was heavily marine, with seas covering parts of the continents. Much limestone remains from this period; it is made up of the remains of crinoids, lime-encrusted green algae, or calcium carbonate.

The amniote egg evolved during the Mississippian. This evolutionary innovation allowed the ancestors of birds, mammals, and reptiles to reproduce on land by preventing the desiccation of the embryo inside.

As Pangaea continued to form, the Late Carboniferous continental collision produced the Appalachian mountain belt of eastern North America.

Pennsyvanian (Upper Carboniferous)
The environment during this period alternated between terrestrial and marine, with periodic massive flooding. These environmental conditions, together with the vast amount of plant material provided by the extensive swamp forests, resulted in the production of coal. Plant material did not decay when the seas covered them; pressure and heat eventually built up over the millions of years, transforming the plant material.

Secondary Exhibit Text:
Icehouse and Greenhouse
The rock record shows that over the past 600 million years, the Earth's climate has oscillated between warmer and cooler. Ice caps sometimes extend far beyond the poles, in what is called an "icehouse" world, and sometimes melt completely, creating "greenhouse" conditions.

We are presently in an icehouse period, perhaps moving toward a greenhouse world. Scientific evidence indicates that human industrial activity is accelerating climate change.

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2. The Changing Earth

Permian
During this period, as the climate became drier, the vast coal swamps disappeared, replaced by dryland forests. Modern conifers first appeared in the fossil record of the Permian.

The Permian Period closed with the largest mass extinction in Earth's history. This extinction event affected many different environments, but marine communities were the hardest hit. It has been estimated that nearly 90% of all species became extinct at the end of the Permian—including trilobites, rugose and tabulate corals, and many species of brachiopods and molluscs.

Secondary Exhibit Text:
The Great Extinctions
The fossil record shows that at several points in Earth's history, like the end of the Permian, the number of species has been drastically reduced during a relatively short period of time. When many species die out simultaneously, we call it a "mass extinction."

The causes of many of the mass extinctions are unknown, though the event that marks the Cretaceous-Tertiary boundary is widely thought to have been caused by the impact of a comet or meteorite, while today's ongoing mass extinction is a wholly manmade phenomenon.

Triassic
The Triassic Period was a time of transition. The dinosaurs made their first appearance in the Triassic; they would dominate the world for the next 180 million years.

Triassic seas were home to large reptiles as well as invertebrate survivors of the Permian extinction, such as ammonites and mollusks. The earliest flying vertebrates also evolved during the late Triassic, as did mammals. The first mammals were tiny—about the size of the modern shrew or mouse.

Jurassic
The Jurrasic is the Age of Dinosaurs. Great plant-eaters roamed the earth, feeding on lush growths of ferns and palm-like cycads, while smaller, vicious carnivores stalked the great herbivores. The oceans were full of fish, squid, and coiled ammonites, as well as huge dinosaurs. Vertebrates, including the first birds, took to the air.

The supercontinent Pangaea began to break apart during the Jurassic. This would eventually create major differences between the northern and southern continents.

Cretaceous
The Cretaceous is the last portion of the "Age of Dinosaurs." During this time, we find the first fossils of many insect groups, modern mammal and bird groups, as well as the first flowering plants and seed plants.

2. The Changing Earth

The end of the Cretaceous was marked by the mass extinction of many previously successful and diverse groups of organisms, such as non-avian dinosaurs and ammonites.

Tertiary
The extinction at the end of the Cretaceous opened numerous ecological niches. These were filled mostly by mammals, which underwent a dramatic evolutionary radiation. By the Late Tertiary, North America was home to mastodons, ground sloths, armadillos, camels, horses, saber tooth cats, giant wolves, giant beavers, and giant bears.

Tertiary seas would have looked fairly familiar to us: gastropods and bivalves were very similar to modern forms. Squid replaced the ammonites, which died out at the end of the Cretaceous. Sea urchins and single-celled foraminifera were abundant, and new forms appeared. Sharks and bony fishes were common.

Quaternary
The Quaternary has also seen the evolution and expansion of our own species, *Homo sapiens*. Quaternary fossils are often abundant, well preserved, and can be dated very precisely. Many paleontologists study Quaternary fossils, such as diatoms, foraminifera, and plant pollen in order to understand the climates of the past. The time since the melting of the last major ice sheet (about 11,000 years ago) is known as the Holocene, or Recent.

3. The Power of the Bay of Fundy
3.1.AVP.1 Written in the Rocks – AV Synopsis

Location: Video monitor forming part of exhibit **3.1. The Big Volume**, on the cliff wall.

Message: Show the geological processes that created the different rocks found at Joggins.

Media: Visitors toggle buttons located beside rock specimens on a display unit in front of the exhibit. As they make their selections, short animations situate the rocks in terms of the geological history of the area and show the processes through which the rocks were created.

At the same time, a map of the site lights up at the area where each of the rock samples is found.

Notes: See the associated exhibit text for a list of rock specimens.

3. The Power of the Bay of Fundy

3.0. The Power of the Bay of Fundy

Zone Introductory Text:

The cliffs at Joggins speak of great age and ancient power. From the endless surge of the tides to the incessant wind and steadily eroding cliffs, natural forces are at work everywhere you look.

But the cliffs hold questions as well. How did the rocks form? Where did they come from? Why are they tilted? What are all the different kinds of rocks? And – most striking of all – what stories do the fossils tell?

Secondary Exhibit Texts:

Reading the Rocks

For earth scientists, the cliffs at Joggins are like books that record past ages of Earth's history. Plants and animals from the ancient world are pressed between the pages, ready to be discovered.

Like a library of stone, the rocks and the secrets they hold are available for everyone – though you have to learn how to read them.

3.1. The Big Volume

Main Exhibit Text:

The "grand exposure" at Joggins stretches over kilometres of distance and reveals millions of years of geological history. In the north, the rocks are approximately 325 million years old. They become progressively younger, layer by layer and bed by bed, as we move south past the Centre. Here, the age of the rocks is approximately 310 million years, meaning that we have passed through some 15 million years of Earth history.

Learn more about the stories each rock has to tell!

Secondary Exhibit Texts:

[note: each of these is associated with a rock sample. Pushing a button by the sample activates a video clip on a flatscreen monitor located on the cliff wall, and also lights up a part of the map showing the site. See the associated synopsis document]

Granule conglomerate

325 mya

The boundary between the two halves of the Carboniferous – the Mississippian and the Pennsylvanian – is exposed near the north edge of the Joggins site. These rocks show the hotter, dryer conditions on the Mississippian side.

Sandstones

325-290 mya

3. The Power of the Bay of Fundy

During the continental collision that formed the Appalachian mountains of eastern North America, rivers flowed across the lowlands, including today's Cumberland Basin and Joggins. Sandy deposits from the rivers formed the thick sandstones at Boss Point, which were used for grindstones.

Salt
350-310 mya
The weight of accumulating sediment caused subsidence in the centre of what would become the Bay of Fundy. Salt, evaporated from ancient seas, pushed outwards at the basin margin under the weight of sediment piling on top – like stepping on a toothpaste tube.

Mud aggregate
320-315 mya
The rocks in the section of low bluffs at Lower Cove are the remains of seasonal rains and flash floods, with narrow, deep streams criss-crossing the landscape. These floods left deposits of pebbles and small stones.

Coal-bearing limestone
315-312 mya
From Little River to MacCarrons Creek, more than 67 individual beds or seams of coal are exposed in the coal and limestone strata. It is these coal-bearing rocks that best record life in the 'Coal Age' forest swamps.

Conglomerate
TBD
This conglomerate, from Ragged Reef, is a remnant of the chaotic conditions of tectonic upheaval that mark the edge of the Joggins site.

Basalt
220 mya
During the Triassic, as Pangaea ripped apart and the Atlantic Ocean formed, the Earth's crust bled out lava along the Annapolis valley and south to Connecticut. The lava cooled to form the basalt that you can see further south along the Fundy coast.

Visit the Fundy Geological Museum to learn more about the geological history of the area.

Erosion and Tilting
TBD
After the beds and strata were tilted, the region was uplifted, then eroded, during the latest Cretaceous and Tertiary. Sediments from the Tertiary are piled up offshore towards Sable Island.

3. The Power of the Bay of Fundy

Glacial Till

~ 10,000 ya

Overlying the surface of the cliffs is a thick layer of clay strewn chaotically with boulders. This material was dumped by the last glacial ice cover as it melted: it is properly called glacial till. More than 300 million years of age separate the inclined Coal Age rocks from the glacial till above.

3.2. The Cliffs Today

Main Exhibit Text:

The Joggins cliffs look as they do today because of two relatively recent developments in Earth history. The first is the end of the last Ice Age, just over 10,000 years ago. The second is the development of extreme tides in the Bay of Fundy.

Secondary Exhibit Texts:

End of an Ice Age

During the Quaternary period, a continental ice cap covered most of Canada, including Nova Scotia. This ice cover waxed and waned over a 100,000-year period, then melted for the last time about 10,500 years ago.

As the ice retreated, the Earth's crust rebounded upward. The former shoreline at Joggins rose as well. This ancient shore forms the flat surface now visible at the top of the rock cliffs, topped by deposits from the glaciers.

Bay of Fundy Tides

Every 6 1/2 hours, tides flood the Bay and then withdraw again, responding to the pull of the moon. The vertical rise and fall of the tides – 44 feet – is the largest in the world.

The funnel shape and gradual shallowing of the Bay causes the water to pile up. The Bay and the Gulf of Maine form a large single basin in which the moving seawater sloshes back and forth like a wave in a tub. This "bathtub effect", almost perfectly synchronized with the bay's tidal cycle, gives the water the extra push needed for these world record heights.

3. The Power of the Bay of Fundy

3.3. The Bay of Fundy Ecosystem

Main Exhibit Text:

The Bay of Fundy, linking New Brunswick and Nova Scotia, is part of the vast Gulf of Maine ecosystem. The Bay's 1,300 kilometres of coastline change from rugged headlands at the mouth to mudflats and salt marshes at the inner reaches.

In the lower Bay, strong tides pump nutrients from the seafloor up into the light, nourishing the marine food chain, which includes plankton, copepods, herring, seabirds and whales. In the shallower upper Bay, licks of single-celled algae flourish at ebb tide on the mud flats, and ribbons of salt marsh supply food to the marine environment. This is churned by the action of the tides into a nutrient soup that feeds a variety of bottom dwellers, fish, and birds.

4. Coal Age Ecosystem at Joggins

4.0. The Coal Age Ecosystem at Joggins

Zone Introductory Text:

"...these beds carry our thoughts back to a period when the district was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades or the Delta of the Mississippi."

-- J. W. Dawson (1855).

Text to be developed with John Calder

4.1. Life in the Water

Text to be developed with John Calder

4.2. Life on Land

Text to be developed with John Calder

4.3. Creatures of the Hollow Trees

Text to be developed with John Calder

4.4. Hollow Tree Interactive

See synopsis 4.4.AVP.1.

4.5. Hollow Tree Experience

See synopsis 4.5.AVP.1.

4.6A. Pillars of the Coal Age Forest – Seed Ferns

Text to be developed with John Calder

Secondary Exhibit Text:

Naming the Pieces

Plants, unlike animals, naturally break apart into pieces while they are still alive-- a leaf here, a branch there and a seed somewhere else. When the plant dies, it breaks apart even more.

Fossil plants reflect this; typically, a leaf is found here and a branch over there. It is quite rare to find a leaf attached to a branch. As a result, scientists usually give a different name to each part of a plant until they can prove that they were part of the same organism. This is why there are different names for different parts of a single plant.

4.6B. Pillars of the Coal Age Forest – *Lepidodendron*

Text to be developed with John Calder

4.6C. Pillars of the Coal Age Forest – *Sigillaria*

Text to be developed with John Calder

4. Coal Age Ecosystem at Joggins

4.6D. Pillars of the Coal Age Forest – *Calamites*

Text to be developed with John Calder

4.7. Life and Death in the Swamp

Text to be developed with John Calder

4.8. Reading Tracks and Trails

Main Exhibit Text:

Footprints can turn into fossils. Ancient crawling invertebrates and prowling tetrapods (four-footed reptiles and amphibians) left behind plenty of trails, footprints and trackways.

Palaeontologists use trace fossils to puzzle out how ancient animals behaved in their environment, something body fossils can't tell us. A single animal can leave thousands of traces in its lifetime, but only one body when it dies. Consequently trace fossils are much more common than body fossils.

In Joggins, the footprints left by Carboniferous tetrapods are both abundant and varied. Palaeontologists call these 'trace' fossils and they paint an evocative picture of life in the 'Coal Age', or Carboniferous Period.

4.10. Coal Age Tree

Text to be developed with John Calder

4.11. How Fossils Form

Main Exhibit Text:

Live, die, get buried, become a fossil? It's not quite that simple.

Most plants and animals never become fossils because they're eaten or decay first. For plants, animals or trackways to fossilize, they must be rapidly buried by mud or other fine sediment. Land conditions usually don't allow for good fossilizing.

So why is Joggins such a rich fossil trove? Prehistoric conditions here were perfect: streams overflowed their banks and flooded lowlands during periods of monsoon-like rains, burying plants and animals. At other times, layers of sediment built up in shallow-water environments burying fish and other aquatic life forms on lake- or lagoon-bottoms. And over time, these turned to rock.

Secondary Exhibit Text:

Bodies and Traces

Fossils, the preserved evidence of ancient life, come in two forms: body fossils and trace fossils.

4. Coal Age Ecosystem at Joggins

Body fossils are direct evidence of ancient life forms -- any part of an actual animal or plant. Bones and skin impressions, teeth, shells, leaves, stems and pollen are all body fossils.

Trace fossils give us indirect evidence of ancient life forms and clues about their behaviour. Trace fossils include trails, footprints, burrows, gnawings, nests and coprolites (fossilized excrement).

4.12. Finding Fossils at Joggins

Main Exhibit Text:
Text to be developed with John Calder

4.14. Raindrops and Ripples

Main Exhibit Text:
Fossils aren't the only source of information about prehistoric life. Other clues hidden in the layers of rock help geologists to reconstruct ancient environments.

The exposed sedimentary cliffs at Joggins were formed from many kinds of rock fragments -- tiny clay particles, grains of sand, gravel and even boulders. These formed layers, or beds, which were moved and shaped by both water and wind.

Some beautifully-preserved sediments captured ancient ripple marks, mud cracks and even raindrops – just like the markings being made today on sandy beaches or muddy river banks.

From these forms, scientists can determine the nature of the landscape, the temperature, the direction and rate of a stream's flow, the depth of a body of water. They help us better understand the original climate conditions.

Secondary Exhibit Text:
Ripples
Ripples are undulations of the sediment surface produced as wind or water moves across sand. Ripples in the rock record may be used to determine ancient current directions.

Mudcracks
Mudcracks are polygonal patterns of cracks produced on the surface of mud as it dries.

Raindrops
Raindrop prints are circular pits on the sediment surface produced by the impact of raindrops on soft mud.

4. The Coal Age Ecosystem at Joggins
4.4.AVP.1. Mystery of the Hollow Trees

"Whether the creature had crept into the hollow tree while its top was still open to the air, or whether it was washed in with mud during a flood, or in whatever other manner it entered, must be a matter of conjecture."

-- Sir Charles Lyell, 1870

Location: Touchscreen monitor forming part of exhibit **4.4. Hollow Tree Interactive**, presented on a standalone showcase.

Message: Visitors will learn how scientists make and test hypotheses about the interpretation of the fossil record and of ancient ecosystems.

Media: Visitors use a touchscreen monitor to navigate through an interactive game. They learn about:

- The discovery of the hollow tree fauna
- The evidence found in and around the hollow trees
- What is known about the original environmental context
- What we know about similar creatures living today

Visitors then explore the different hypotheses, observing the strengths and weaknesses of each.

- Falling into the trees
- Living in hollow tree stumps
- Washed into the trees during a flood

The game concludes with a question: What do you think happened to the creatures in the hollow trees?

Notes:

5. Fossil Lab

5.1. Microfossils

Main exhibit text:
Microfossils—fossils so small you need a microscope to see them—are the tiny remains of ancient bacteria, fungi, animals and plants.

Microfossils are one of the most varied and abundant of all fossil groups. They occur in such large numbers that some thick layers of rock are made entirely of microfossils, like the White Cliffs of Dover or the stones of the Great Pyramids.

These tiny prehistoric remains help scientists date different rock strata and compare geological formations from around the world. Besides their importance in pure science, microfossil studies are used in mining and fossil fuel exploration, where they guide billion-dollar decisions.

Microfossils may be tiny, but they're really important. Take a peek at some!

5.2 Fossil Preparation

Main exhibit text:
There's more to preparing a fossil display than you might think! Finding fossils is challenging enough, but that's just the first step. Getting it ready for a museum is painstaking work that requires great patience and skill.

Once a fossil has been collected, it needs to be removed from its matrix—the rock in which it's embedded. Acid or abrasive cleaners, sandblasters, dentists' drills and picks, air hammers, rock saws or ultrasonic toothbrushes are used, depending on the specimen. Sometimes some of the matrix is left, to show the geological context. Finally, broken pieces are glued together, cracks are filled, and the piece is ready for display.

To see fossil preparation first-hand, visit the Fundy Geological Museum, our partner institution just down the coast in Parrsboro.

5.3 Research Today

Note: Text in development with John Calder.

5.4 On The Beach

Note: Text pending final selection of fossils.

4. The Coal Age Ecosystem at Joggins
4.5.AVP.1. 24 Carboniferous Hours

Location: Sound and light show inside the **4.5. Hollow Tree Experience** area.

Message: Aimed especially at children, this sound and light show will present 24 hours inside a Coal Age hollow tree.

Lightning, wind, strange insect sounds, an *arthropleura* slithering by, a *megasecoptera* flying overhead – the sights and sounds of a day in the life of *hylonomous*.

Just scary enough to be exciting, this area will immerse visitors in the sights and sounds of a world long since past.

Media: Hidden speakers, theatrical lighting and projections all contribute to the effect.

Notes:

6. Big Ideas

6.1. The Evolution of Life

6.1.1 What's the Big Idea?

Main exhibit text:

First made famous by Charles Darwin in the 19th century, evolution has become a fundamental idea of modern science. The theory helps explain the history of life in the fossil record, as well as genetic relationships and the geographical distribution of organisms both today and in the past.

The central idea of evolution is simple but powerful: given enough time, creatures will adapt to better fit their environments. While seemingly straightforward, the theory has been the subject of much debate.

The fossil record at Joggins featured in many of the early debates on evolution, and scientists continue to make new discoveries about the history of life at Joggins today.

Secondary Exhibit Text:

This "miserable little *Dendropupa*"

The oldest known land snail, the tiny Dendropupa, was first discovered here at Joggins in 1852. It gained unexpected fame by being held up to ridicule by Bishop Wilberforce, an early opponent of evolutionary theory. "This miserable little dendropupa" was judged to be an inadequate proof that complex life had existed in the remote past.

6.1.2 The Joggins Connection

Main Exhibit text:

Scientists quickly realized that the cliffs at Joggins offered a remarkable window into the Coal Age. Joggins offers as complete a picture of life in the Carboniferous as is ever likely to be found on Earth.

But even given these near-ideal conditions, the fossil record is incomplete. The slow creep of evolution is not clearly visible, despite kilometres of exposed cliffs and excellent conditions for fossilization.

In Darwin's best-known work, *On the Origin of Species*, he regretfully recognizes that no clear proof of his theory of evolution may ever be found – even at Joggins.

6.1.3 The Continuing Story

Main exhibit text:

The origins and evolution of the amniotes, like the early interrelationships of the reptiles, birds and mammals, remain somewhat mysterious. No one knows precisely when many of the major evolutionary events took place.

Researchers in molecular evolution and genetics have recently brought new tools to bear in this search, using the 'molecular clock' of DNA to study evolution. In recent research, the first appearance of the amniotes at Joggins has been proposed as the 'zero mile' marker against which other evolutionary events will be measured.

6. Big Ideas

Secondary Exhibit Text:

Molecular Clocks

DNA analysis has opened up many new avenues for scientific research. Among these is the idea of a “molecular clock” – the notion that we can compare DNA sequences from two different creatures and, working backwards, estimate how long ago the two species shared a common ancestor.

6.2. The Dynamic Earth

6.2.1 What's the Big Idea?

Main exhibit text:

Vast periods of time, constantly shifting continents, changing climates and evolving life are all part of the modern understanding of the planet.

Each of these is made up of small pieces of knowledge, gained through detailed studies and painstaking analysis. Together, they offer powerful insights into how the Earth has become what it is today, and what it was in the past.

For more than one hundred and fifty years, the Joggins cliffs have contributed to our understanding of the processes that shape the earth.

Secondary Exhibit Text:

Basin subsidence

Sedimentary basins, such as Joggins, are places where the subsidence of Earth's crust has allowed sediment to accumulate on top of other rocks.

Sedimentary basins and sedimentary materials cover most of the Earth's surface. Understanding the evolution of sedimentary basins, and the reasons for their existence in particular places at specific times, can provide fundamental insights into a wide range of Earth processes.

6.2.2 The Joggins Connection

Main exhibit text:

The impact of Joggins on Sir Charles Lyell, a leading geologist of the 19th century, changed the course of geological history. Many of the preserved remnants of former life, including the fossil forests, confirmed principles outlined in Lyell's pioneering book, "Principles of Geology."

Lyell’s research at Joggins was pivotal in establishing the stratigraphic record as an archive of Earth’s evolving landscape. Moreover, Lyell’s friendship with Darwin helped ensure that their fields of expertise contributed to a better and more complete understanding of the Earth and its processes.

6.2.3 The Continuing Story

Main exhibit text:

For earth scientists, the sediments that surround and protect the fossil record are as important as the record of life itself.

6. Big Ideas

Current research focuses on understanding the relationship between the physical environment, including changes in climate, to local basin evolution and global-scale processes such as sea level change.

The span of time revealed in the cliffs at Joggins allows scientists to assess these responses. But teasing apart the different variables remains a huge challenge in the study of the ancient earth.

6.3. The Prehistoric World

6.3.1 What's the Big Idea?

Main exhibit text:

The scientific use of the rock and fossil records to recreate past environments is known as paleoecology. It is a relatively young science that draws on many other areas of modern science.

The field studies fossil organisms in terms of their life cycle, their living interactions, their natural environment and how they died. Paleoecologists work to understand the original environments of the once-living organisms that we find today as fossils. This means studying and interpreting the complex interactions among environmental factors (temperature, food supplies, sunlight) in the ancient world.

Secondary Exhibit Text:

Nova Scotia's Provincial Fossil

Among the most famous fossils found at Joggins are the skeletons of the earliest known reptile, *hylonomus lyelli*, entombed in fossil tree trunks. The fossils, like others at Joggins, are found in the precise context where they died. This helps scientists to better piece together the conditions in which they lived.

6.3.2 The Joggins Connection

Main exhibit text:

"[it is better to study]... plants as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum."

-- Sir William Dawson,1868.

Sir William Dawson, born in Nova Scotia, made an enormous contribution to the science of geology. He possessed a remarkable ability to comprehend the prehistoric world, and carried out a great deal of fieldwork, looking at fossils and rocks where they were deposited.

From Joggins and elsewhere in the Maritimes, Dawson made many other important discoveries of fossil life, great and small. These included fossil plants, trackways of invertebrates, footprints and skeletons of reptiles and amphibians, millipedes and the earliest land snails. He had an uncanny ability to understand the ancient environments in which rocks had formed and to decipher their correct ages. Dawson died in 1899, but his greatest legacy is still with us his classic book Acadian Geology, published in five editions from 1855 to 1892.

6. Big Ideas

6.3.3. The Continuing Story

To be developed with John Calder.

6.4. Tree of Life Interactive

See synopsis 6.4.AVP.1

Secondary Exhibit Text:

"The affinities of all the beings of the same class have sometimes been represented by a great tree... As buds give rise by growth to fresh buds, and these if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications."
Charles Darwin, 1859

6.5. Big Ideas Theatre

See synopsis 6.5.AVP.1

6. Big Ideas
6.4.AVP.1 Understanding the Tree of Life – AV Synopsis

Location: Touchscreen video monitor with headphones, in front of exhibit **6.5 The Tree of Life**.

Message: What is the Tree of Life? Why is Joggins significant? What makes *Hylonomous* and *Dendropupa* so special?

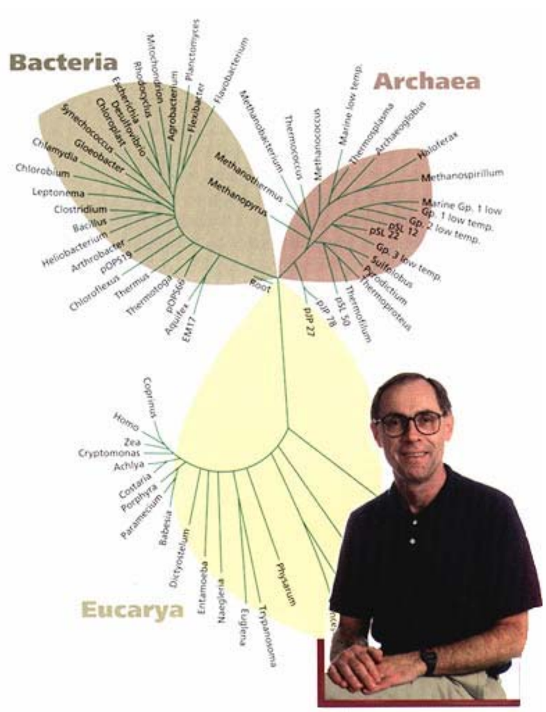
Media: Visitors touch the screen to select one of three video clips. The clips present short extracts from interviews with specialists who answer some basic questions:

1) What is the Tree of Life illustrated? How has it been put together? What does it tell us? What is still unknown?

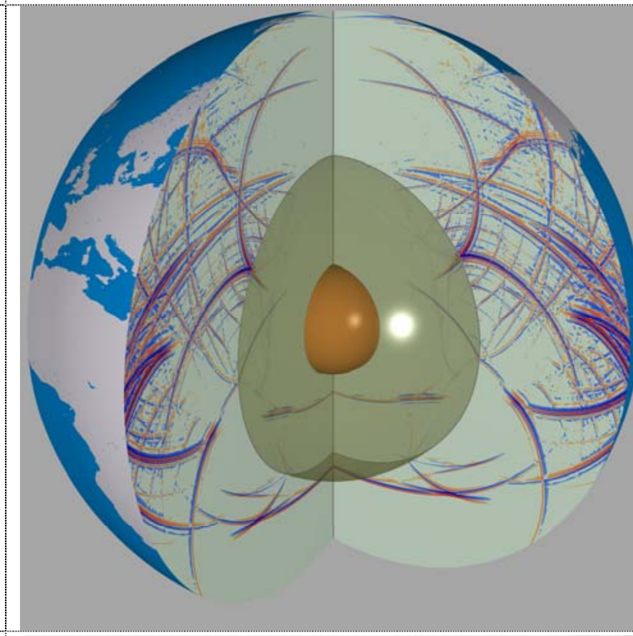
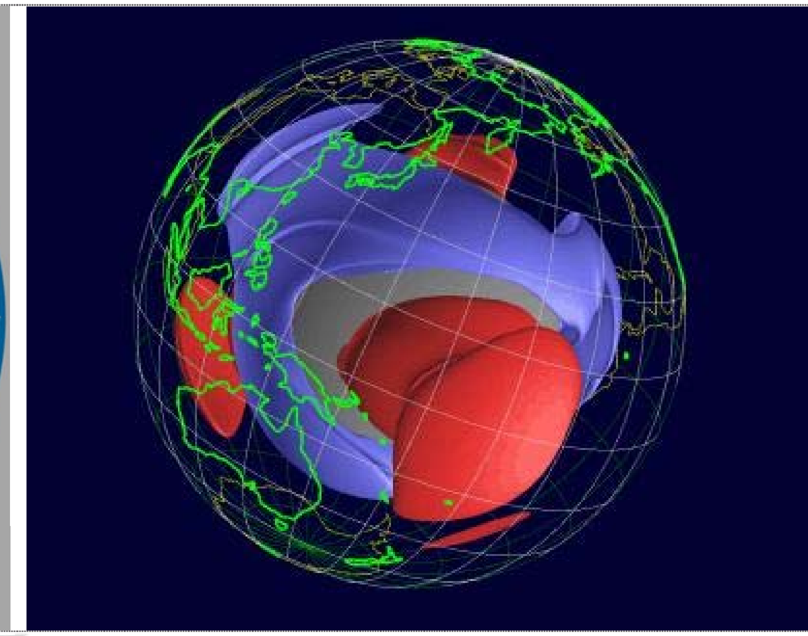
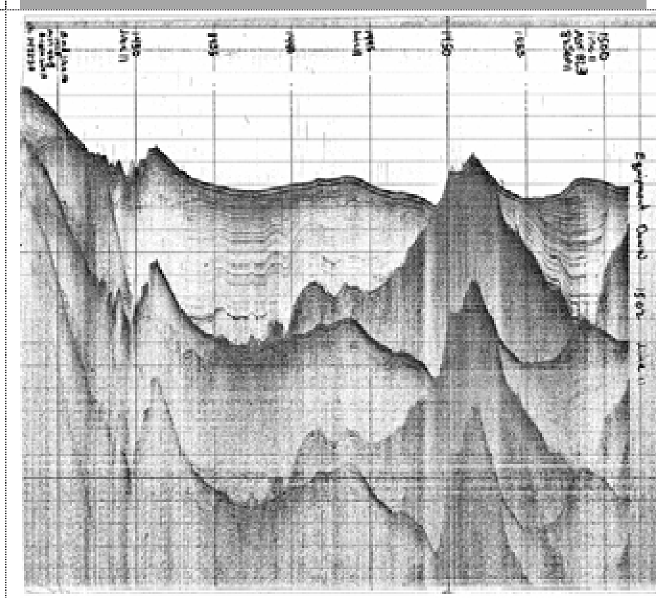
2) What role has Joggins played in the development of the Tree of Life?

3) What makes a fossil like *Hylonomous* so special? How do scientists determine where it fits on the Tree of Life? What makes them so sure?

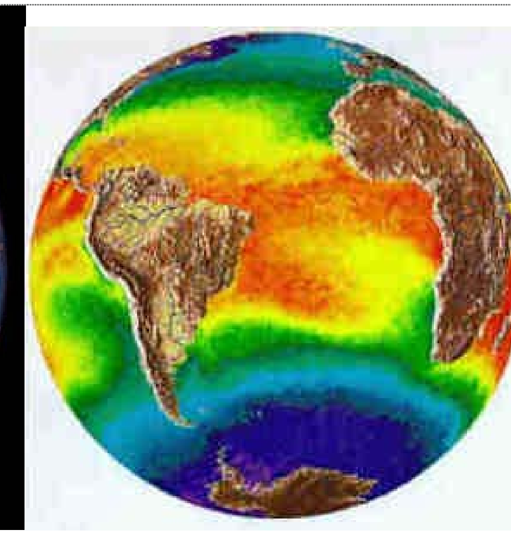
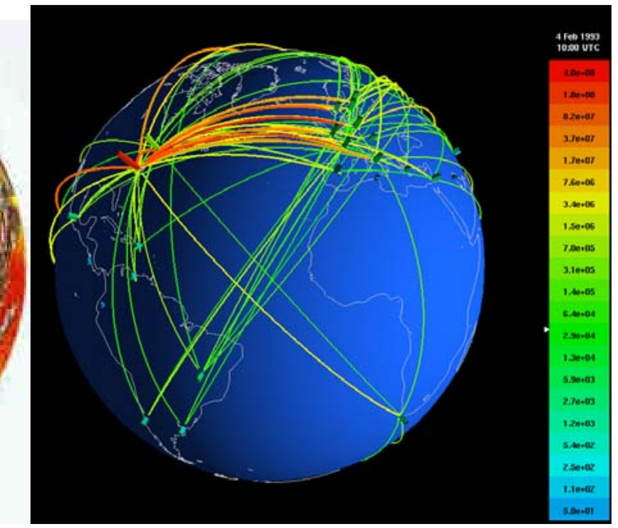
Notes: John Calder will advise as to the choice of scientists who will answer each of the questions.



6. Big Ideas
6.5.AVP.1 The Big Ideas – AV Synopsis

Approximate timing	Description	Inspirational imagery
00:15	***Title sequence.***	
00:30	The earth sciences – the sciences that study the evolution of the Earth and of life on this planet -- have drastically changed over the past two centuries. Today's earth scientists have a palette of powerful tools at their disposal, many of which are in use right here at Joggins.	 
00:45	Scientists can now establish the age of rocks by examining minute radioactive traces left from the ancient past. Seismic studies and computer modelling let them look under the surface of the planet to better understand what is happening inside the Earth. Microfossil studies and sedimentary studies reveal long-hidden secrets about ancient environments. DNA analyses help them understand the steps in the evolutionary process that eventually led to the emergence of human beings.	 

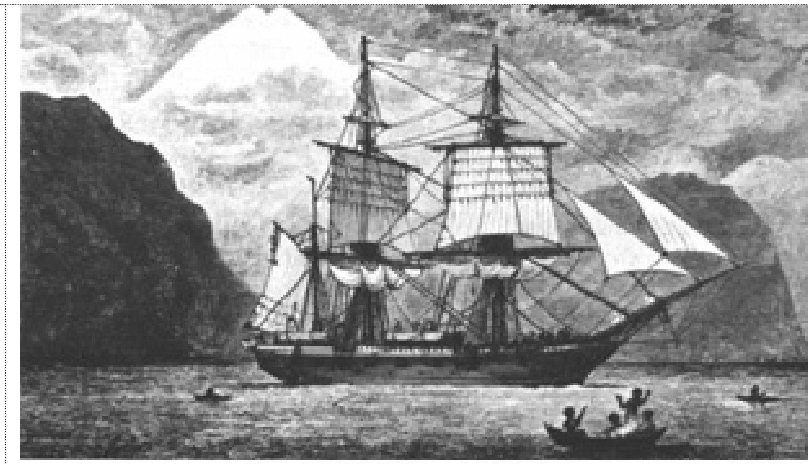
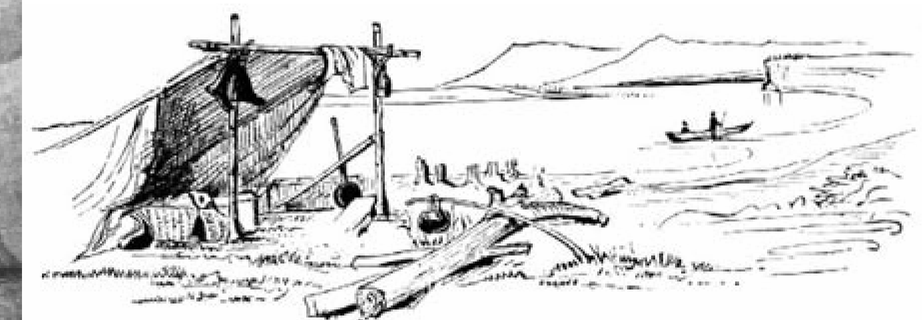
6. Big Ideas
6.5.AVP.1 The Big Ideas – AV Synopsis

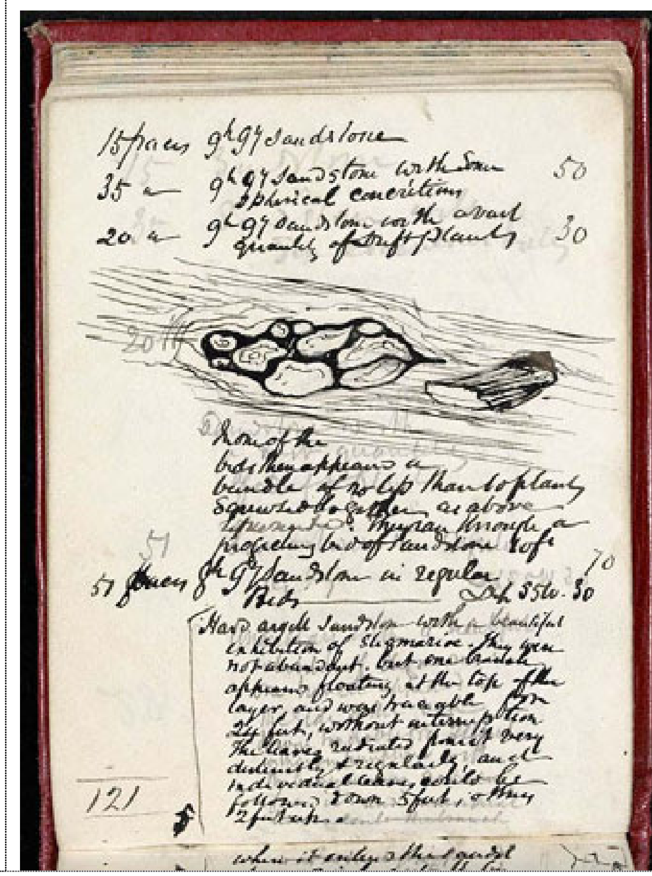
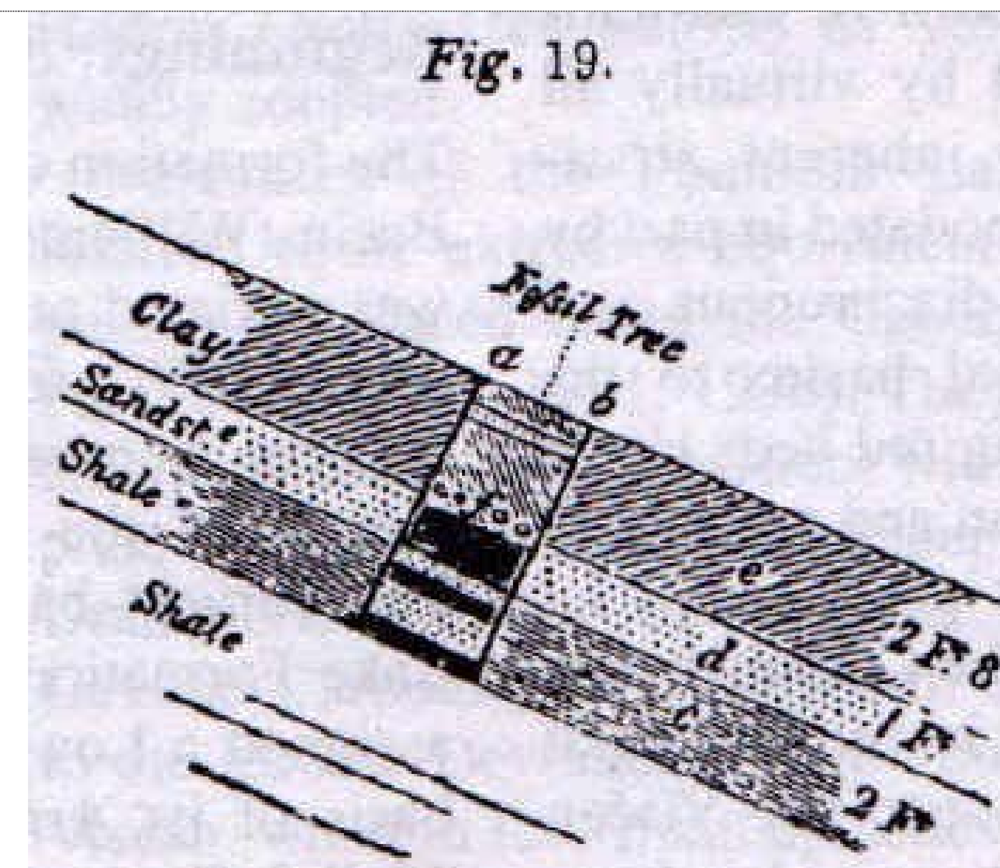
1:00	Communications technologies, most recently the Internet, allow information to be instantly shared around the world. Satellite images and aerial photography help them understand the planet as a single entity, where climate, environment, life and geography form parts of a greater, more complex whole. And new means of travel make the planet smaller than before, allowing them to explore the furthest corners of the globe. All of these contribute to the ongoing development of geology and the earth sciences.	  
1:30	This change has been so fast, and so widespread, that it's hard for us to imagine what it must once have been like to look at fossils and rocks. In the ancient world, fossils were understood as strange and amazing objects, remnants of a mythological time long since past. But the finer details were mysteries. There was no real understanding of the vast periods of time and the different processes that could create fossils, bury them deep in the rock, then bring them once again to the surface at sites around the world, like here at Joggins.	   Illustration of a shark and its teeth from a catalogue of the Vatican's collections

6. Big Ideas
6.5.AVP.1 The Big Ideas – AV Synopsis

<table>
<tr>
<td>2:00</td>
<td>The Victorian age was the turning point for the earth sciences, the moment in history at which it started to seem reasonable to think that the stories of our planet and of life itself could be understood and explained, using the new techniques and technologies of science.

Around the world, men and women travelled vast distances, exploring the Earth's surface, looking carefully at rocks, living creatures and fossils, and trying to understand how it all fit together.

At special sites like Joggins, they recorded what they found in words, numbers and drawings, reported what they found to their colleagues and to the general public, and endlessly debated what it all meant.</td>
<td>
H.M.S Beagle in the Strait of Magellan

My tent
Logan's Journal, 1843.</td>
</tr>
<tr>
<td>2:30</td>
<td>Their legacy proves that anything that scientists of the time may have lacked in technology, they more than made up for in imagination, ingenuity and perseverance.

Of course, they had the most important tools of any scientist, then or now: the eyes and the mind.</td>
<td>

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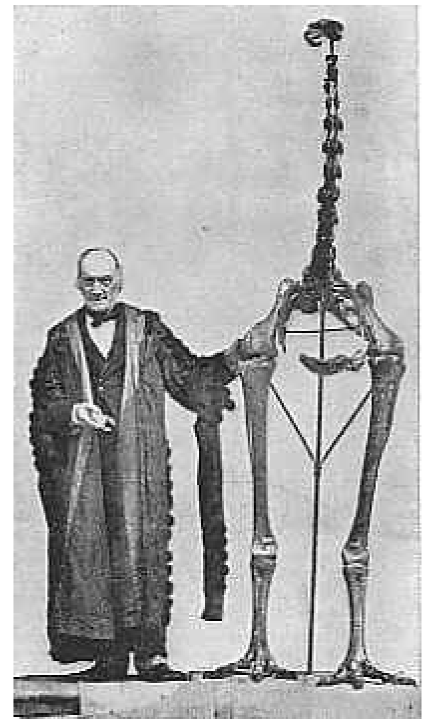
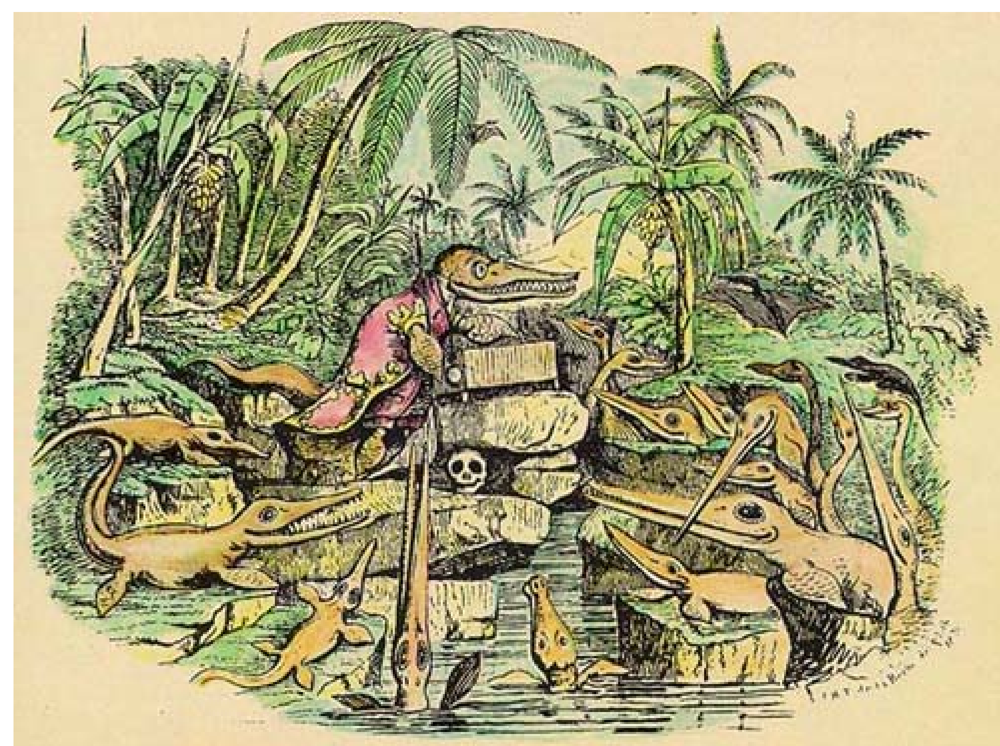
</table>

6. Big Ideas
6.5.AVP.1 The Big Ideas – AV Synopsis

2:45	And so, from the late 18th century on, geologists were at the cutting edge of a new understanding of the world and our place in it. Their findings were the breaking news of the age, and their controversial conclusions were eagerly awaited and hotly debated. From the origin of dinosaurs to the source of coal and the origins of species, the questions raised were fundamental, and often came dangerously close to territories long occupied by religion. These questions seem deceptively simple: • How old is the Earth? • How did humans come to exist? • Was there ever a time with no humans? • When did life really begin? • What did the Earth look like in the ancient past?	 
3:15	The evidence brought to these debates was carefully gathered at places like Joggins, where from the earliest days of European exploration in the area, both the coal and the fossils had been noted. The most famous expedition of discovery to Joggins was that made by two pioneers of modern geology, Sir Charles Lyell and Sir William Dawson, in 1852. Their trip yielded not only the oldest known reptile, named *Hylonomus lyelli* in honor of the senior scientist, but also the first known land snail, the tiny *Dendropupa*.	 

6. Big Ideas
6.5.AVP.1 The Big Ideas – AV Synopsis

3:45	Not long after this debate, that same *Dendropupa* made an appearance in one of the most famous scientific debates of all time: the Oxford Society debate of 1860, where Thomas Huxley—also known as Darwin's Bulldog—defended the theory of evolution newly published theory of evolution against Bishop Wilberforce, The debate was about evolution – but more than that, it was about science, and evidence, and who to believe. It was about a big idea: an idea so powerful, it could change the way we see the world and our place in it.	  
4:15	The fossil record and the cliffs at Joggins have contributed to many of the big ideas that underlie our scientific understanding of the Earth, its history, and our place in it – in the past, the present, and the future.	 

7. The Place in Recent Times

7.1. People of Joggins

Main exhibit text:
The earliest known human presence at Joggins is that of the Mi'kmaq people who came here to take advantage of the vast fish stocks.

Europeans were drawn to the site by timber and the coal that was clearly visible from the water. The shore is marked as a "coal cliff" on early maps. Coal was mined by French settlers, British military and New England traders alike, starting in the early 1700s.

Later, the sandstone beds in Lower Cove were quarried to produce fine grindstones. The quarry opened in the early 1800s and continued to produce stones until 1919.

Diorama text:
The Mi'kmaq named this area *Chegoggin* – the place of weirs. They were probably catching shad in their weirs. An estimated one million shad still migrate into Chignecto Bay each August and September.

7.2. A Village Rooted in Coal

Main exhibit text:
The community here developed alongside the mines; the town was actually known from 1856 to1937 under the name of Joggins Mines. From 1854 on, a wharf provided access for coal and goods alike.

The opening of new mines in the 1880s brought new buildings and businesses to the community. It was more closely connected to the rest of the east coast in 1887 through the Intercolonial Railway at Maccan. The railroad continued to operate until 1961.

The combination of mine closures and the Depression hit Joggins hard in the late 1920s. While old community traditions like the July 1st Fireman's Parade live on, no new industry has replaced the mines that were at the heart of Joggins.

Diorama text:
Early Coal Gathering
Archaeological excavations of French merchant Sieur d'Aulnay's 1643 fort at present-day Annapolis Royal revealed a blacksmith's forge containing coal that came from Joggins. At the time it was the practice to gather "sea coal" from the eroding cliffs.

Secondary exhibit text:
The Great Fire of 1928
A disastrous fire on December 31, 1928, drastically changed the face of Joggins. The fire started in the basement of the Wonderland Theatre, and destroyed hotels, the school, post office, a shoe shop, a blacksmith shop, and several houses and barns. Tough economic times meant that the buildings were never rebuilt.

7. The Place in Recent Times

7.3. Coal Mining at Joggins

Main exhibit text:

The first attempt at commercial mining at Joggins took place in 1819, but the venture was unsuccessful. Joggins No. 1 Mine, the first successful industrial mine, was opened in 1854. Mining activity increased after 1887 with the connection of the Maccan-Joggins Railway to the Intercolonial Railway, and was active through the early 20th century.

The last mine closed in 1980 in River Hebert. Although the five major coal seams of the Joggins coalfield rarely exceeded 1 meter in thickness, six million tons of coal were still taken from 83 different mines that stretched though River Hebert and Maccan to Styles Brook, 30 km inland.

Secondary exhibit texts:

Secrets Underground

Did you know you are standing right above an old mining site? Three mines have been on this very location, one on top of the other: a shallow French mine in the 1720s, then Joggins #7, and finally Bayview, 300 meters below.

Mining with Electricity

The Shore Mine, opened in 1905, was the largest mine to ever operate in the Joggins area. The first mine in Canada to be operated by electricity, it went as deep as one mile underground, stretching far out under the bay.

Diorama text:

Miner at the Coal Face

Coal mining was hard and dangerous work. The narrow coal seams of the Joggins coal field made working conditions particularly cramped.

7.4. William Logan and the Search for Coal

Main exhibit text:

Industry in the 1800s was powered by coal, so it is not surprising that when Geological Survey of Canada (Canada's first scientific agency) was founded, the search for coal was its top priority.

During the first field season in1843, the new director, William Logan, investigated the grand exposure of coal-bearing rock at Joggins, hoping to find clues that could lead to the discovery of coal deposits in Lower and Upper Canada (Quebec and Ontario).

Sir William Logan went on to become one of Canada’s most honoured and beloved scientists. Mount Logan in the Yukon, the highest mountain in Canada, is named after him.

Diorama text:

A Fine Week’s Work

In just five days in June 1843, William Logan measured the thickness of each sedimentary bed along a 15-kilometer section of the cliffs—a total of 14,570 feet 11 inches (4441.24 m).

7. The Place in Recent Times

His detailed log stood as the reference description of the section for 150 years. It was eventually updated by an international team, who took considerably longer than five days!

***Note**: The historical flipbooks for this exhibit area are still in development and the texts are not included in the present report.*

8. Stewardship

8.1. When You Find a Fossil

Main exhibit text:

Joggins is a Protected Site under the Nova Scotia Special Places Protection Act. All fossils are the property of the Province of Nova Scotia. They belong to all of us, and should be left for others to study and enjoy.

When you find fossils on the beach, you can have them identified by a JFC monitor. If your find is unique, it and your name could become part of the JFC permanent collection—and part of history.

8.2. Community Stewardship

Text pending feedback from Advisory Committee.

8.3. Canada World Heritage Site

Note: This panel will be left deliberately blank pending UNESCO review.

Main exhibit text:

Statement of Universal Value

The classic coastal section at Joggins, Nova Scotia, is of outstanding universal value. It contains an unrivalled fossil record preserved in its environmental context, which represents the finest example in the world of the terrestrial tropical environment and ecosystems of the Pennsylvanian 'Coal Age' of the Earth's history.

Ongoing discovery and research at the site, hewn and replenished by the world's highest tides, ensures that Joggins will continue to play a seminal role in the development of important geological and evolutionary principles.

9. Fossil Centre Interior

9.1. Green Building

Note: Text pending feedback from WHW Architects.

9.2. Site Map

Main Exhibit Text:

Welcome to the Joggins Fossil Cliffs, the best place in the world to study Carboniferous life. More than 300 million years ago, this site was home to giant insects, towering trees, and the first known terrestrial animals.

To get the most from your visit:

- Take a guided or self-guided beach tour from the Interpretation Centre.
- See the fossils and exhibits at the Centre to get the whole story.
- Pay attention to the safety messages.

Safety

To safely visit the fossil cliffs, respect the powerful natural forces of the tides, the constant erosion, and the unpredictable weather.

- The safest time to be on the beach is from mid-tide to mid-tide, the period between three hours to low-tide and three hours to high tide.
- Every day rocks fall from the unstable cliffs. Stay at least as far away from the cliffs as the cliffs are high.
- Wear sturdy footwear. Be careful of wet and loose rocks. Seaweed covered rocks are too slippery to walk on safely.
- It is often cold and windy on the beach. Dress in layers.
- Take water. Travel in pairs. Keep an eye on your children. Don’t count on cell phone coverage.
- When on top of the cliffs, stay away from the edges.

Stewardship

The local community in collaboration with partners at all levels of government are preserving and promoting this outstanding heritage site for all the people of the world. This is a Protected Site under the Nova Scotia Special Places Protection Act. All fossils are the property of the Province of Nova Scotia.

You may pick up fossils from the beach and have them identified by a JFC monitor. If your find is unique, it and your name could become part of the JFC permanent collection.

UNESCO logo and text location

Note: Space to be left blank pending approval.

Tide Table

Note: This must be changeable and updated at regular intervals.

What to See at Joggins

Note: Text under development

9. Fossil Centre Interior

9.3. Nova Scotia Tourism Sites

Note: Text pending feedback from Advisory Committee.

9.4. Hylonomus and Arthropleura Menus

Note: Text under development

9.5. Coprolites

Main exhibit text:

Poking around in smelly animal poop might not be your idea of a good job, but it's what biologists do to learn about an animal's diet, digestion, and place in the food chain and ecosystem.

Paleontologists study animal poop for the same reason, but they get to handle it in the hard, non-stinky, fossilized form called coprolites.

Anything organic has the potential to become a fossil, including poop! Coprolites are, as you might guess, common fossils. There are many at Joggins, though they're not always the easiest to spot.

10. Fossil Centre – Exterior

10.1 Standard Sign

Main Exhibit Text:

Welcome to the Joggins Fossil Cliffs, the best place in the world to study Coal Age life. More than 300 million years ago, this site was home to giant insects, towering trees, and the first known terrestrial animals.

To get the most from your visit:

- Take a guided or self-guided beach tour from the Interpretation Centre.
- See the fossils and exhibits at the Centre to get the whole story.
- Pay attention to the safety messages.

Safety

To safely visit the fossil cliffs, respect the powerful natural forces of the tides, the constant erosion, and the unpredictable weather.

- The safest time to be on the beach is from mid-tide to mid-tide,
  the period between three hours to low-tide and three hours to high tide.
- Every day rocks fall from the unstable cliffs. Stay at least as far away from the cliffs as the cliffs are high.
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UNESCO logo and text location

Note: to be left blank pending approval.

Tide Table

Note: This must be changeable and updated at regular intervals.

What to See at Joggins

Note: Text under development

10. Fossil Centre – Exterior

10.2 Fossil Fuel

Main Exhibit Text:

Did you arrive here by car? On an asphalt highway? You can thank energy from ancient sunlight.

Fossil fuels—which include the oil in your car as well as natural gas and coal—come from creatures that were once alive. Many fossil fuels, like the coal found here at Joggins, are formed from plants and animals that lived during the Carboniferous period, more than three hundred million years ago—a period also known as the Coal Age.

Energy from the sun, in the form of carbon transformed by photosynthesis, is stored in the fossil remains of plants. When burned, fossil fuels release that same carbon back into the atmosphere as carbon dioxide, a greenhouse gas that contributes to global warming.

Asphalt, plastics and fertilizers are by-products of fossil fuels. Can you think of others?

10.3 Coal Mining at Joggins

Main exhibit text:

A hundred years ago, the view from this spot would have been very different. This was a busy industrial site, with coal-burning locomotives chugging to the nearby engine house. Close by, in the buildings at the head of the mine, hundreds of miners went underground to work. Where you are standing, a tramway carried coal from the mine to the loading facility, a structure built high over the beach enabling coal to be loaded into vessels.

The last official mine in Joggins closed down in 1952, and the railway that served mines in the area made its last run in September 1961. Since then, vegetation has begun to slowly return the site to a natural landscape.

Secondary Exhibit Texts:

Mapping the Mines

A plan of underground mine workings looks much like a city map. Cables lowered cars down the main slope, a sort of central boulevard. The blocks between the “streets” had to be left untouched so that the tunnels would not collapse. Miners followed seams of coal that sometimes extended far out under the bay.

The Joggins Colliery Bankhead

In the early 1900s, miners were lowered into the mine from these buildings, and coal was brought to the surface in carts pulled by cable. This was the first mine in the country to be operated by electricity, although horses were still used to bring coal from the side tunnels to the main slope.

10. Fossil Centre – Exterior

Chronoframe Text:

The Joggins Wharf

With no natural harbour, the mines at Joggins needed wharves so that ships could safely load coal. Archival photographs show a bustling little port filled with coastal schooners and small steam vessels.

On the beach at low tide you can still see the remains of the wooden cribwork that once formed an L-shaped breakwater and wharf, as well as a second smaller coal loading facility. By the 1970s, the breakwater was in disrepair, while the loading facility had disappeared years before, destroyed by the tides, storms and blocks of winter ice that are common in the Bay of Fundy.

10.4 Dugway Time Tower

Introductory Panel Text:

As you go down the stairs to the beach, you're travelling way back in time –300 million years back, to a period geologists call the Carboniferous, or Coal Age.

Watch for the signs that explain the steps along the way – the names scientists have given to the periods of Earth's history. We need to go back five steps to get to the Coal Age. Can you find them all?

Geological Period Panel Texts:

Note: Text under development

10.5 Bay of Fundy

Main exhibit text:

Life in the Bay

The legendary tidal action of the Bay of Fundy supports a diverse and productive ecosystem. Its funnel shape and gradual shallowing causes a piling up of the inrushing water. Nutrients are pumped to the surface by the constant turbulence, supporting a wide array of plant and animal life in both the outer and upper bays.

Secondary Exhibit Texts:

Marshes and Mudflats

The salt marshes and mud flats of the upper bay, formed by sediments eroded from the surrounding soft rock by the tidal action, are busy nurseries for fish, birds, plants, and animals.

A Historic View

The view from where you are standing is not very different from the view that Lyell and Dawson would have had when they arrived at Joggins in 1851 to study the fossil record – a journey that put Joggins on the world stage.

High Tide Marks

The Bay of Fundy's tides are world-famous. Every day more than one hundred trillion litres of water move in and out of the bay – a flow equivalent to that of all the rivers of the world combined.

10. Fossil Centre – Exterior

Turn around and look at the windmill by the Centre. The blue mark on its shaft shows you the height of a typical tide. It's hard to imagine that the whole bay rises and falls that height, twice a day!

10.6 Evolution Maze

Introductory Panel Text:
Find your way through the evolution maze, and try not to hit the dead ends. If you're not careful, one of your favorite species might end up as a fossil – extinct!

"Evolutionary Dead End" Panel Texts::
Climate Change
See ya, trilobites!

Bigger Predators
Better luck next time, tetrapods!

Meteor Impact
Take that, dinosaurs!

11.Little Cove – Drop-Off
12. Grindstone Quarry

11.1 Standard Sign
See 10.1

11.2 Fossil Box
Note: Text under development

12.1 Standard Sign
See 10.1

Introduction to Programs

1. Goals and Outcomes for all JFC Programs

The JFC Advisory Committee identified overarching goals and outcomes for the JFC during the Drivers and Paradox exercises:

- *ensure* that the visitor has a clear sense that (s)he is in a coastal village rooted in coal; experiencing the present-day Bay of Fundy ecosystem; at an outstanding Carboniferous fossil site, 350 million years after all those *Lycopod* trees and *Hylonomous lyelli* were alive on this very spot!
- *create* an understanding for the visitor of the significant role that the Carboniferous cliffs have played in the development of science and the history of ideas from a global perspective
- *address* the multiple intelligences of visitors and satisfy visitors' needs for interaction.

2. Audiences

The audiences will be a mix of people on vacation (generally from outside the region) or a weekend break (more local), families with children, adults, people with some related knowledge, people with little or no knowledge.

The guided beach tours will appeal to people who want some social interaction as well as learning, so we suggest the interpreters/group leaders incorporate the opportunity for everyone to find out a couple of things about each other at the start of every tour, namely where people are from - by country or by state and province - and what level of knowledge they have – hard-core enthusiast, some knowledge or experience, or novice. In this way the interpreter learns the composition of the group, and also if there is someone in the group with a Ph. D. or field experience who might like to assist the novices. And the participants know something about each other and may chat along the walk.

3. Program Themes

Every program should have a central concept, expressed in a complete sentence. Ideally the visitor remembers it, if nothing else, from their experience. The theme is developed and illustrated by the various components of the program.

4. Program Objectives

Each program should have cognitive, affective, and behavioural objectives which support the central theme. Once one is clear about what one wants visitors to know, to feel, and to do as a result of the program, one can develop activities, scripts, and props to achieve those results and illustrate the theme.

Introduction to Programs

5. Staffing

It is assumed that the programs at the JFC will be highly imaginative and satisfying to visitors and help to generate excitement about the site and the region. This will depend on the quality, management, and motivation of staff involved with interpretation and customer service.

Essential qualifications for interpreters: creativity, team-work, sparkle, intelligence, leadership, self-motivation.

Just as interpretive programs need to address the affective and behavioural as well as the cognitive, the interpreters should be hired for what they can do, even more than for what they know. Most people can learn the content but the spark cannot usually be taught. A technique used by Kananaskis Country, the Royal Tyrrell Museum, and the Calgary Zoo is to hold a recruiting workshop. All short-listed candidates spend a day together, doing activities designed to reflect the qualities being sought in interpretive staff that are difficult to determine in the traditional interview. The prospective employers observe how well each candidate works with others, holds up under stress, communicates ideas, etc. while candidates demonstrate how they deal with activities related to the development and presentation of skits and programs and other job-related activities.

As a community economic development project, the JFC will want to hire locally. At the same time, as a world-class operation, the JFC will want to hire people who can not only deliver programs but be creative as well. Given the proximity of The Ships Company Theatre in Parrsboro, JFC should be able to find local prospective interpreters who have done the Company's drama camps as well as develop a relationship with the Company to assist and support the JFC in its quest to attract and feature a creative and effective interpretation staff.

6. Locations

Everyone on the Advisory Committee agreed that the beach and cliffs required live interpretation, so a menu of beach programs is a primary component of the overall interpretation program.

Everyone also recognized that in times of high tides and bad weather, interpretive staff will be available to offer programs in the Centre, so a menu of Centre programs is also essential. Some of these will take place in the demonstration area and fossil gallery in the exhibit space, others in the multi-purpose room.

A program, wherever it occurs outside the exhibit galleries, should reference what can be seen and learned in the exhibit galleries.

7. Duration

Introduction to Programs

A complete menu of programs offers programs as short as a ten-minute lab demonstration and stretching all the way to a four-hour intensive beach tour.

8. Number of participants

The number of participants depends on the location, the content, and the communication techniques. Schools often try to fill a 40-person bus and usually a group that size needs to be divided into two or three smaller groups. The size of the JFC bus will limit programs that use it to 15. Programs in the multipurpose room will have the least distractions and can match the capacity of the room.

9. Frequency

Arbic has determined the frequency and participation rates that are required to meet revenue targets.

10. Equipment required

Being heard outdoors in the windy environment of Joggins will be a challenge for interpreters. Light weight portable PA systems should assist.

Devices that help people see more clearly will often be useful. These include magnifiers, scopes, and projecting microscopes.

The Centre should have a standard range of audio visual equipment including media projectors, laptop computers, TV monitors, PA systems with microphones, a lectern and laser pointers.

Interpretation centres and museums often find it useful to have program materials on two-shelf carts that can be wheeled into public areas for an event and then put away (setting up and putting away program materials can take longer than the actual program if you have to go looking for materials each time).

Program: The 15-million Year Walk

Description: A 3-hour expeditionary walk on the beach from Little River to the Centre with a JFC interpreter.

Theme: The cliffs at Joggins can be read like books to tell the story of 15 million years of Carboniferous history.

Audience: Families with older children (this could be arduous and long for smyall children), adults with no kids, people with some related knowledge, people with little or no related knowledge and people with good mobility.

Communication goals: To address the overarching goals identified by the JFC advisory committee.

Cognitive Objectives: Participants will *learn* :
- how to be reasonably safe while on the beach
- to respect and support the stewardship message/collecting policy
- that the cultural landscape is a relic of 100 years of industrial coal mining (Bus ride)
- how geologists read these cliffs to understand the 15 million years of Carboniferous history that are exposed in the designated section at Joggins
- the visual sweep from Boss Pt. to Ragged Reef and beyond about 10 mya.
- the Mississippian rocks (+ ~ 5 mya) are beyond Boss Point ,
- the Pennsylvanian are from Boss Point to McCarrons (+ ~ 10 mya)
- the actual walk from Little River to the centre spans about 2 to 3 million years
- what geologists in the 1800s were looking for and what they discovered
- how the cliffs were created and then exposed
- the impact of the present-day power of the Fundy
- some of the cognitive objectives from the self-directed tour should be integrated in this guided tour as well

Behavioural Objectives: Participants will *do* these things:
- read the Joggins Cliffs
- see alternating sedimentary beds of Carboniferous sandstone, siltstone, and shale and the overlying (Quaternary) glacial till
- see the coal seam at Coal Mine Point
- look for, and hopefully see, fossilized evidence of Carboniferous life and events, particularly tree trunks or moulds of trees.
- see the remains of the wharf
- act responsibly
-

Affective Objectives: Participants will *feel*:
- empowered
- satisfied
- amazed

Duration: 3 hours, including the bus trip

Program: The 15-million Year Walk

Number of participants: 15 (the number of seats in the bus)

Location: From Centre (safety, stewardship and comfort message) by bus (landscape message) to Little River drop-off (safety message, identification of participants -see preamble) to Beach for hike (Carboniferous/geology content) back to the Centre.

Frequency: 54 times/year on specific advertised dates and times, according to projections by Arbic. Schedule determined by tide. Can book in advance.

Equipment required for the interpreter: portable PA, a backpack containing binoculars for seeing Boss Point, a few examples of fossils, a waterproof copy of Logan's drawing of the section of the Cliffs, a magnifying glass or hand lens(es), a basic first aid kit.

Equipment provided by JFC: a handout with map of the grand exposure, photo of cliffs clearly showing strata like p. 8 of *Joggins* by L Ferguson, and a drawing of the cliff showing typical features like p. 11 of *Joggins* by L Ferguson, illustrations of some key fossils, and space to make notes and drawings. This handout could be used for all the guided walks and might include the fossil permit. It could be designed as a folder to hold the "passport" and other specialist guides that might be produced.

Equipment recommended for participants: suitable clothing and footwear, water bottle, binoculars optional (an asset for seeing Boss Point and looking at the cliffs from a safe distance).

Program: Self-Guided Beach Tour

Description: A printed guide that will help visitors have a meaningful visit to the beach and cliffs without a live interpreter.

Theme: The exposed cliffs at Joggins provide fossil evidence of the life and events at this very spot 300 million years ago during the Carboniferous era, before dinosaurs and birds, when the waters and the forested wetlands were home to a diverse population, including the earliest-known reptiles and giant insects.

Communication goals
To help people make sense of where they are and what they are seeing and experiencing:
- an outstanding Carboniferous fossil site, 350 million years after Hylonomous and all those trees were alive.
- the present-day Bay of Fundy ecosystem
- a coastal village rooted in coal

Cognitive objectives: People will *know*
- know, before their beach tour, that seeing the fossils on display (and the exhibits) in the Center will help them recognize fossils and provide info to make their beach experience more successful
- know how to recognize fossils and other features of the shore
- understand some key geological processes while on the beach: e.g. sedimentation, subsidence, fossilization, coal formation
- know the role that water played during the Pennsylvanian Carboniferous period in
- creating the beds/layers that are now the fossil cliffs, through cycles of flooding and deposition of sediments and marine creatures among the inundated plants
- creating the waterlogged conditions that resulted in peat and coal
- understand the tilted layers of sedimentary rock (alternating layers of sandstone, siltstone, and shale) represent the deposition of sediments by water eroding a mountain range over a million or so years.
- understand what the Carboniferous environment was like (climate, weather)
- know that this is the first place and time where creatures lived their entire life on land: fossils of the earliest known reptile (Hylonomous lyelli) have been found here
- to know to head across the beach to the cliffs/exposed section
- learn the names of 5 Carboniferous inhabitants
- understand the stewardship message
- understand the safety message

Affective objectives: People will *feel*
- satisfied with their experience
- confident in their interpretation of the material provided to them
- that they know where the best area is for fossils and where various finds have been

Program: Self-Guided Beach Tour

made
- a sense of wonder about this place and what it tells us about the history of our earth and our knowledge of it.
- cautious about the tides, rock falls, and other dangers of the shore

Behavioural objectives: People *will*
- visit the Center before going to the beach and to revisit the exhibits after the beach
- read the panels at the top of the site and down the Dugway
- see the shell coal at the foot of the Dugway and the brick-like red stones that formed above layers of burnt coal
- observe the remains of the wharf and coal mining operations
- head across the beach and around the reef to the cliffs
- walk carefully, be mindful of rock falls and slippery rocks
- look for the coal seam at Coal Mine Point
- observe the Cliffs to see alternating sedimentary beds of Carboniferous sandstone, siltstone, and shale and the overlying (Quaternary) glacial till
- look for, and hopefully see, fossilized evidence of Carboniferous life and events, particularly tree trunks or moulds of trees in the cliffs and impressions of bark, fragments of ferns, or pieces of tree roots on the beach
- engage in some family-friendly activities (see below)
- sing the Joggins song
- do some follow up activity or reading
- tell friends about the site and programs

Audience: families with children, couples/adults with no kids, people with some related knowledge, people with little related knowledge, people with no mobility problems

Duration as long as people want to be on the beach, within the limits of the tide.

Number of participants: N/A

Location: the Centre, the Dugway Tower, crossing the beach, at the Cliffs, and return via the same route.

Frequency: daily, as tides allow.

Equipment recommended: appropriate clothing and footwear, sunscreen, binoculars, and a magnifying glass or hand lens(es) + brochure and permit for collecting fossils.

Notes :
- There may be an opportunity here to rent or sell some of the equipment.
- Binoculars add immensely to the pleasure of observing the cliffs and trees in the cliffs

Program: Self-Guided Beach Tour

Program: Carboniferous Capers

Description: Theatrical performances featuring songs and skits.

Theme: The "capers" themes and content could change annually or more frequently, depending on the skills and talents of staff.

Theme example: Water has shaped the landscape and life at Joggins, during and since the Carboniferous period. (How water made the Joggins Cliffs what they are today: *Water Rules OK*)

Examples of program elements:
- Dissolve every Mountain
- Who let the mud in?
- A new place to live, and the place I leave behind (a young reptile's bittersweet farewell to the pond as she embraces an exciting but dangerous terrestrial lifestyle.)
- Chill out, it's only frozen water (glaciers)
- Don't mess with me, I'm the tide.

Some other examples of themes for "Capers":
- It Takes All Types (biodiversity in Carboniferous at Joggins)
- Never ask Coal Its Age (How do geologists know how old these rocks are?)

Cognitive objectives: People will *know*
- how water has shaped the Joggins landscape by supporting and destroying life through erosion, glaciation, deposition, and creating conditions for peat to form.

Affective objectives: People will *feel*
- engaged
- amused
- stimulated

Behavioural objectives: People *will*
- sing
- laugh
- remember some of the lyrics
- tell others about the fun time

Audience: This kind of program addresses multiple intelligences, appealing particularly to families and school groups, but all ages should enjoy the presentations. Similar programs at other sites have been attractive to local audiences who will come out to see the latest "caper."
"Capers" are excellent programs to use for outreach to schools or at promotional events like the Saltscapes Expo.

Duration: 20 minutes

Program: Carboniferous Capers

Number of participants: 20 to 80, the capacity of the multipurpose room.
Location: Multi-purpose room or off-site locations

Frequency: Can be regularly scheduled and should be a mainstay during times when tide times limit beach experiences. Can also be offered when bad weather keeps people from the beach. Early evening performances would attract people staying in the area as well as locals.

Equipment Required:

Costumes, props, and backdrops for this type of performance are traditionally very simple and produced in house.
Wireless microphone and a PA system.
A music production device e.g. a Karaoke machine, or simple synthesizer.
A playback device.
Some simple stage lighting will add production values.

Program: Small Wonders

Description: An interpreter offers visitors of all ages the opportunity to examine microfossils under magnification and to understand their significance.

Theme: Although Joggins is famous for its large fossil trees, tiny pieces of Carboniferous life have also been preserved as fossils and can tell us much about those times.

Cognitive objectives: People will *know*

- Just because a fossil is small doesn't mean it's not important
- Small fossils help us understand the diversity of life in the terrestrial and aquatic environments of Carboniferous Joggins
- Microfossils are used to determine the age of deposits.

Affective objectives: People will *feel*

- Awe that items so small can be preserved so perfectly
- Greater insight into the practice of paleontology.

Behavioural objectives: People *will*

- Use magnifying devices to see micro fossils
- Visit the beach with a greater variety of fossil "search images"

Audience: general visitors.

Duration: 15 to 20 minutes.

Number of participants: 1 to 15

Location: Demonstration area.

Frequency: Daily programs, as posted at Centre and on website. Announced on the PA system. More programs on days when tides limit cliff visits. Special programs added during poor weather.

Equipment required: video microscope connected to a monitor or media projector, hand lenses.

Program: Small Wonders

General comments:
Any interpreter assigned to the demonstration area should encourage questions and develop strategies to draw visitors into a dialogue. Interpreters must be prepared to tell the same story over and over while keeping it sounding fresh. They must feel rewarded by helping people marvel at what to them has become familiar and commonplace.

The interpreter's activities become a "program" when it has been scheduled and publicized. Often visitors who do not believe that they want to participate in a program will "sample" the offering from the edges of a group so as not to be trapped in something that does not interest them. The challenge for the interpreters is to develop presentations that are fascinating and engaging enough to convert these "lurkers" into participants

Program: Black to Green: Joggins Then and Now

Description: Guided experience on the Centre site and in the Centre building.

Theme: Who knew in the 1800s that the use of coal for energy that drew people to work and live in Joggins Mines (and coal mining communities like it all over the world) would also be linked to accelerated climate change in the last 40 years? In response to the scientific evidence that tells us we must find alternative energy sources now to slow down that rate and keep us going at the same time, this Interpretation Centre is an example of green design, demonstrating ways of thinking that start with the idea of sustainability.

Cognitive objectives: People will *know*

- how the community used to look and why it looks the way it does today
- the scale of industrial development that was once on the site
- Joggins had the first mine operated with electricity
- what constitutes green building design: the five categories used by LEED to quantify 'greenness': sustainable site, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation & design process.
- the green features of this building: planted roof, heat pumps for cooling and heating, solar glazing (made in Cape Breton) with an R5 value that also transmits high quality light without glare, solar collectors to heat water, wind turbine, photo voltaic cells, recycled content (steel, flyash in asphalt), regional materials (Wallace stone, wood deck, glazing), grates at doors to catch dirt, compact fluorescent lightbulbs, low-flow toilets using water from cistern.
- that the carbon stored by fossilized plants is released into, and trapped by, the atmosphere when we burn coal, changing our Icehouse climate (when the climate and temperature differ dramatically from the equator to the polar regions) into a Greenhouse environment (when global climate is evenly warm)
- coal has been the source of power since the later 1700s (the industrial revolution) and we will continue to depend on it and other fossil fuels during this century. That means we will continue to release carbons into our atmosphere.
- the Joggins project fits neatly in the 1995 World Summit on Social Development definition of sustainability as *"the framework for our efforts to achieve a higher quality of life for all people,"* in which *"economic development, social development and environmental protection are interdependent and mutually reinforcing components"*.

Affective objectives: People will *feel*

- amazed at how the former industrial site is being masked and healed by natural vegetation
- some human connection with the Joggins community through stories and photos
- motivated to do something about carbon use

Behavioural objectives: People *will*

- recognize traces of mining activity that can be still seen in the landscape.
- observe the wind generator and the solar panels

Program: Black to Green: Joggins Then and Now

- examine the green roof design
- see the "knobs and dials" (control panel) in the public zone
- think about how they can make a difference in the effort to reduce greenhouse gasses.
- visit or revisit the exhibit galleries to see the Place in Recent Times unit.

Audience: General visitors, families with older children, people interested in cultural history, people interested in green design and alternative energy.

Duration: One hour.

Number of participants: 15 - 25 people

Location: Centre site and building, including the exhibit section on the Place in Recent Times.

Frequency: As scheduled, particularly when the tides prevent people from visiting the shore. A good program for people who are interested in: cultural history; environmental issues; green design.

Equipment Required:
- Graphic to illustrate climate change (Al Gore uses a great example)
- Mounted images of the mine bank head, locomotive shed, Main Street before the fire.
- Samples of the roofing material.

Joggins Fossil Cliffs Centre

100% Design Development

July 21, 2006

Design+Communication Inc.

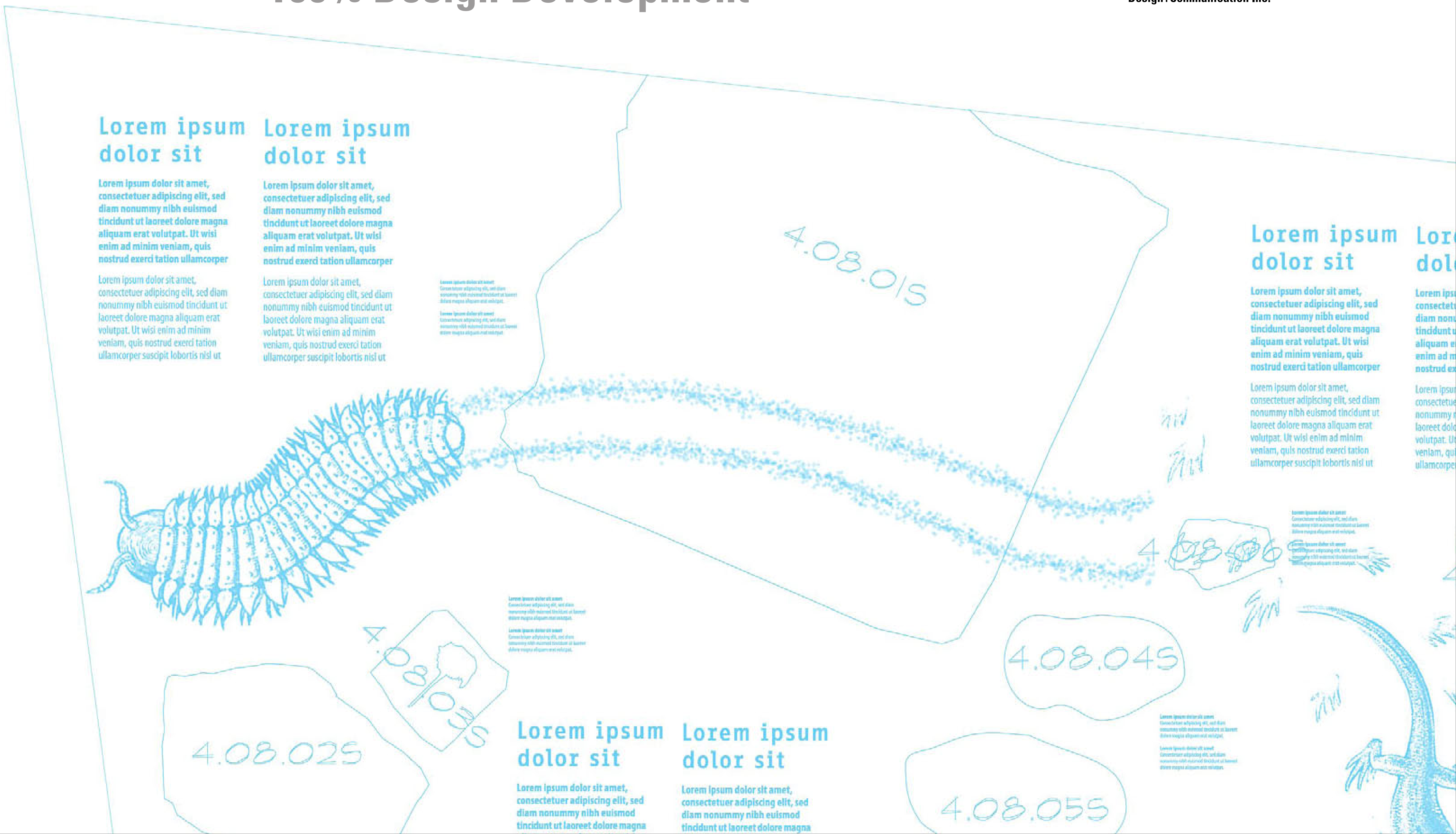

Exhibit Fonts

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Info Office Bold Italic

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Main text (Level 1)

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Actual size

Main text (Level 2)

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Secondary text (Level 3)

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Caption (Level 4)

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Text
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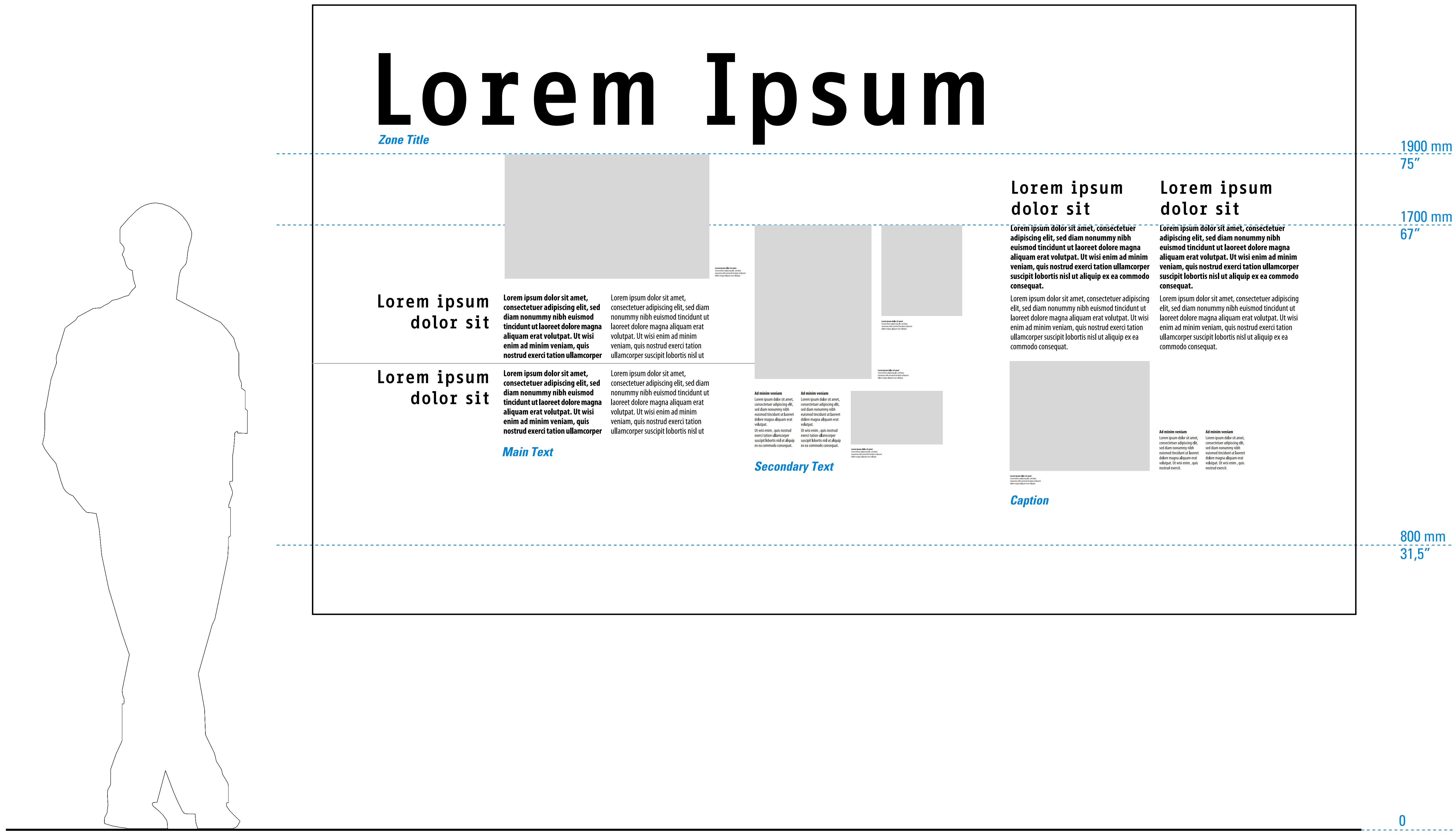
18 / 20 pts

Actual size

Actual size

Actual size

Panel /text height



1. Introduction

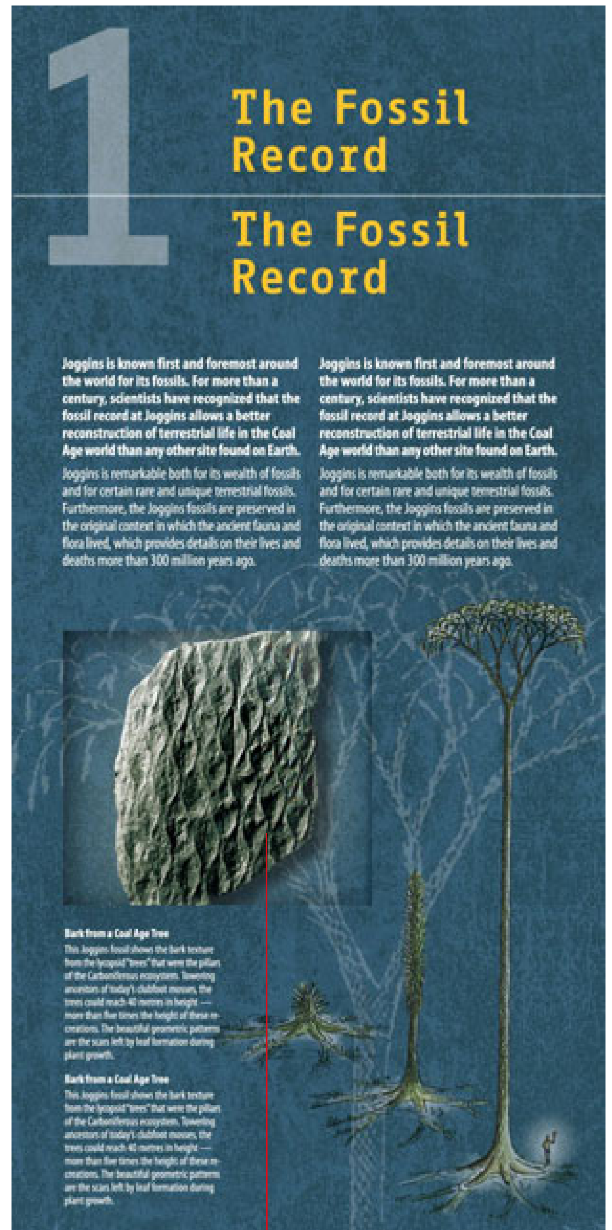
View of Introduction
from entrance

1.1 Why is Joggins World Famous ?

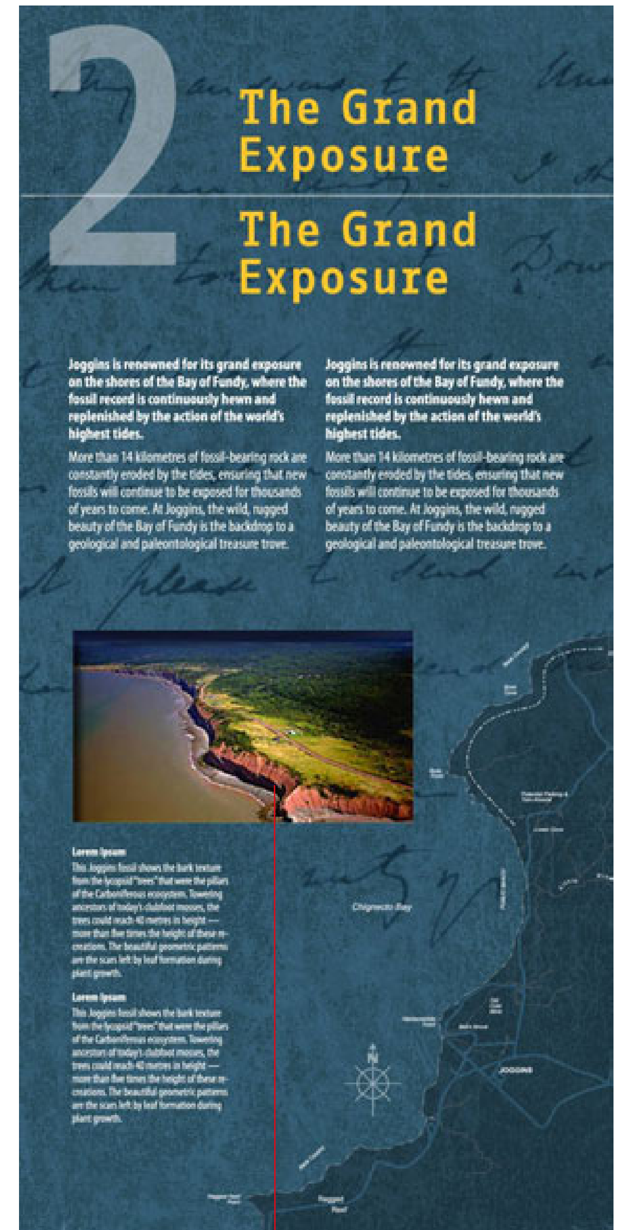
1.2 The Fossil Record

1.3 The Grand Exposure

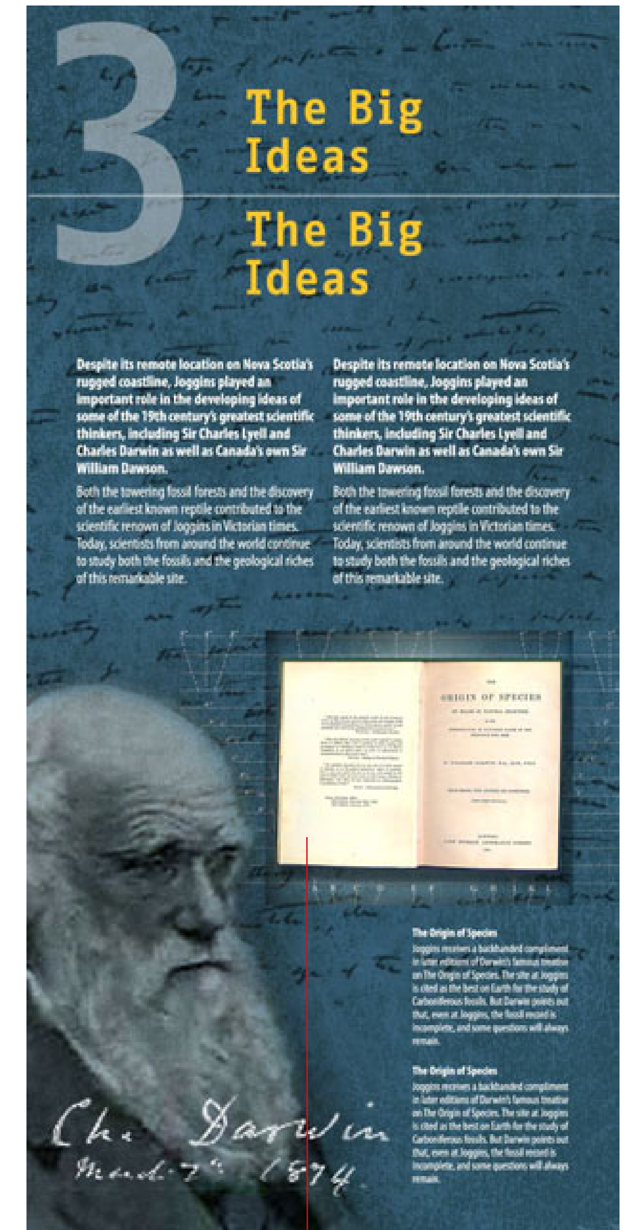
1. The Big Ideas



"Sigallaria"
Tree bark specimen

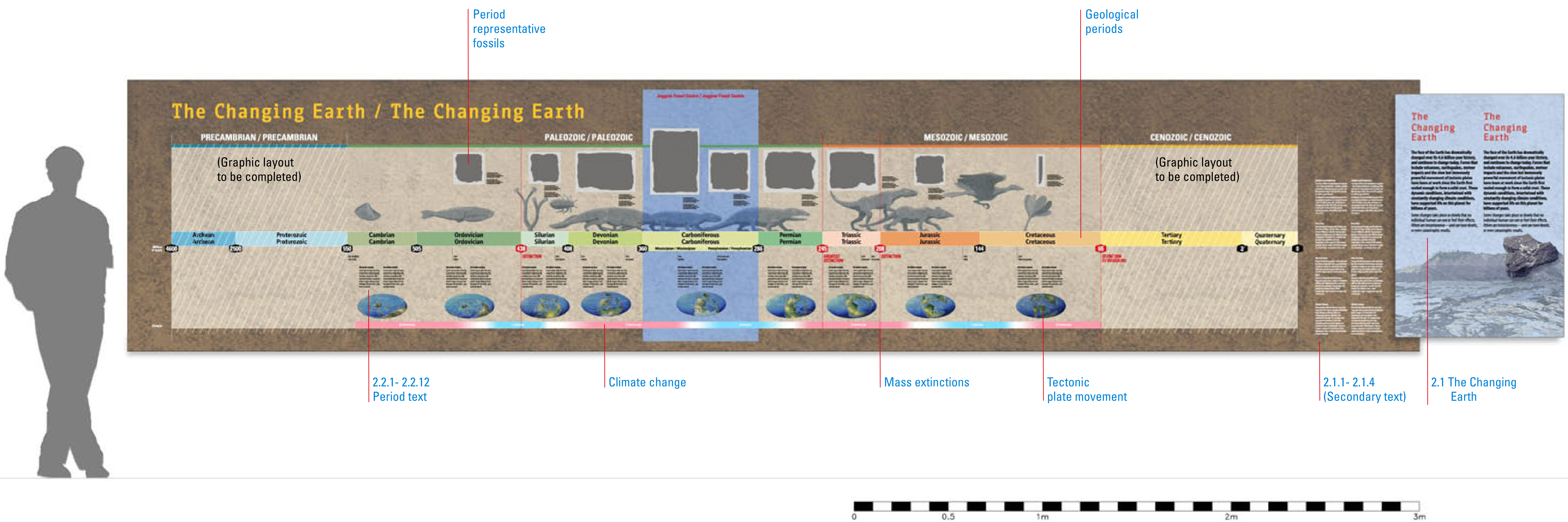


Grand Exposure
Videoclip

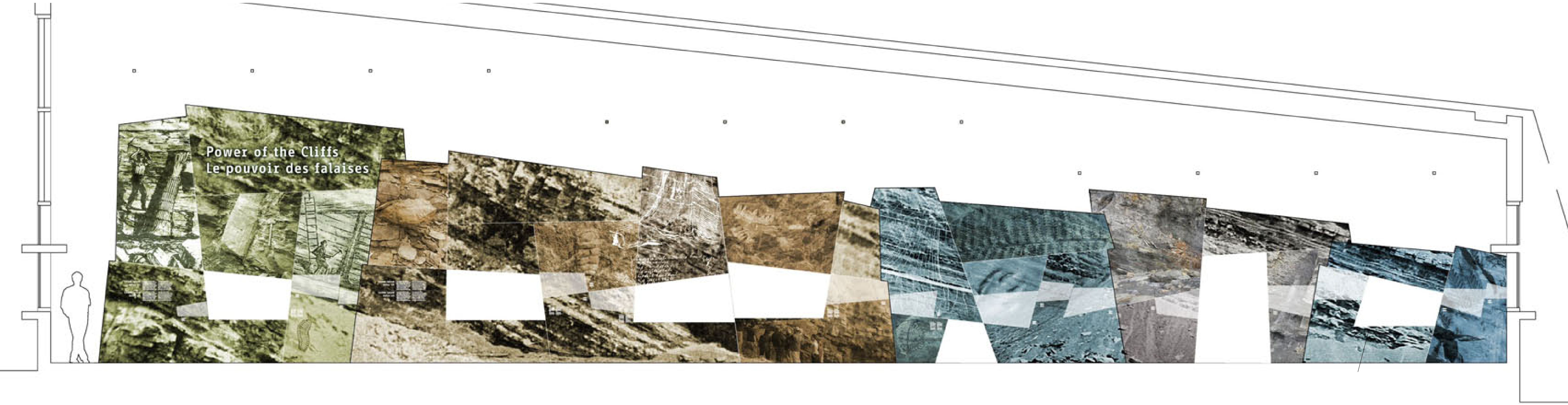


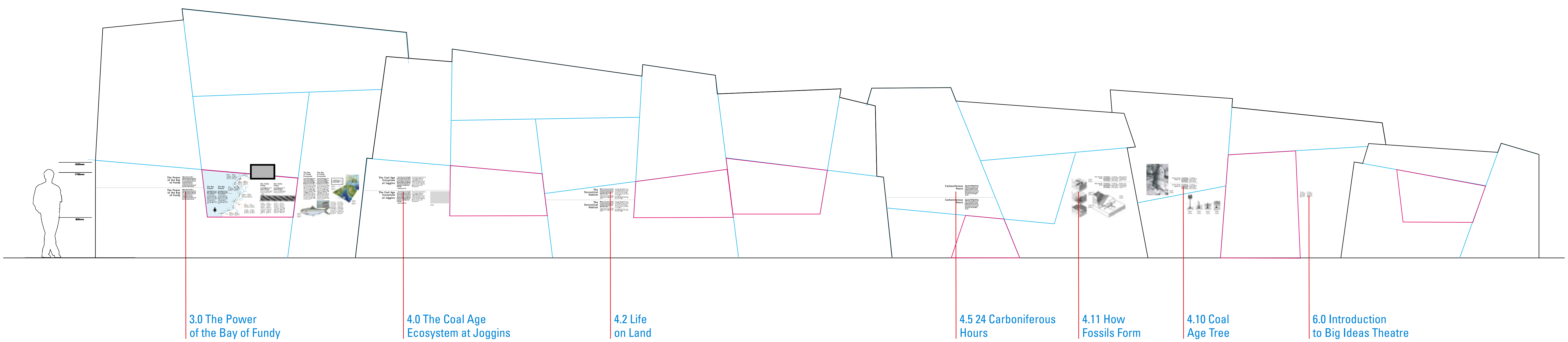
Historic copy of Darwin's
"On the Origin of Species"

2. The Changing Earth

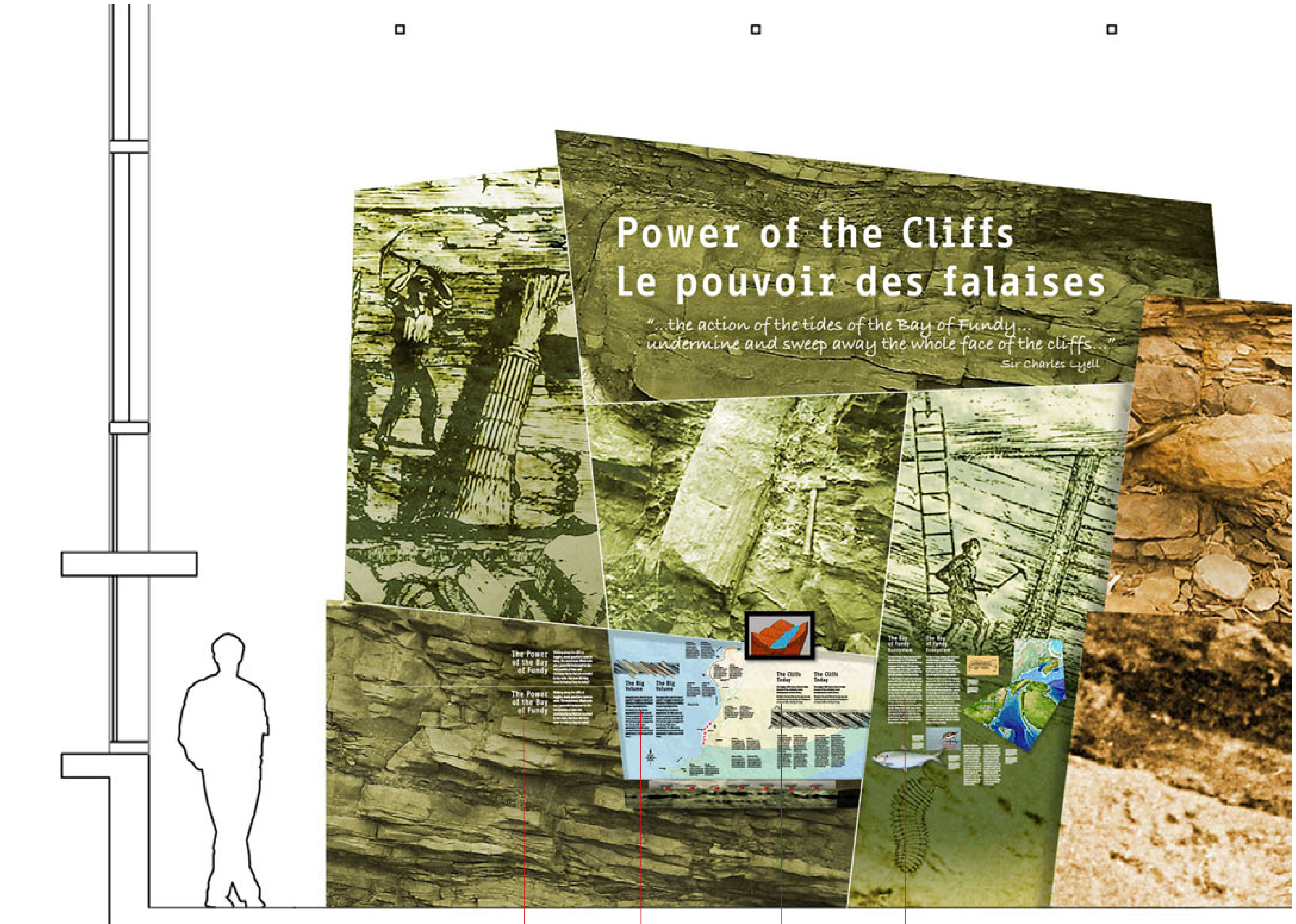


Power of the Cliffs



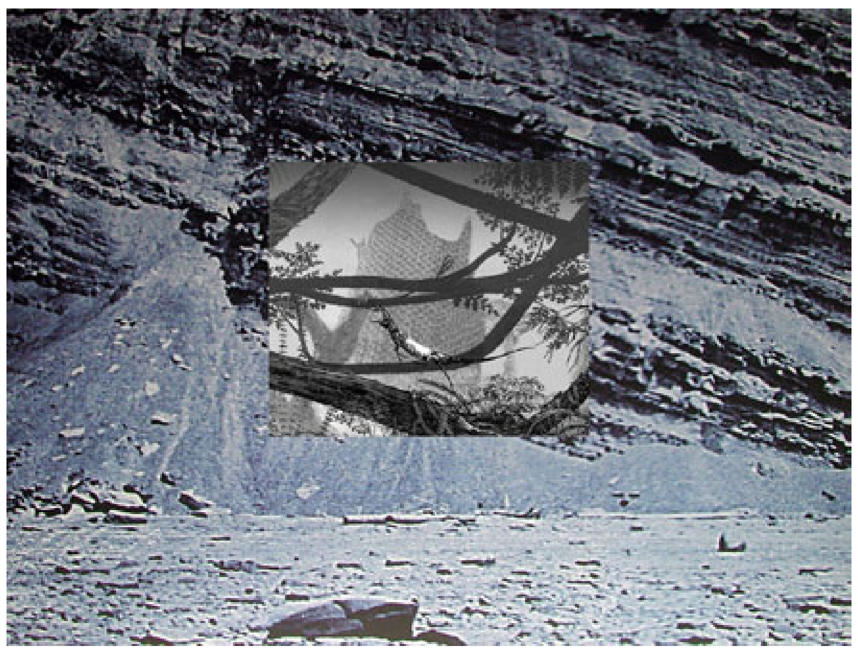


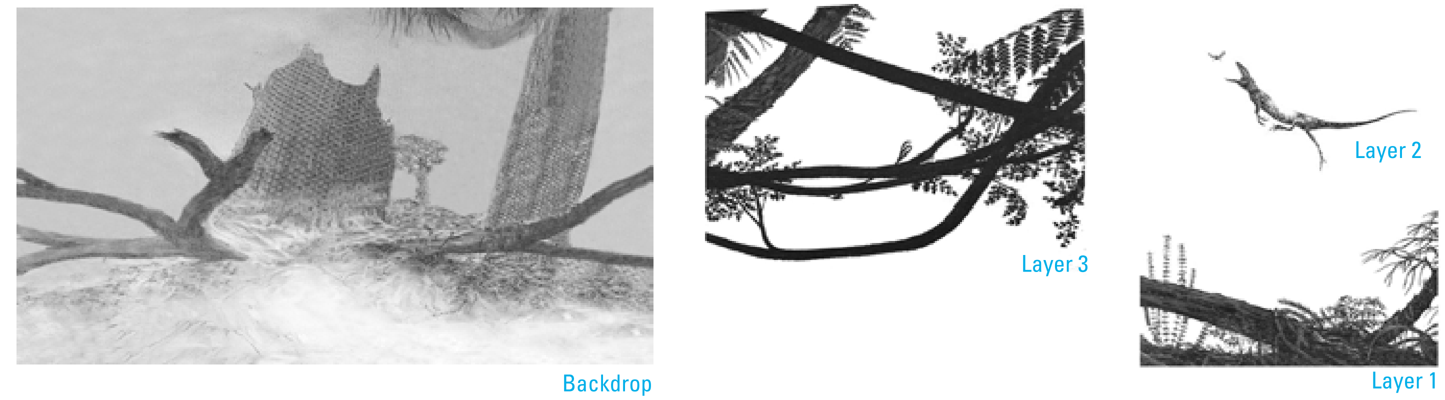
3. Power of the Bay of Fundy



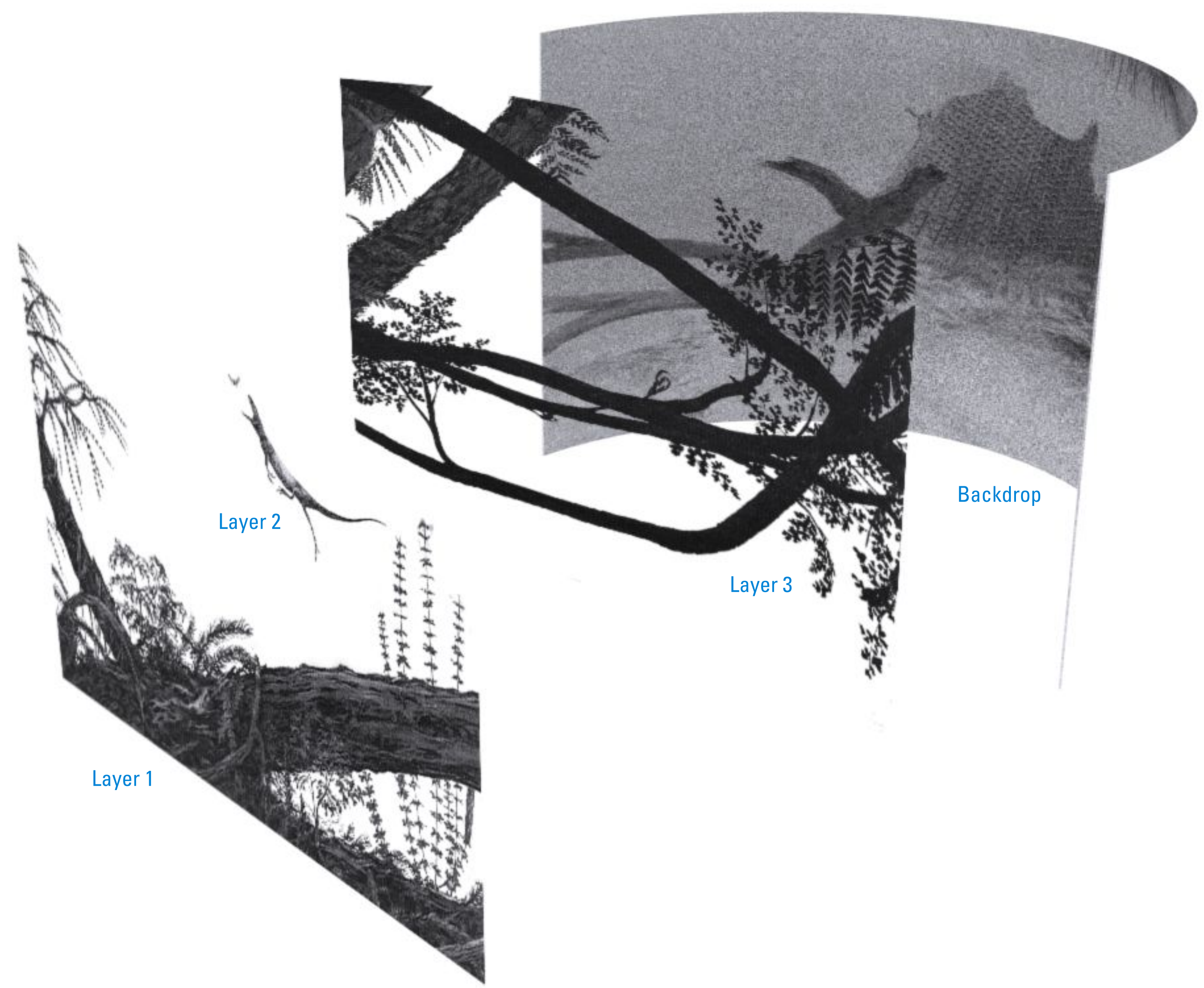
3.0 The Power of the Bay of Fundy | 3.1 The Big Volume interactive | 3.2 The Cliffs Today | 3.3 The Bay of Fundy Ecosystem

Layer Diorama Concept Using Doug Henderson's Illustrations





Layers



Showcases Design Development

For dioramas, button indicate associated illustration

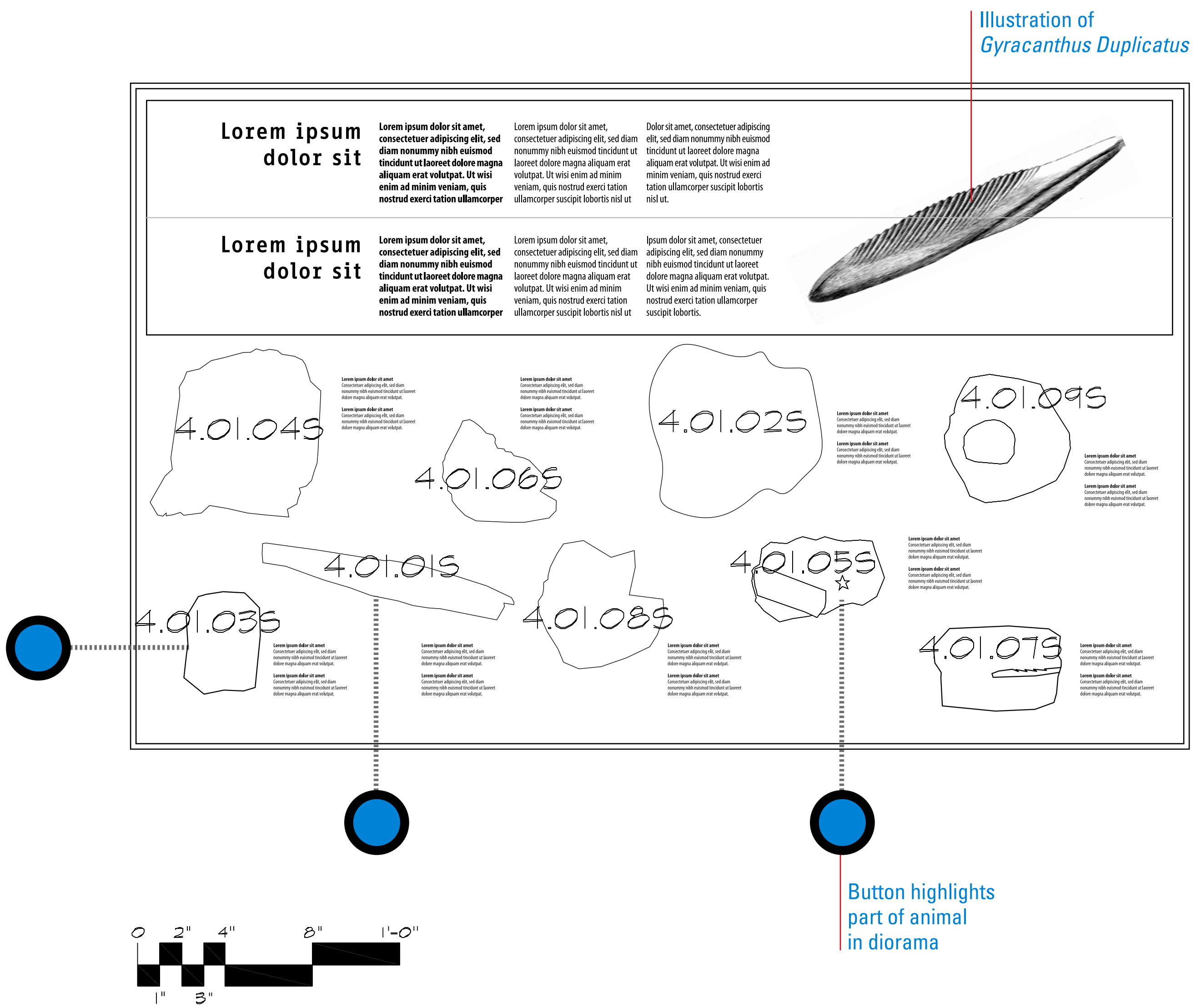
Possibility of edge lighting

Standalone showcase design

Showcases Design Development

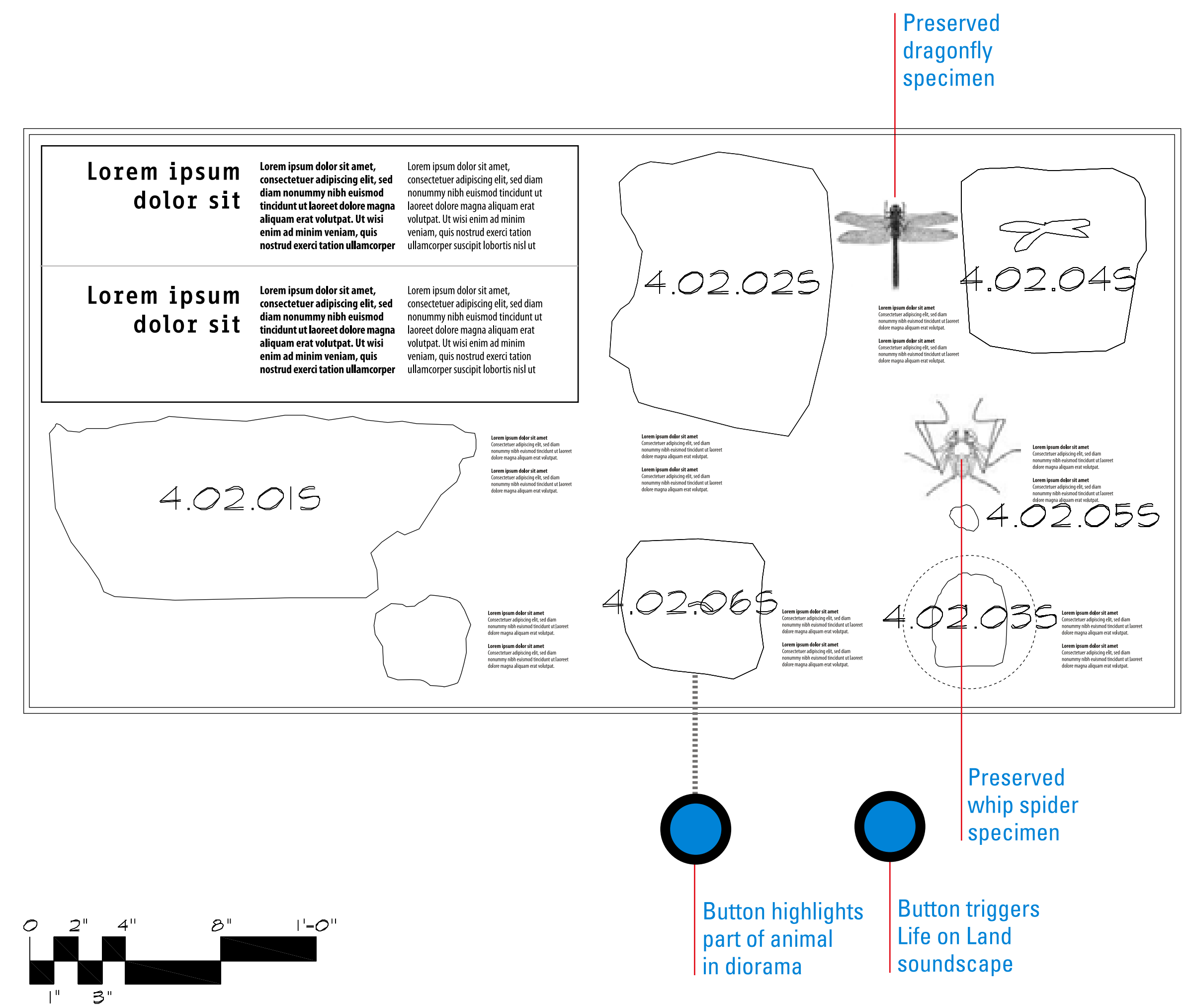
4.1 Life in the Water

48″x 30“



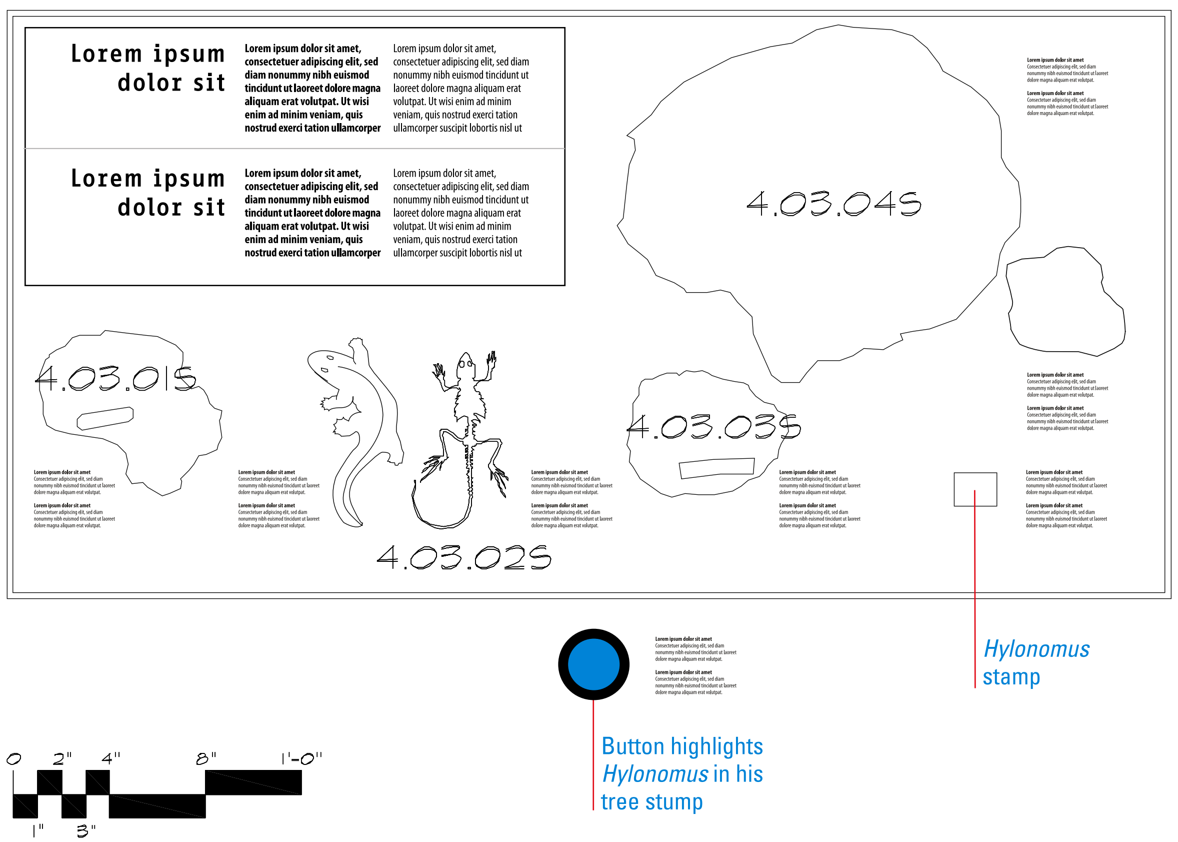
4.2 Life on Land

48″x 24“



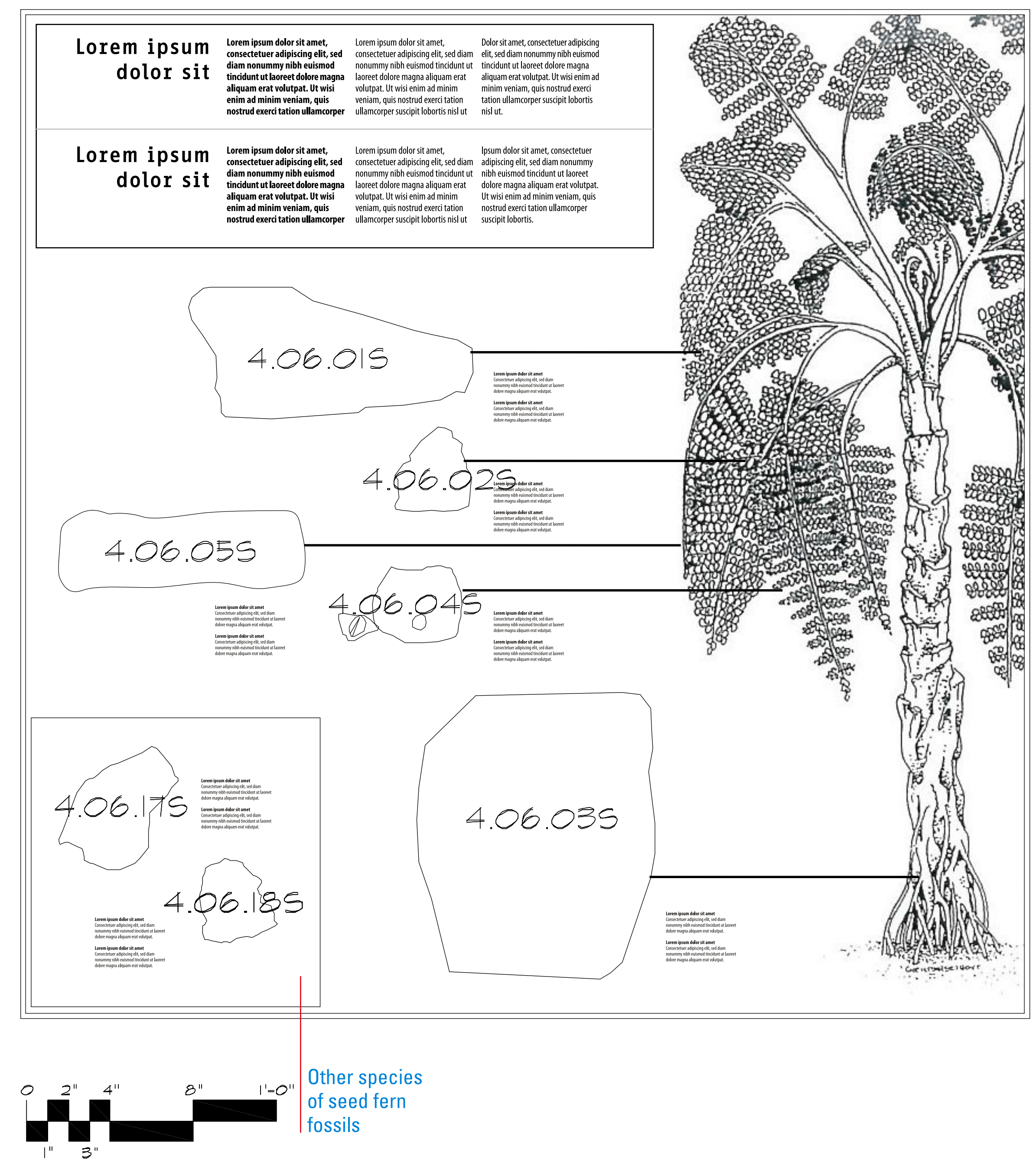
4.3 Hollow Tree Fauna

48″ x 24″



4.6A Coal Age / Seed Fern

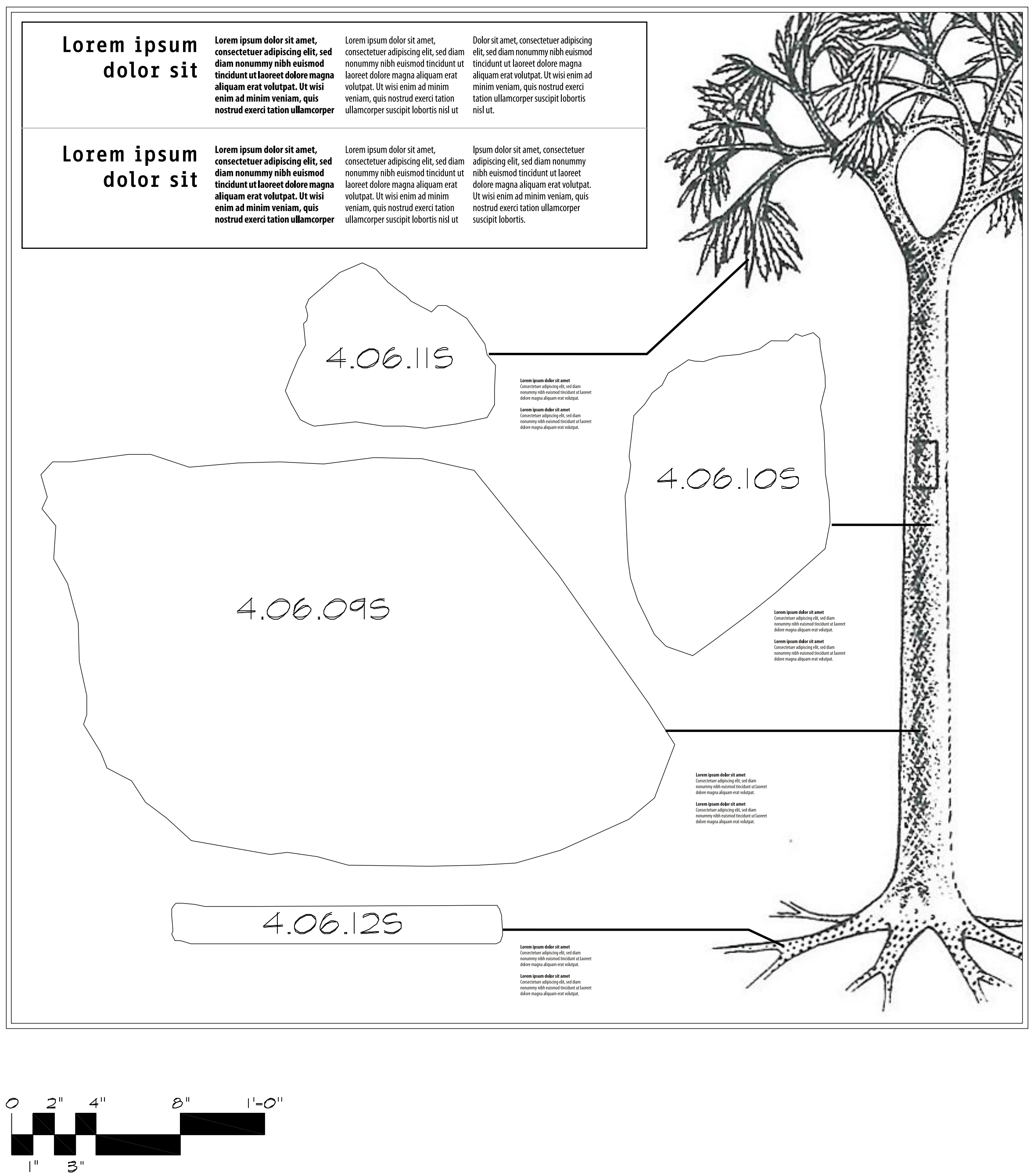
48″ x 48″



Showcases Design Development

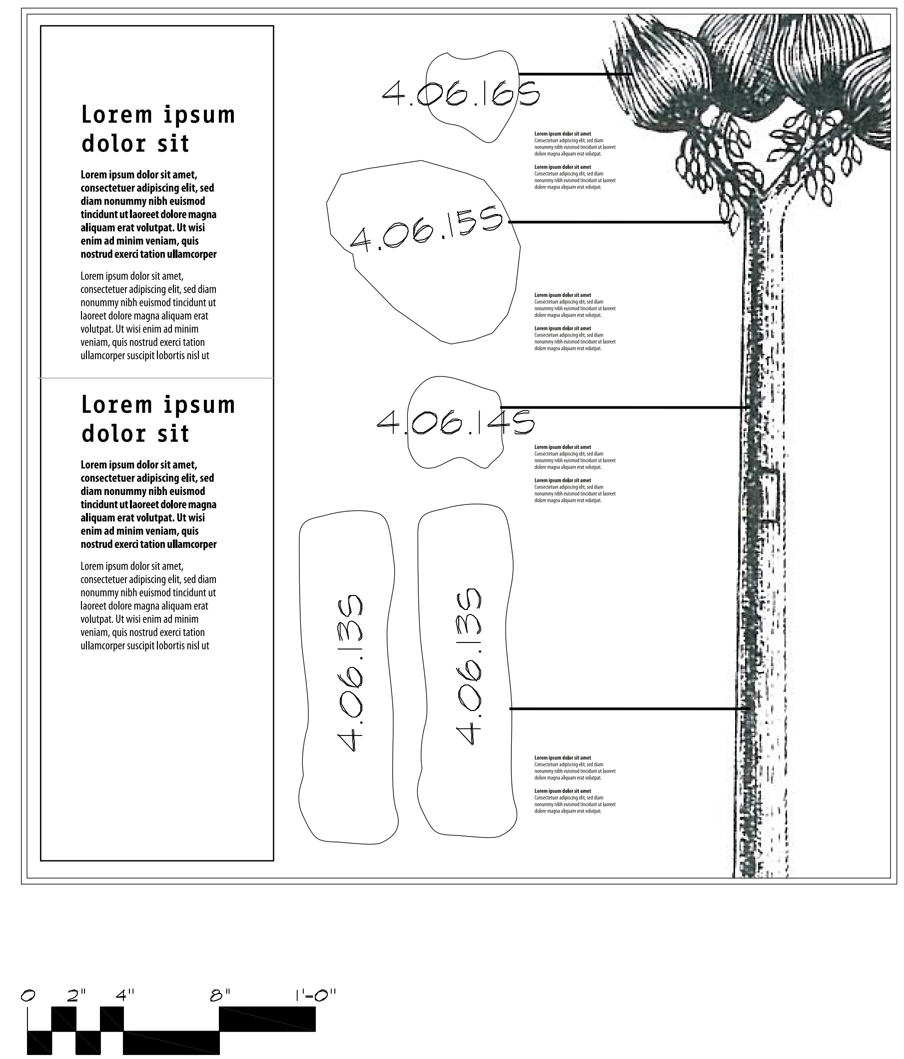
4.6B Coal Age Forest / Lepidodendron

48" x 48"



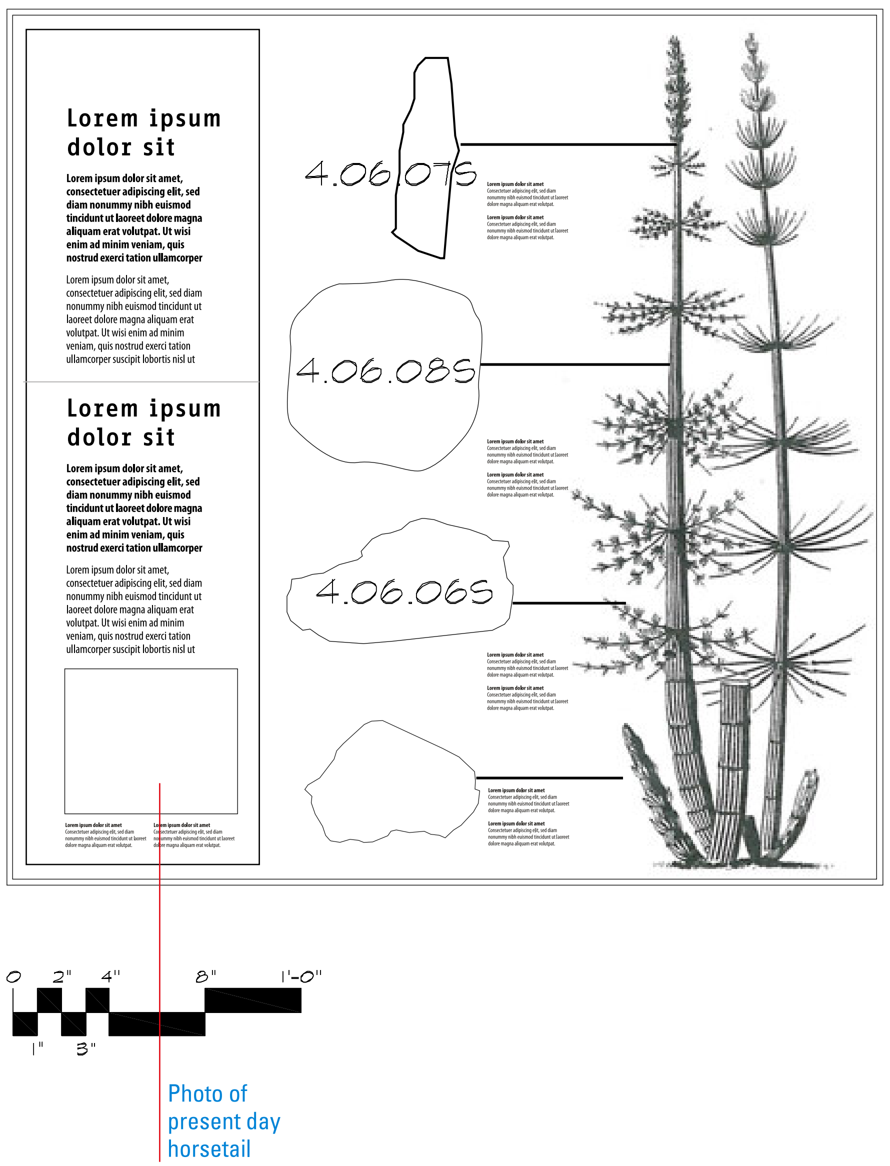
4.6C Coal Age Forest / Sigillaria

36" x 36"



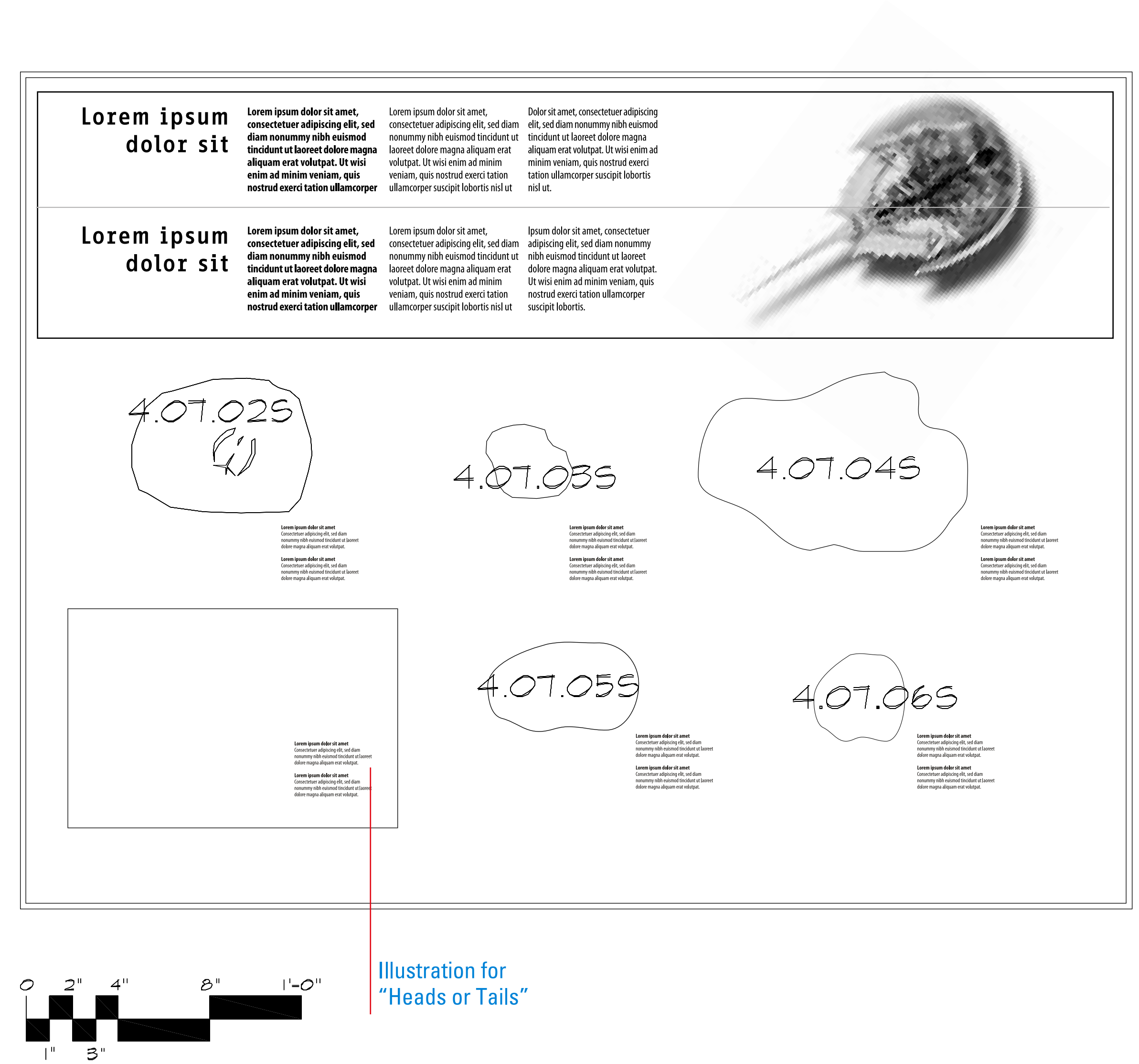
4.6D Coal Age Forest / Calamites

36″ x 36“



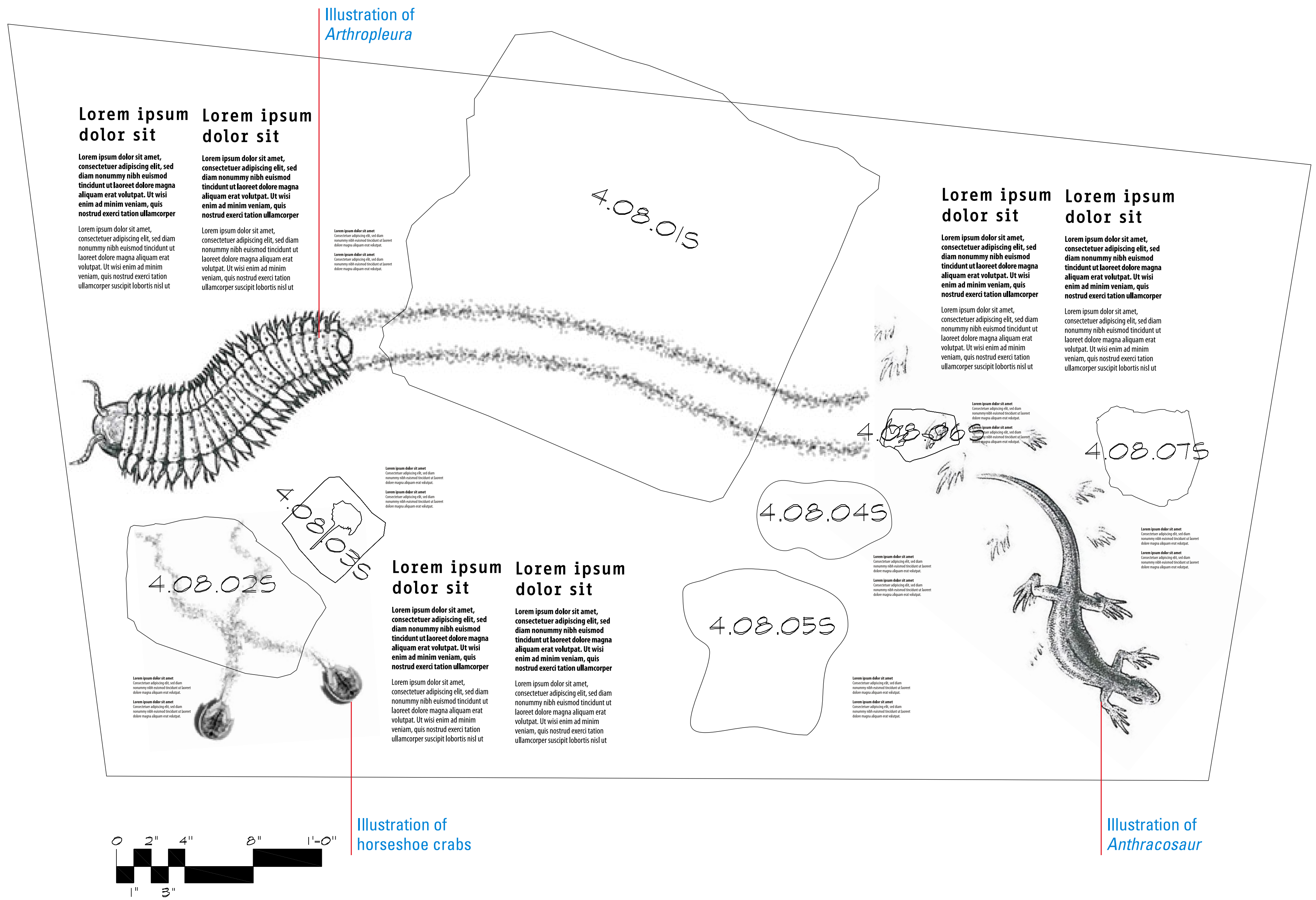
4.7 Life and Death in the Swamp

48″ x 36“



4.8 Reading Tracks & Trails

72"x 48"



Showcases Design Development

4.9 The Top Predator

48″x 24“

Text on cliffs wall

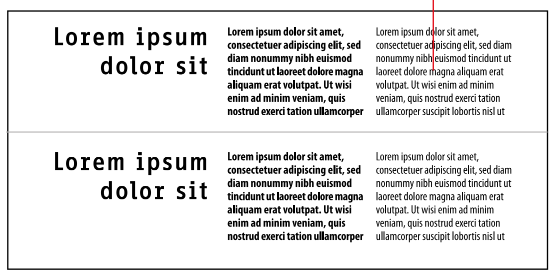
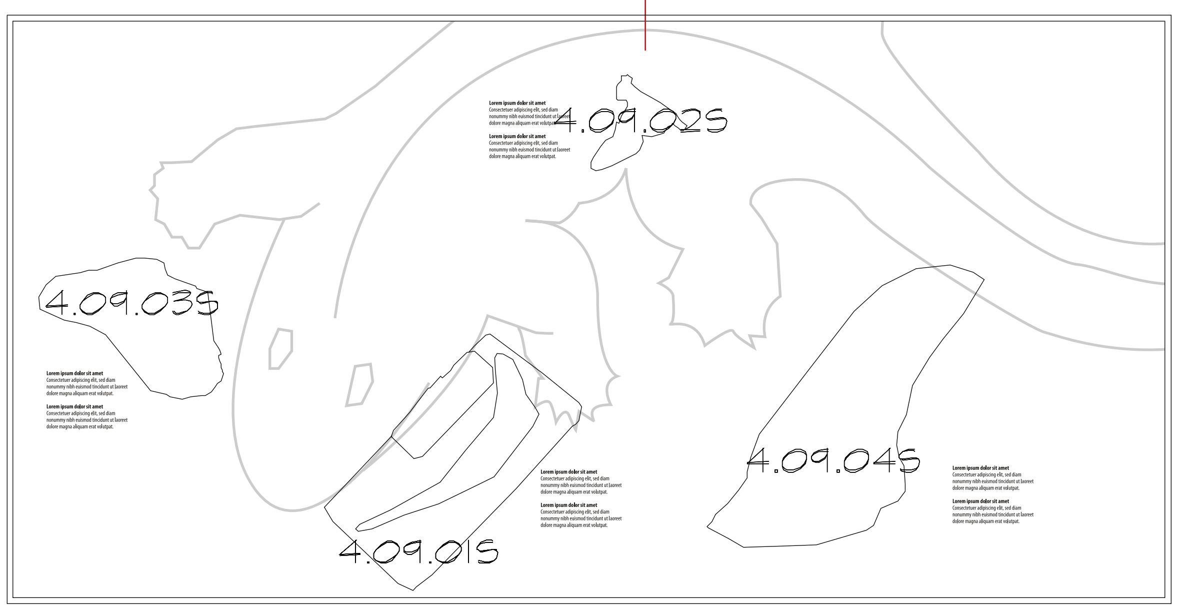
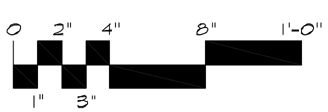


Illustration of *Baphetes*

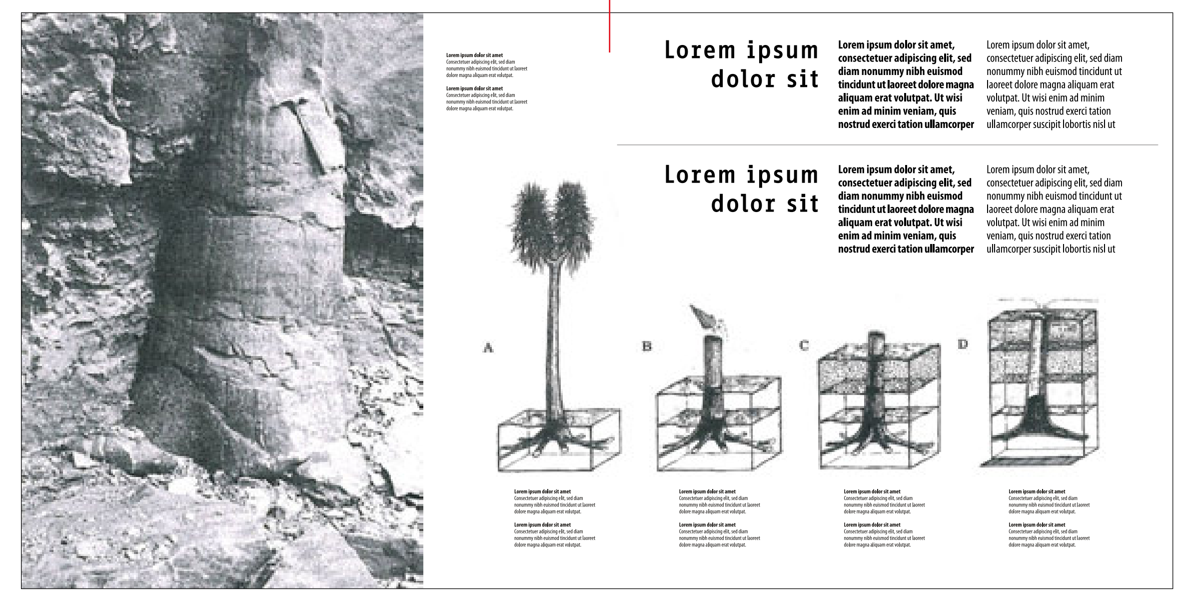


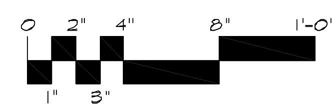


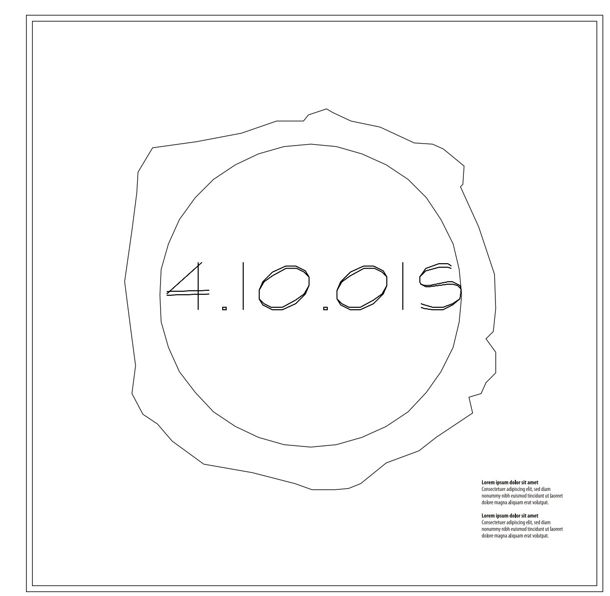
4.10 Coal Age Tree

24″x 24“

Text & graphics on cliff wall







4.11 How Fossils Form (showcase)

48″x 24“

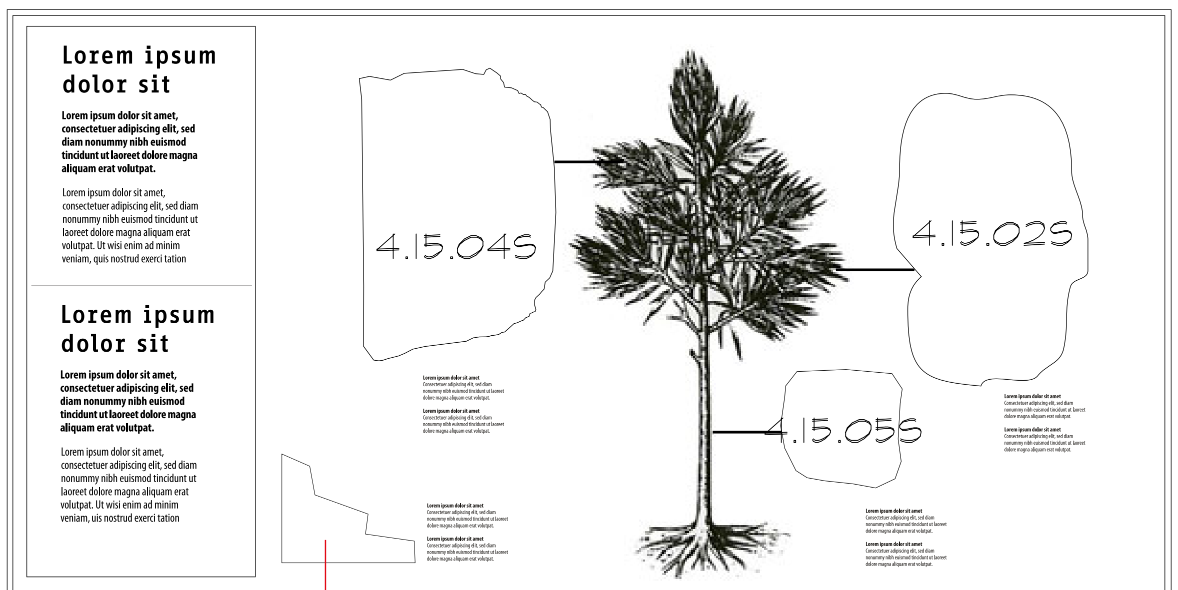
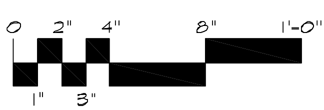
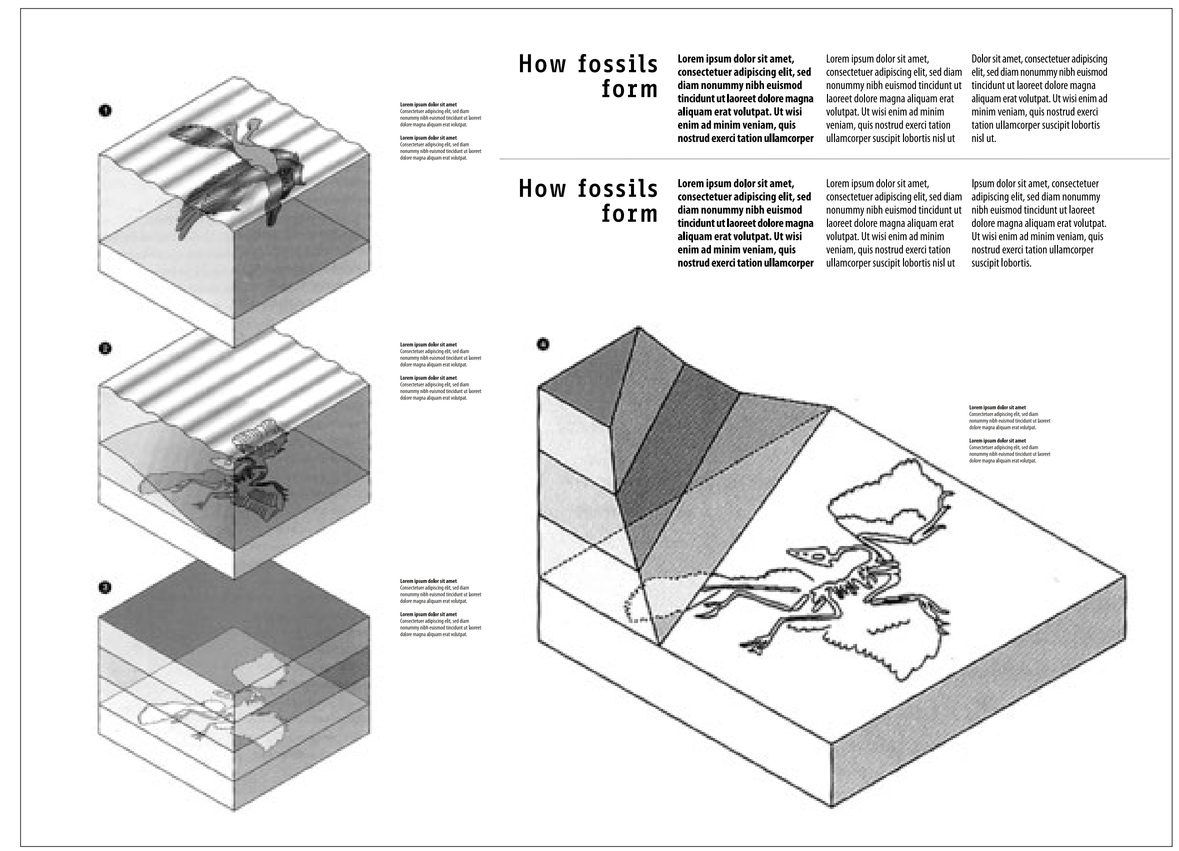


Diagram of upland and lowland plants of Joggins



4.11 How Fossils Form (wall graphic)



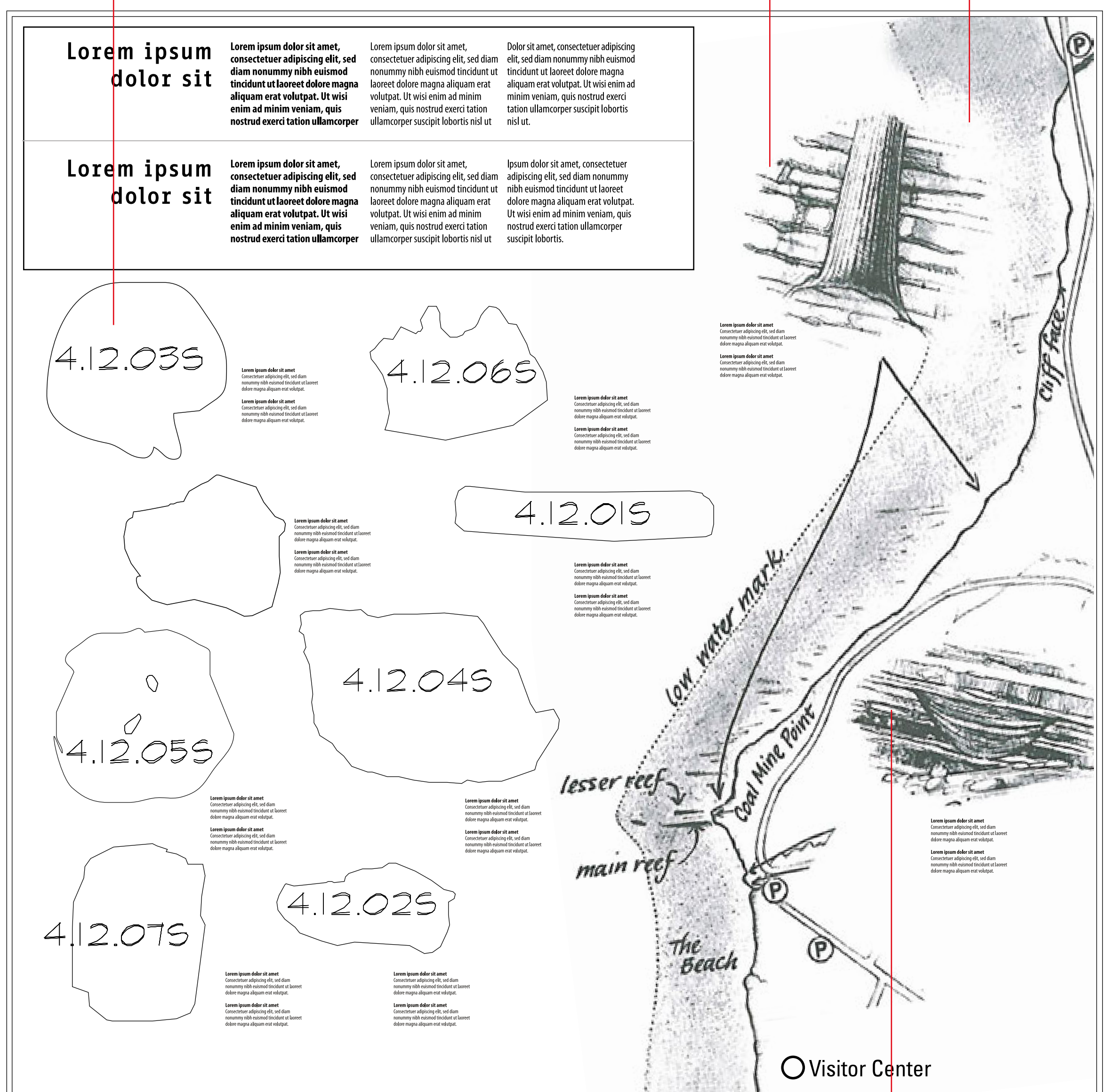
4.12 Finding Fossils at Joggins

48″x 48“

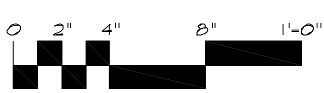
Examples of most typical fossils found at Joggins

Photo/illustration of fossil tree

Map of Joggins Cliffs

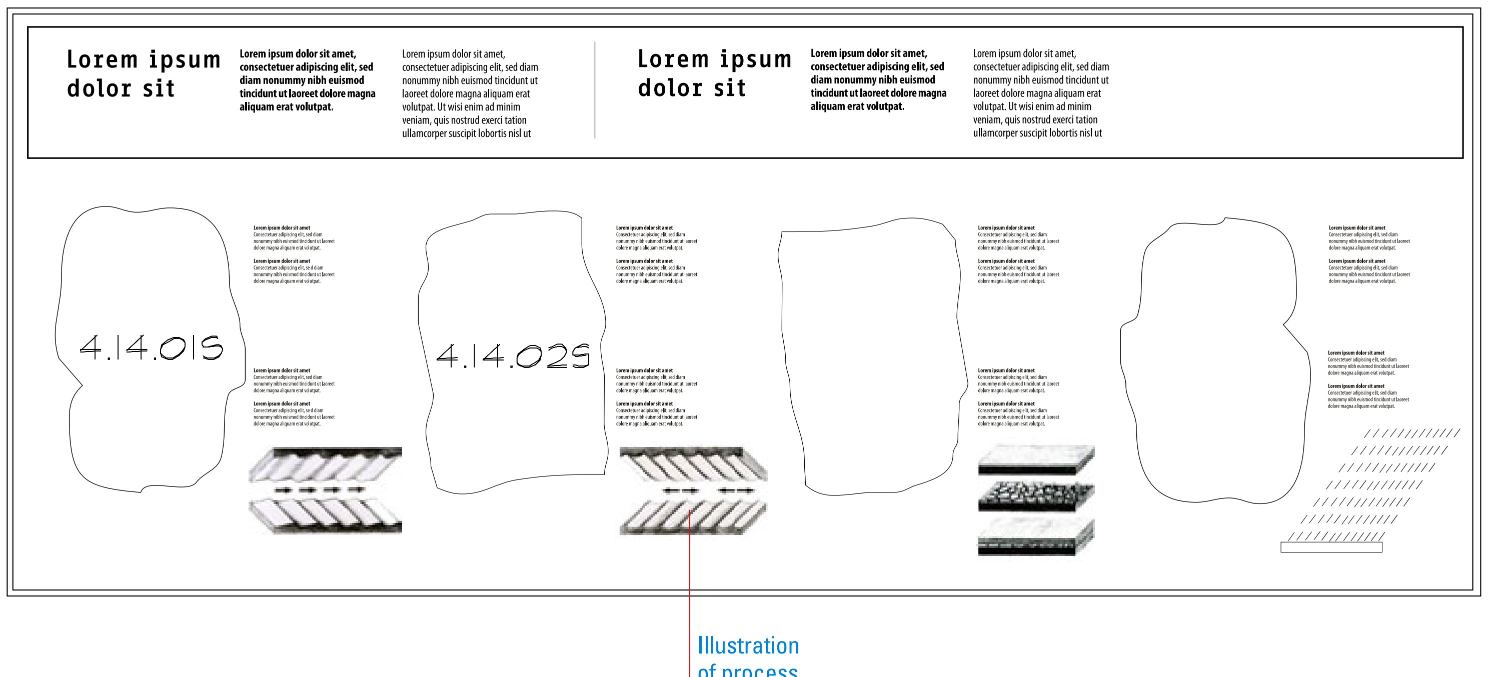


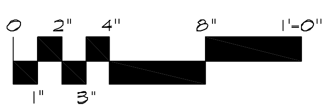
Photo/illustration of channel in the cliffs



4.14 Raindrops & Ripples

60"x 24"



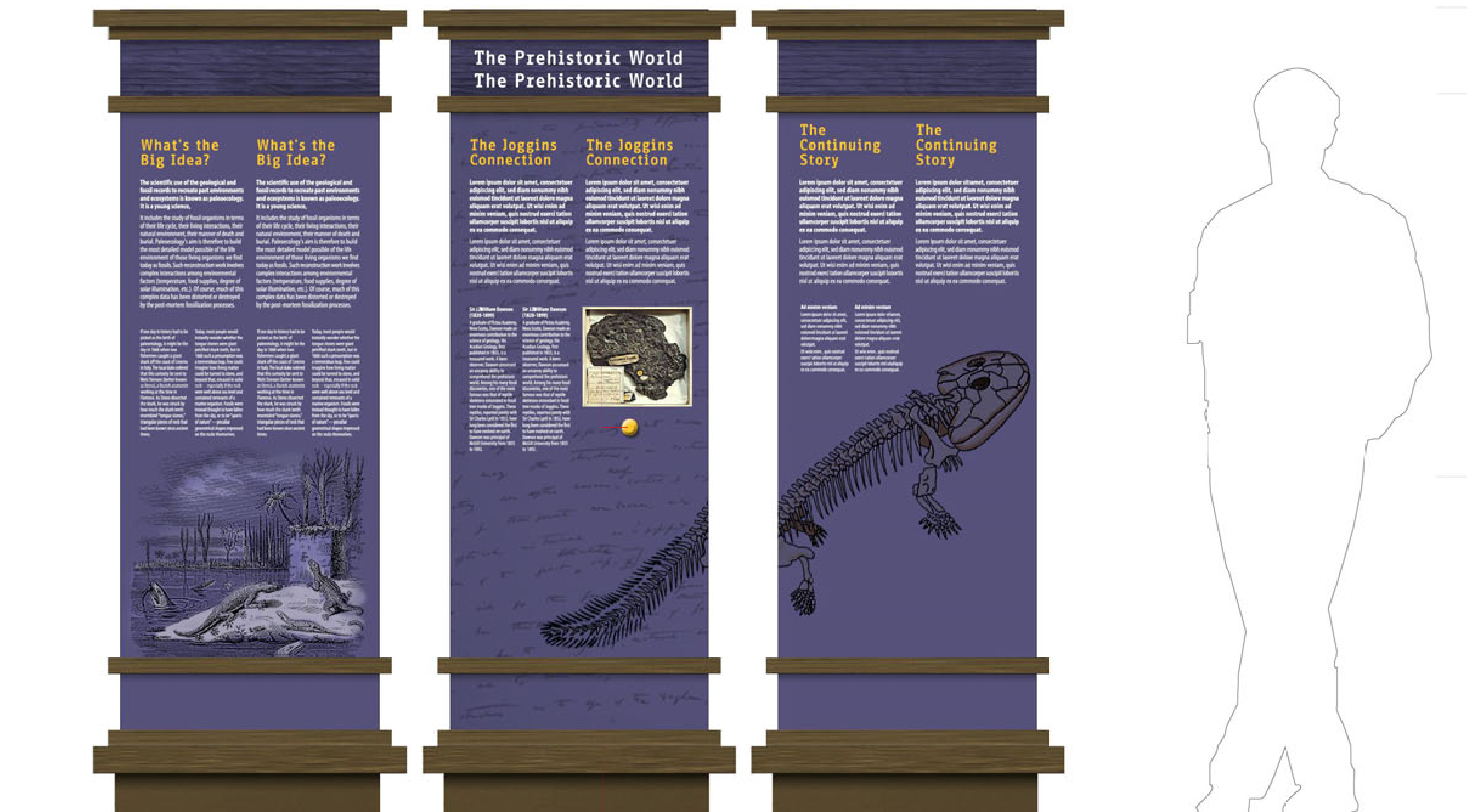


6.1 The Evolution of Life

6.3 The Prehistoric World

6.2 The Dynamic Earth

6.3 The Prehistoric World



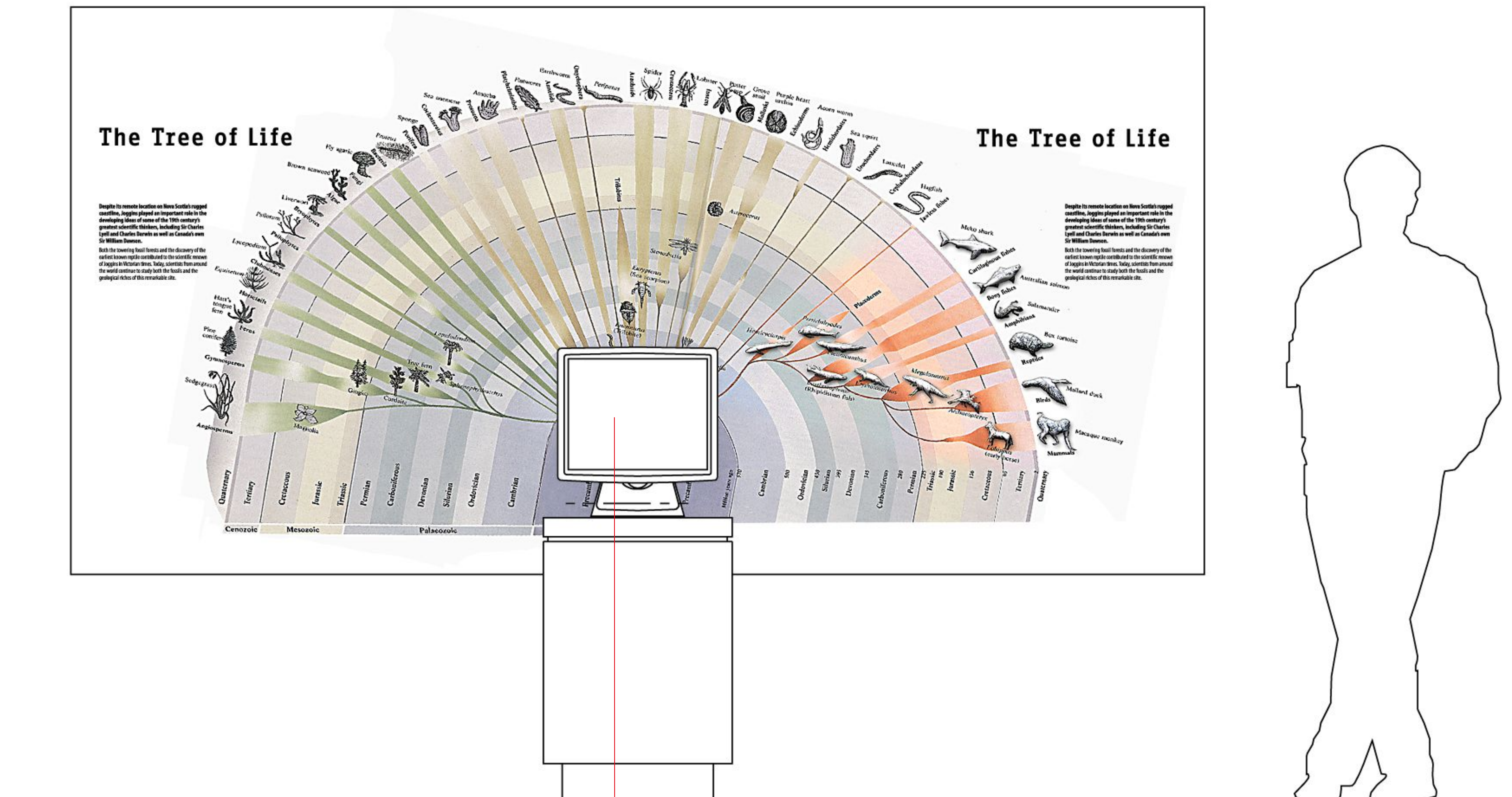
6.3.1 What's the Big Idea?

6.3.2 The Joggins Connection

Button reveals historic *Hylonomus* fossil

6.3.3 The Continuing Story

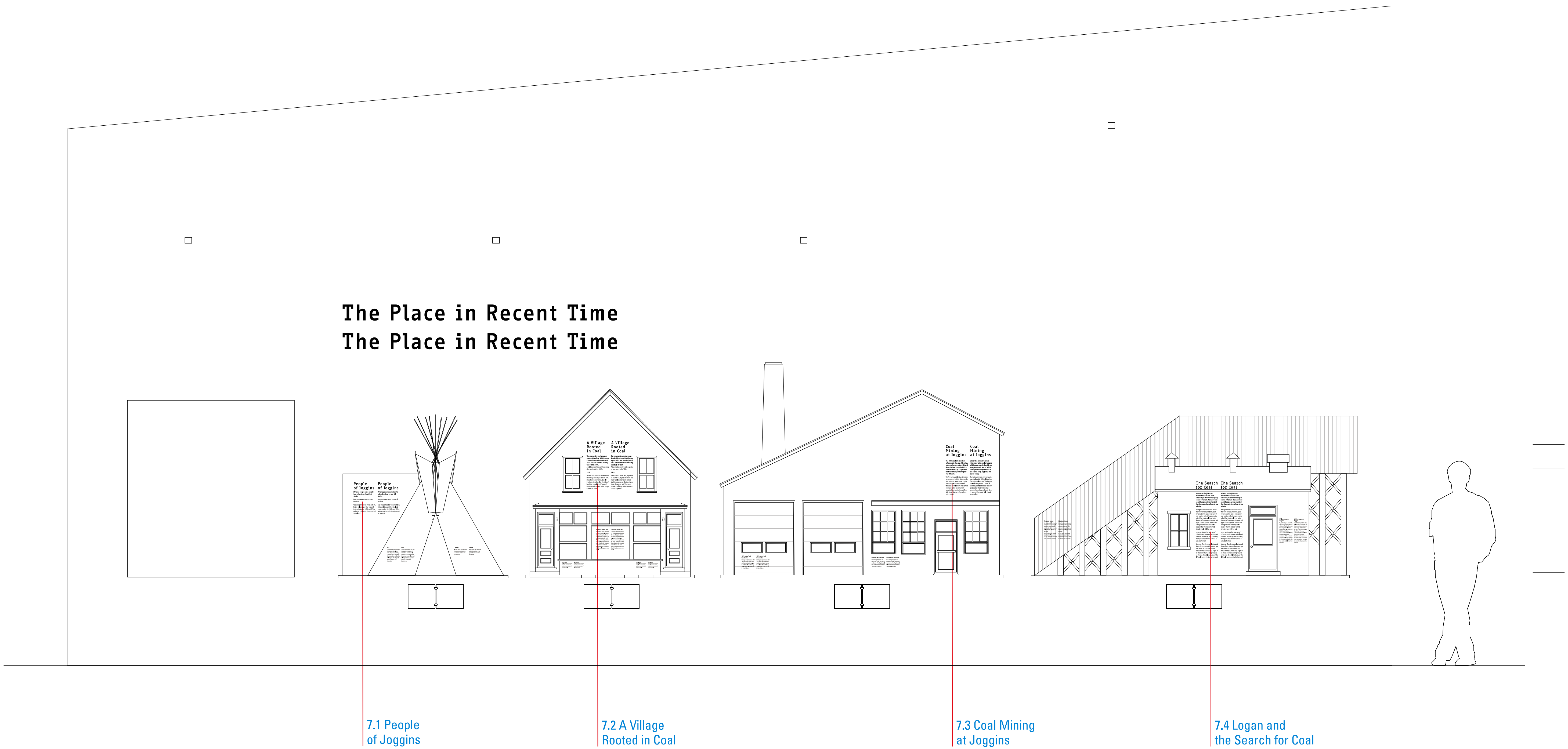
6.4 The Tree of Life



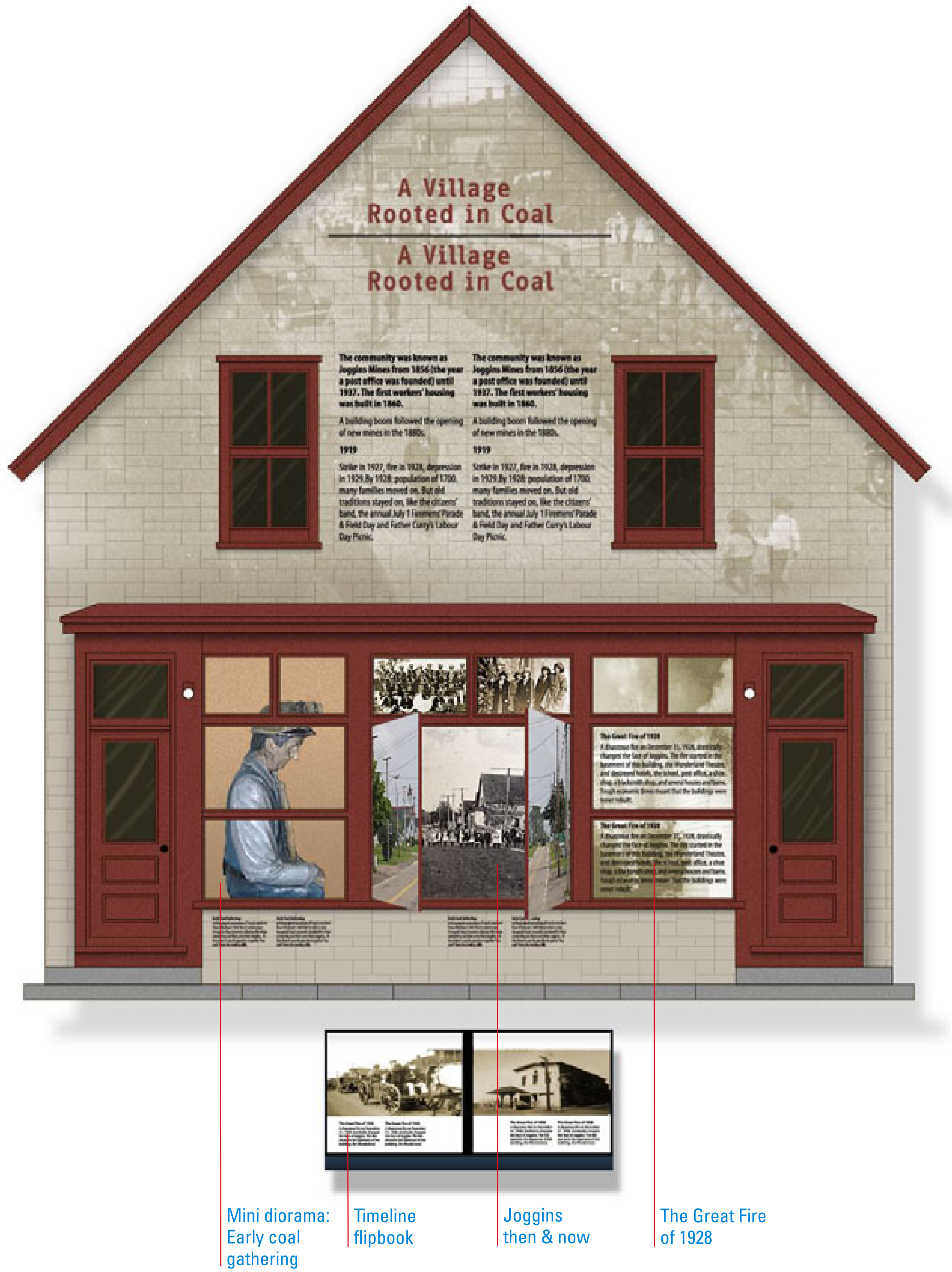
Tree of Life
AV interactive

6.5 Big Ideas Theatre

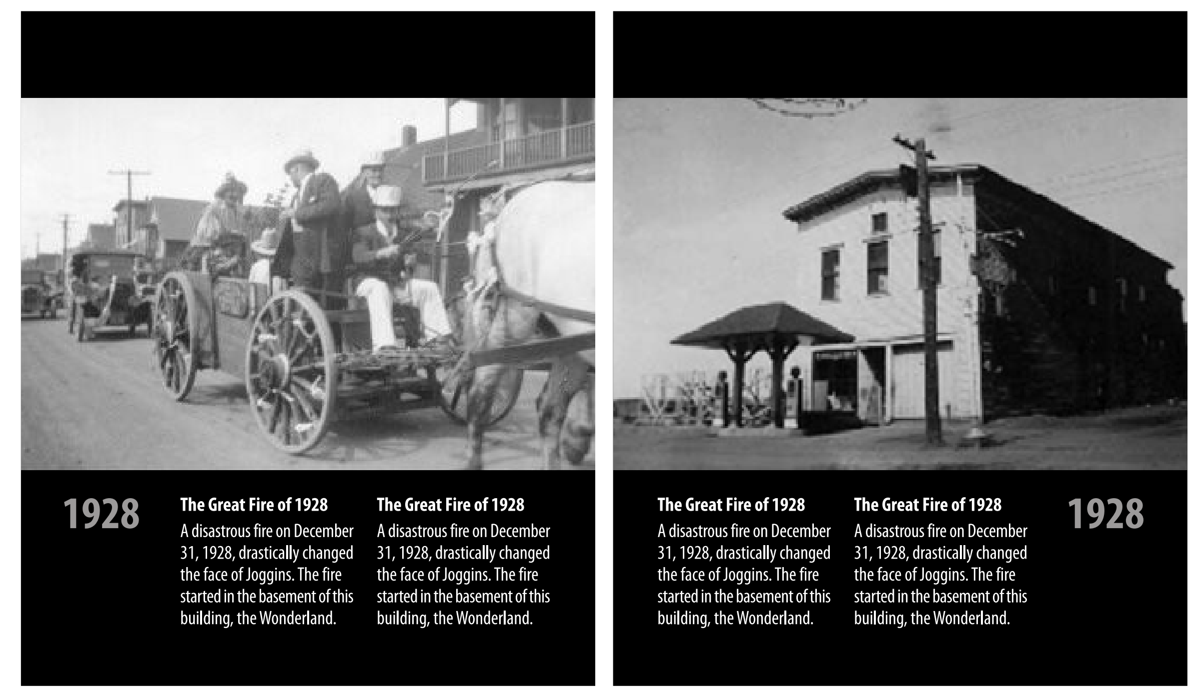
7. The Place in Recent Times



7. 2 A Village Rooted in Coal



Timeline flipbook

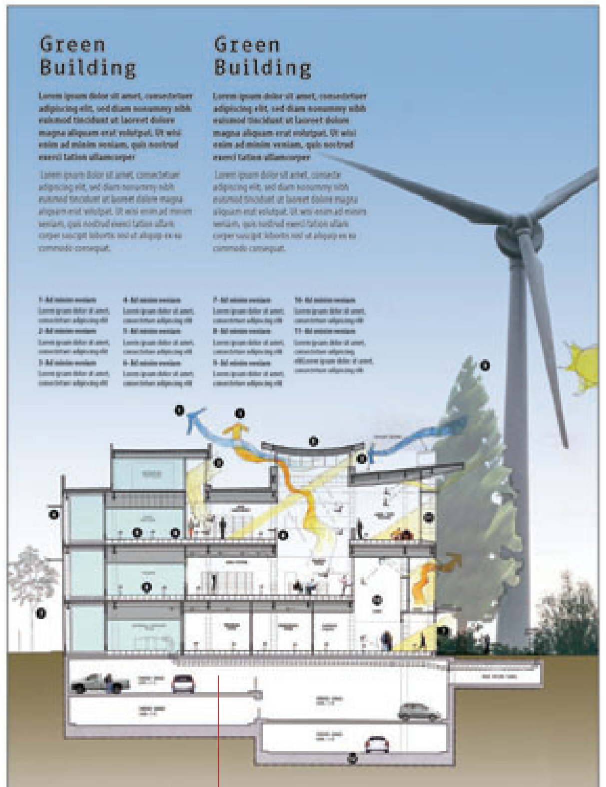


8.1 When You Find a Fossil

8.2 Community Stewardship

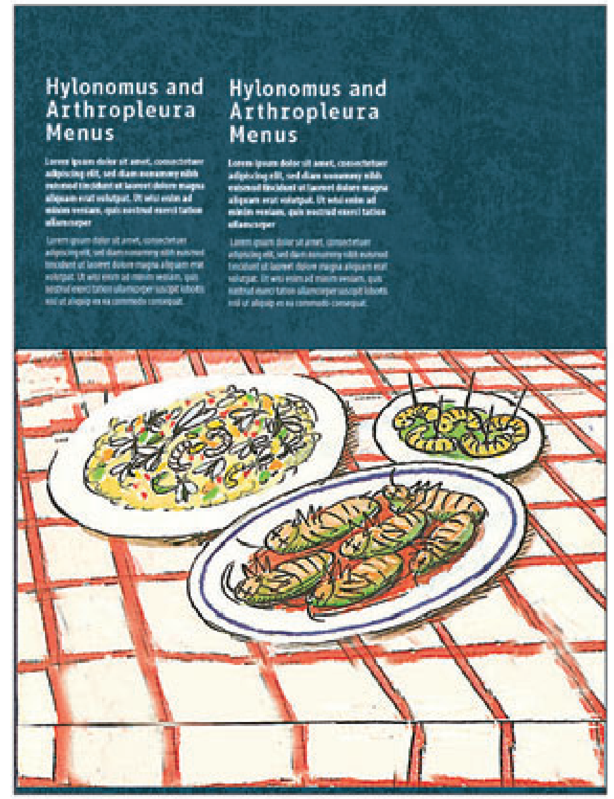
8.3 Unesco Nomination

9.1 Green Building

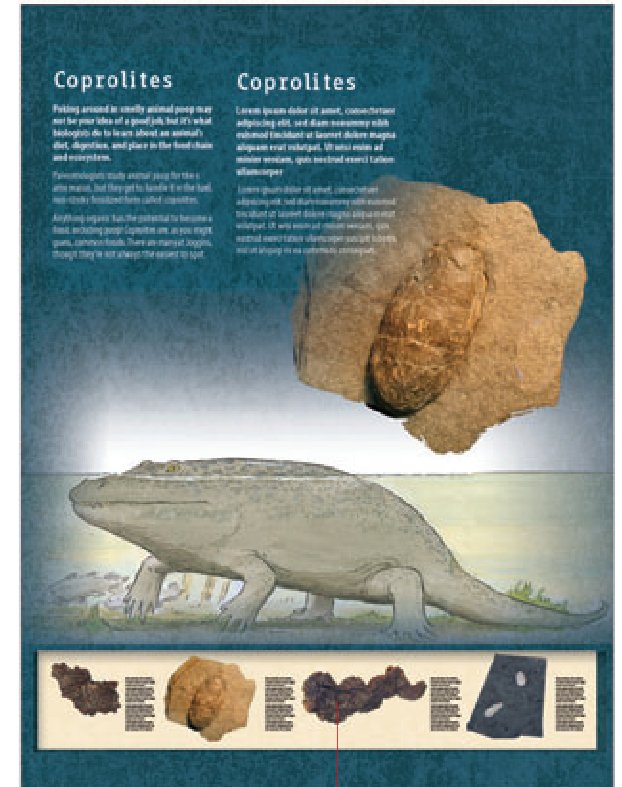


Green Building
diagram of Joggins Fossil Centre

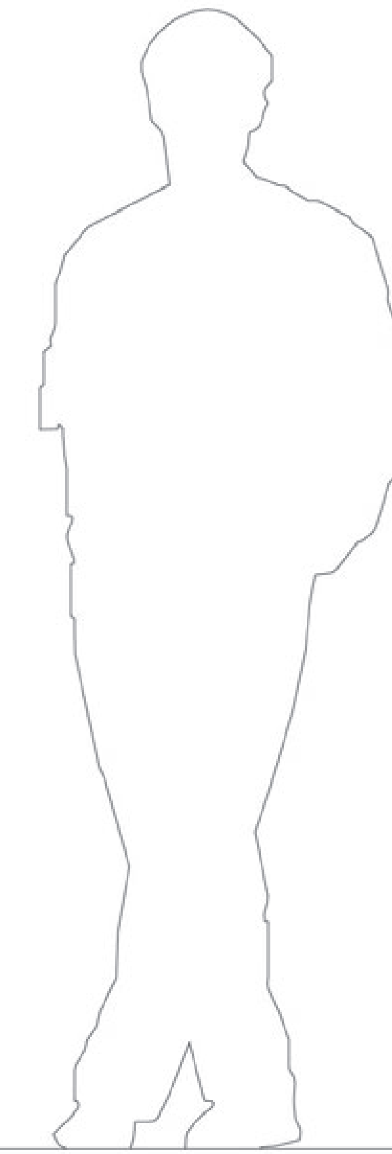
9.4 Hylonomus Menu



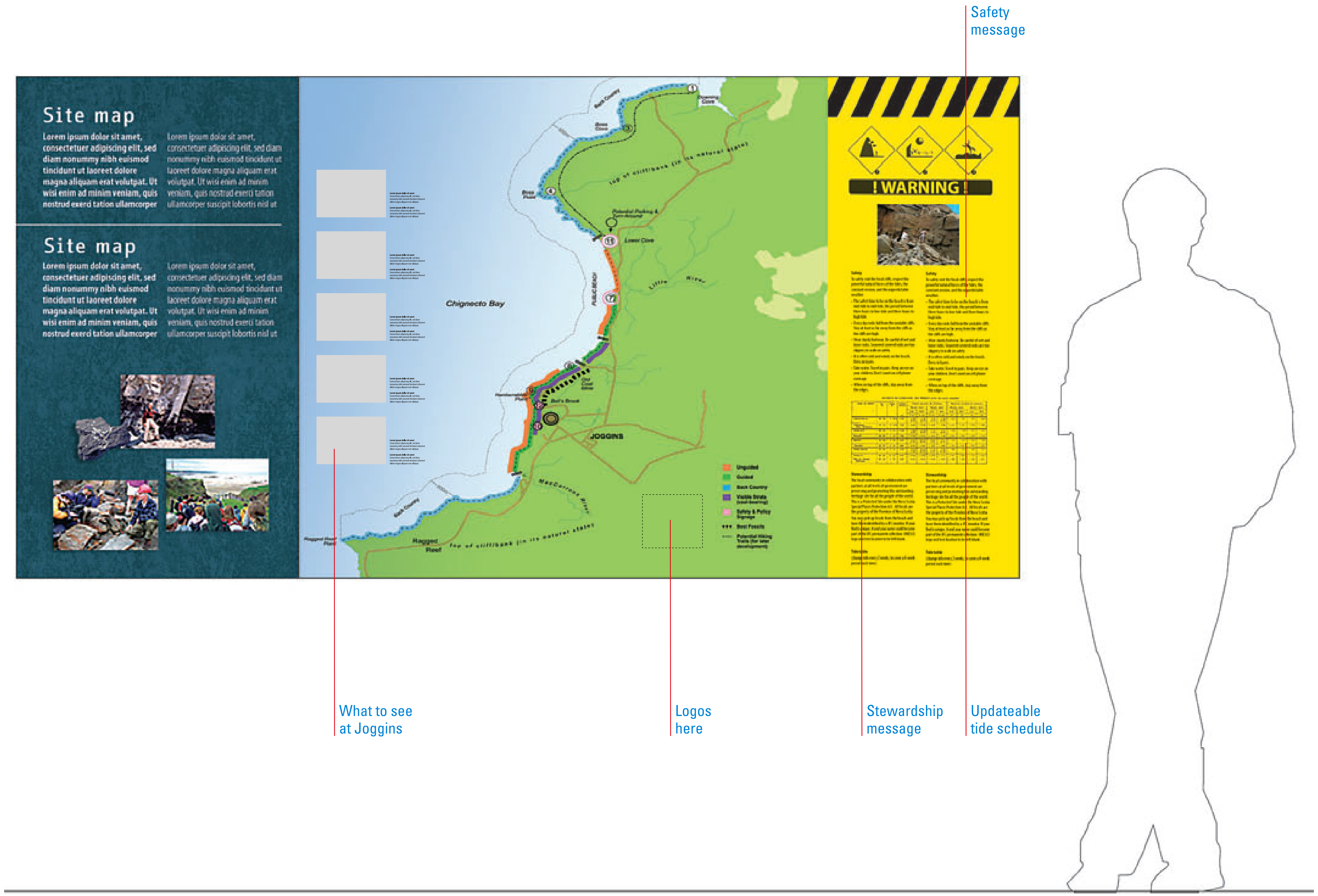
9.5 Coprolite



Coprolite
specimens



9.2 Site Map


Safety message
Site map
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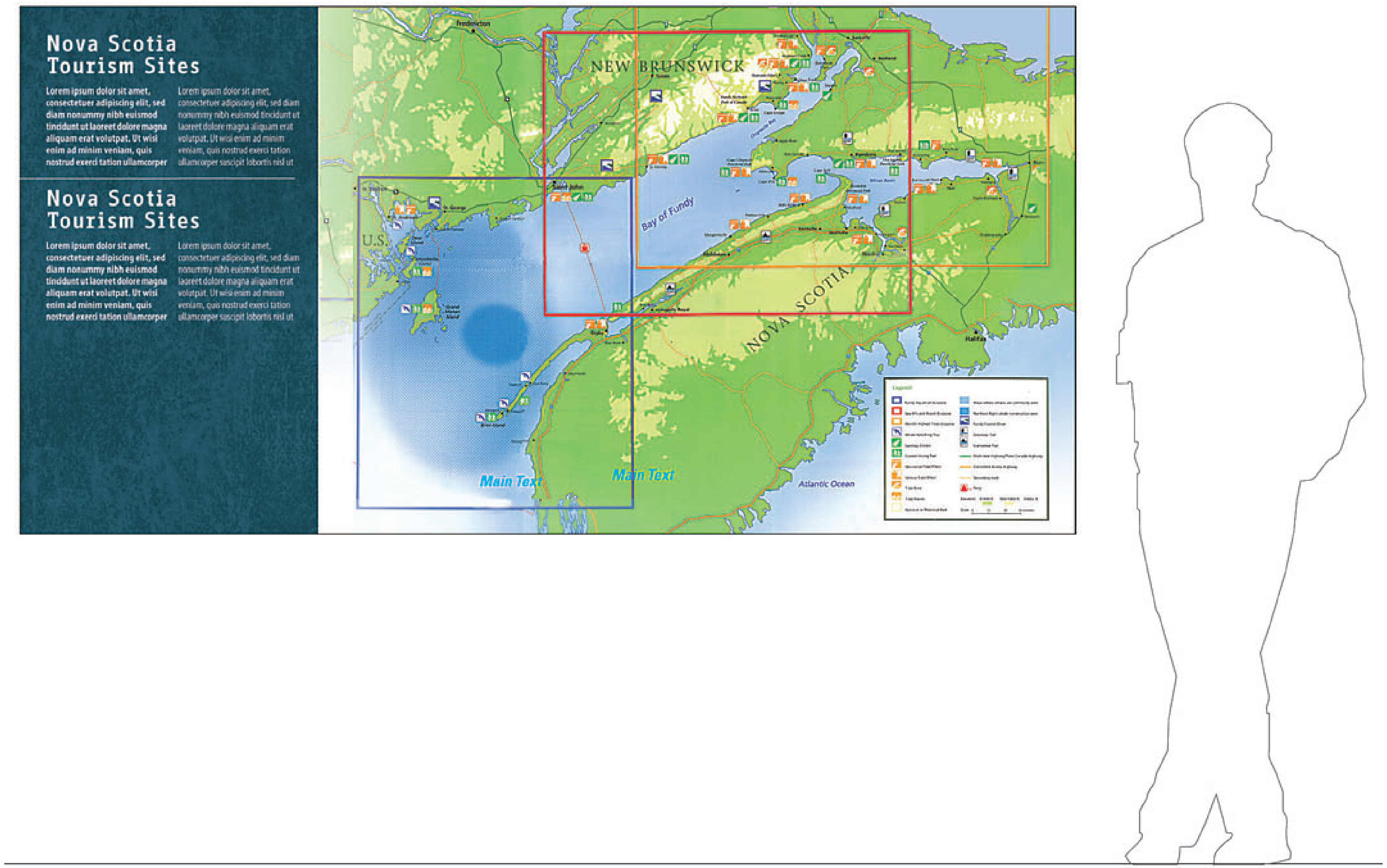
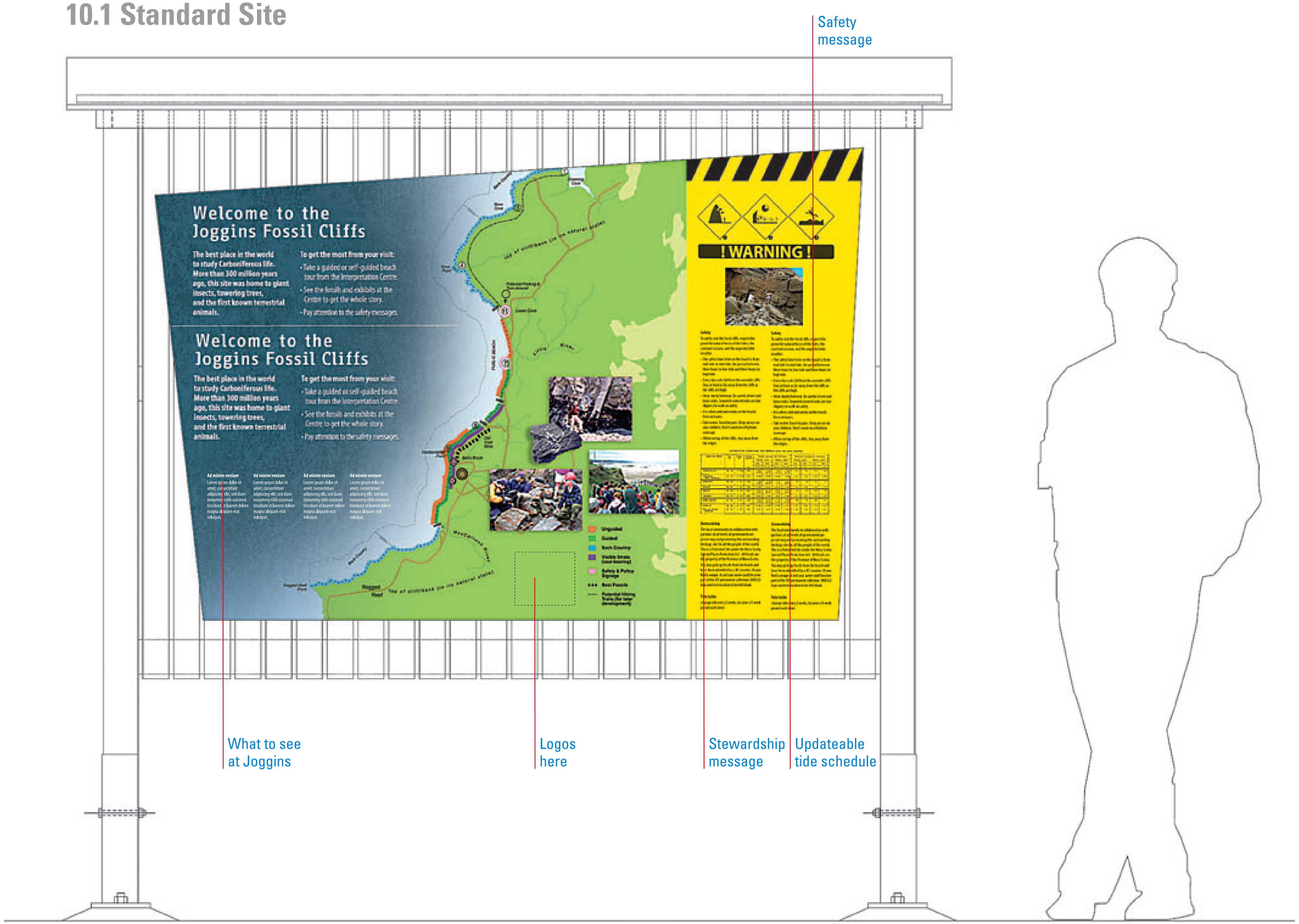
Site map
Chignecto Bay
JOGGINS
! WARNING !
What to see at Joggins
Logos here
Stewardship message
Updateable tide schedule

9.3 Nova Scottia Tourism Sites

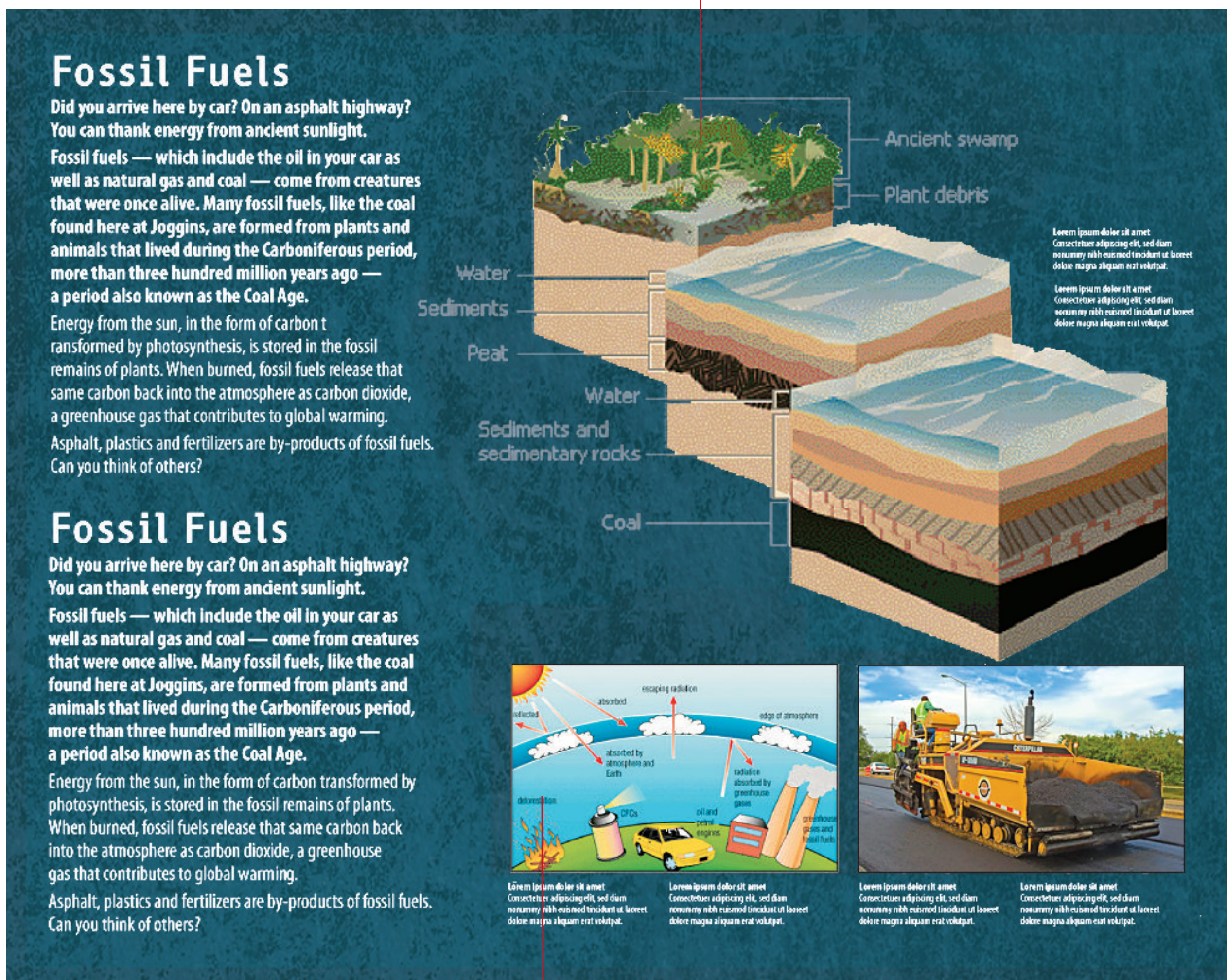


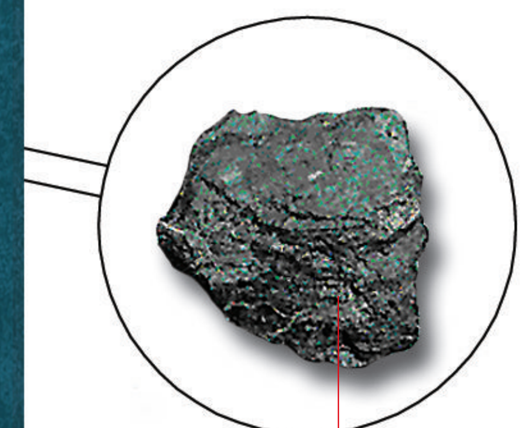
10.1 Standard Site

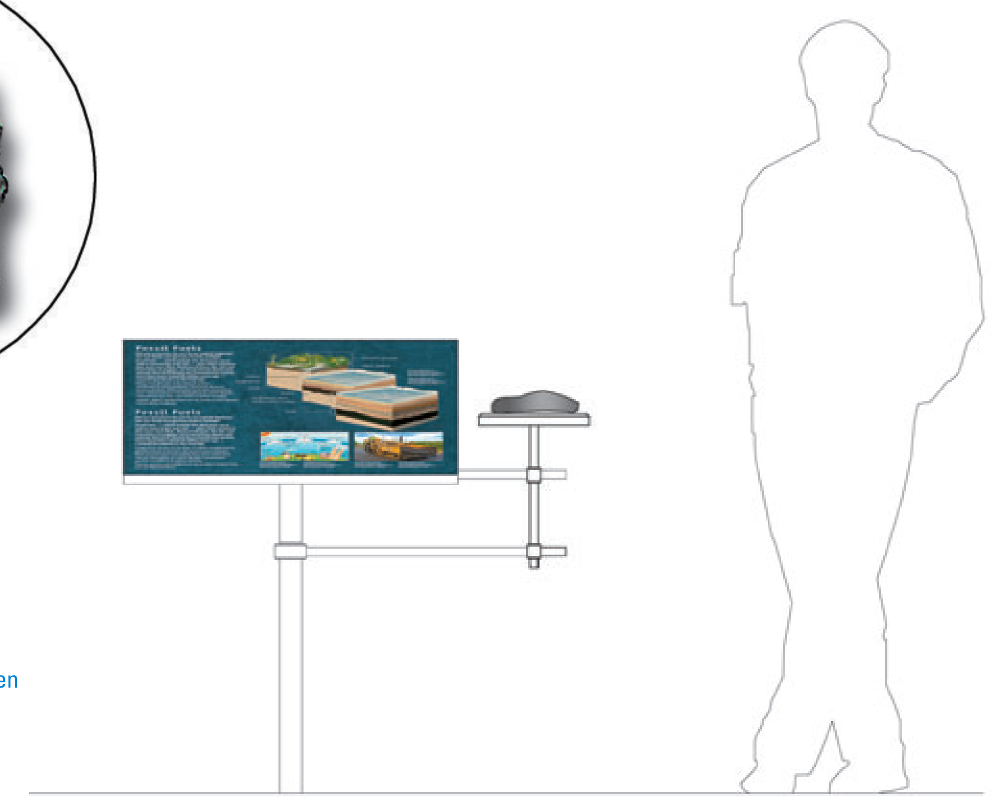


10.2 Fossil Fuels

Coal formation diagram



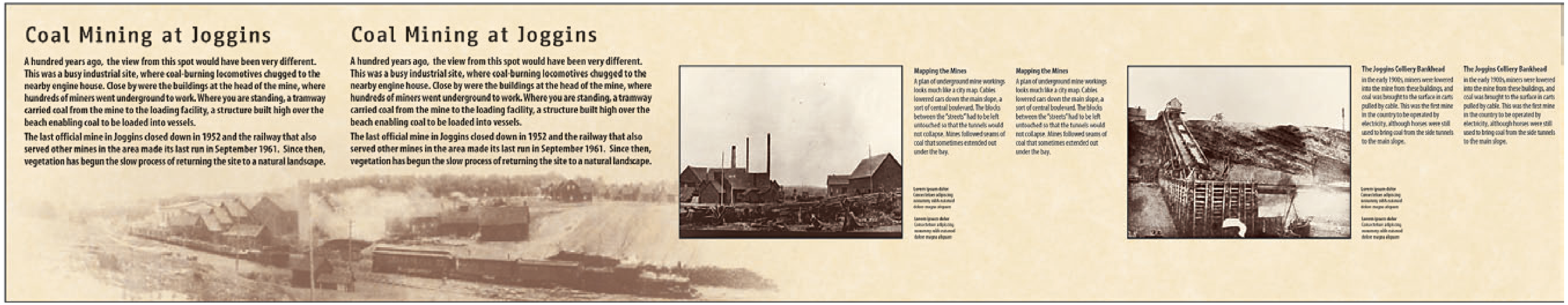


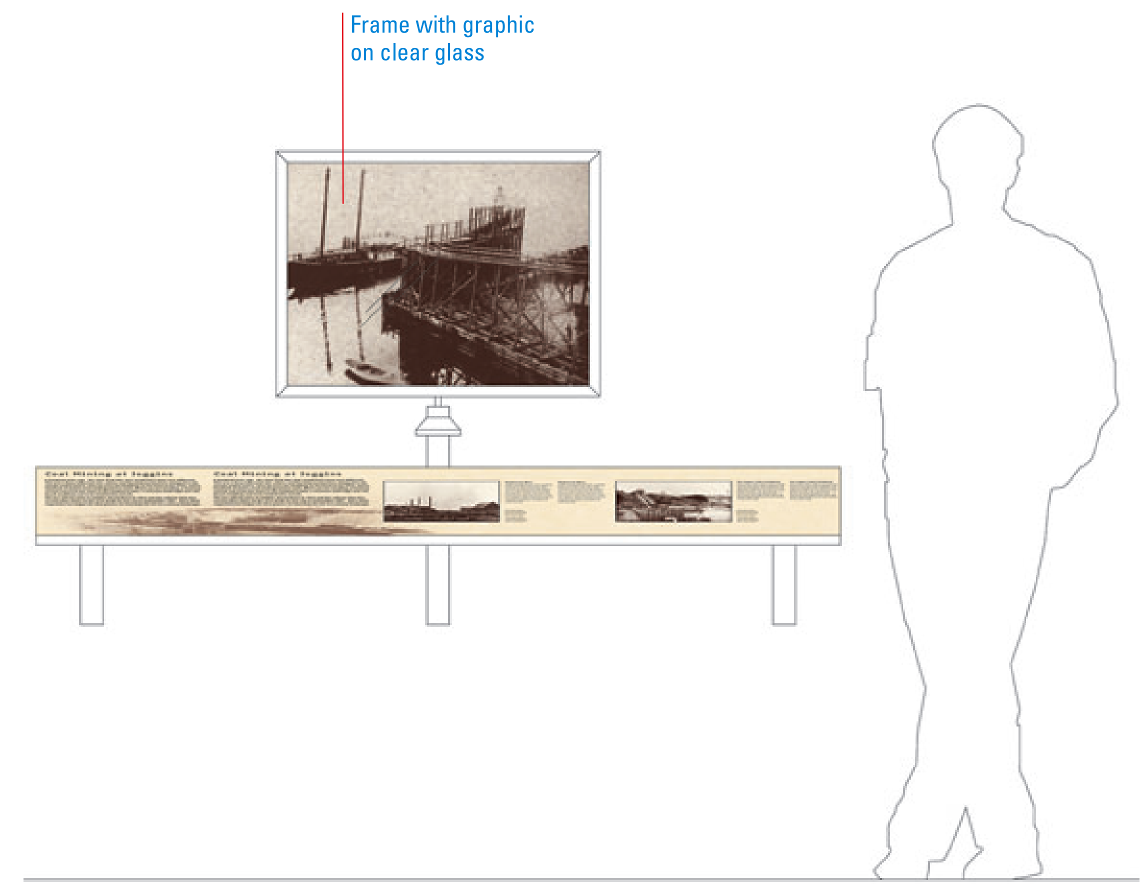


Greenhouse gas diagram

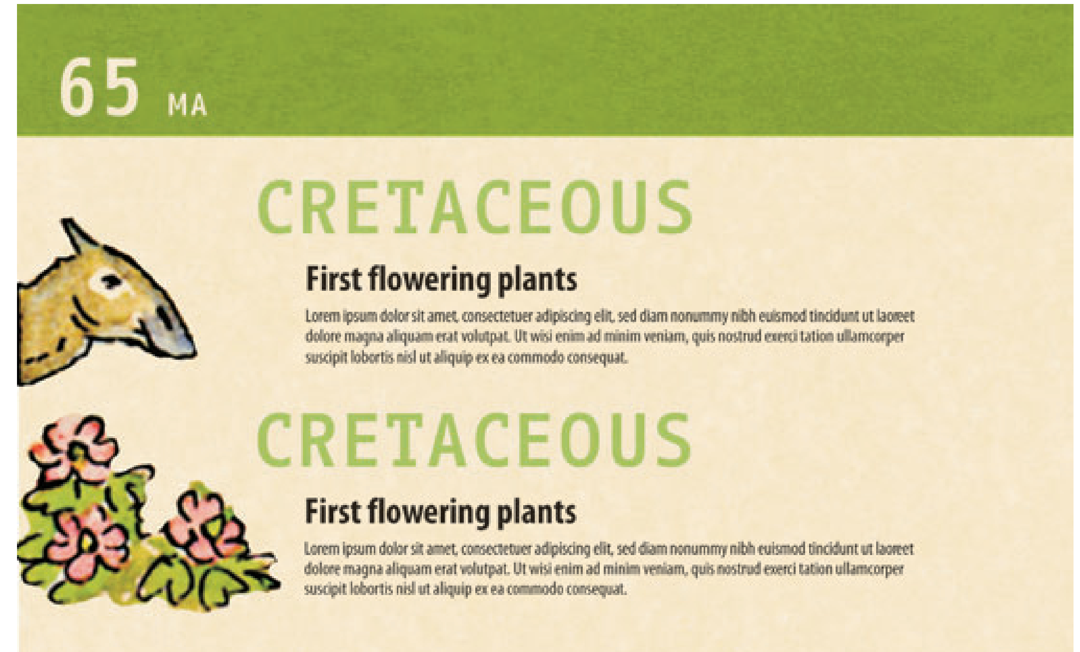
Coal specimen

10.3 Coal Mining

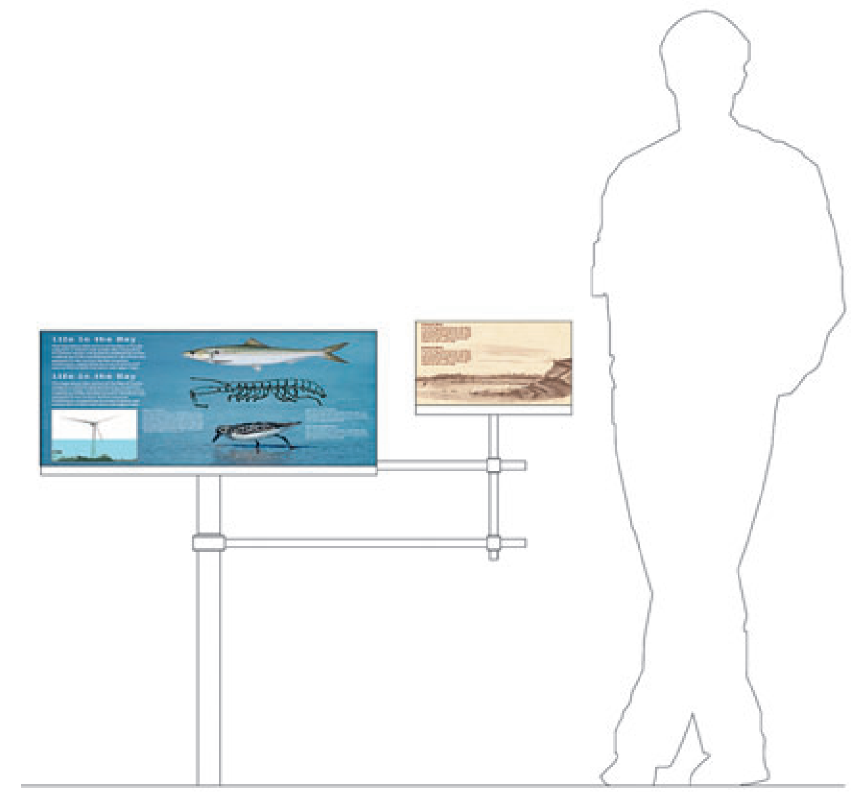


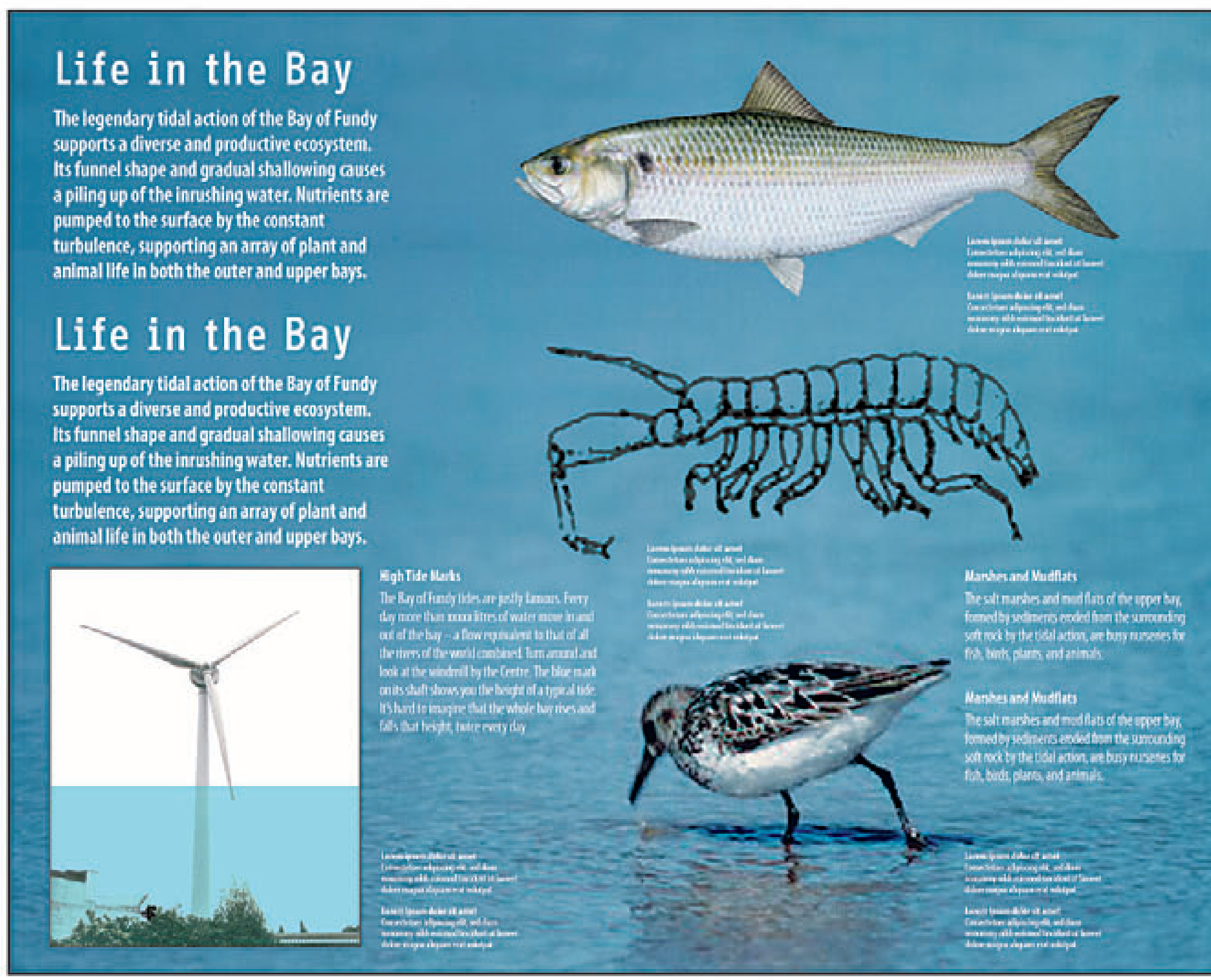


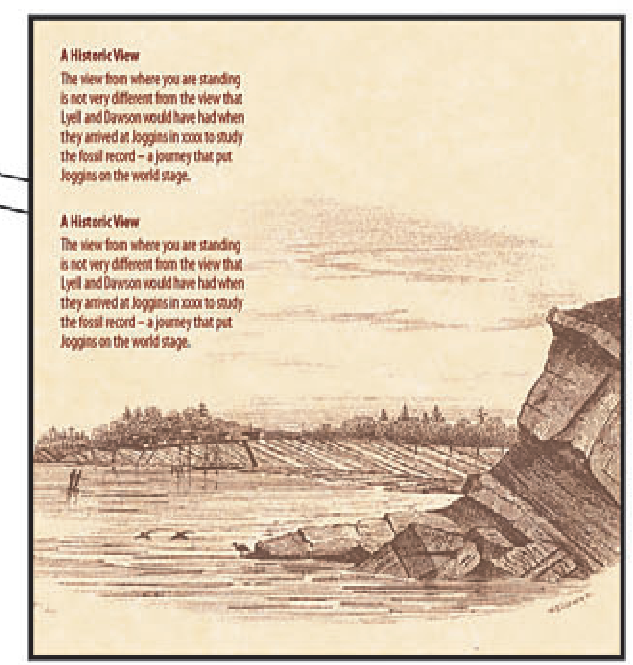
10.4 Dugway Time Tower



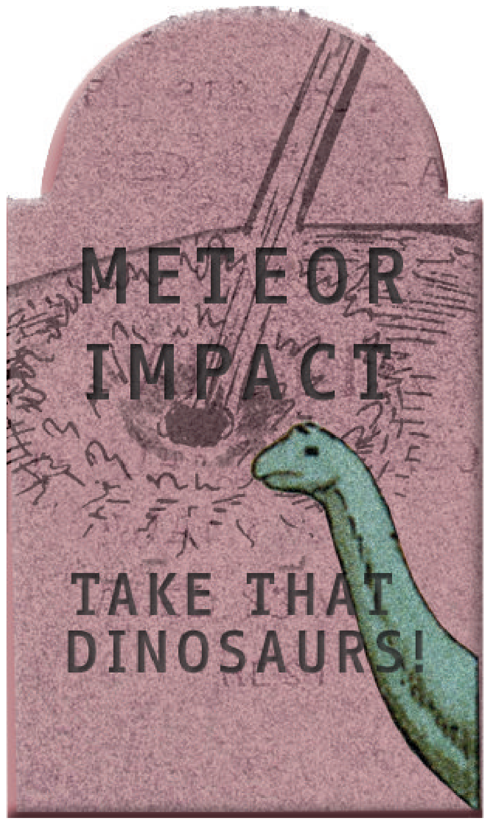
10.5 Bay of Fundy

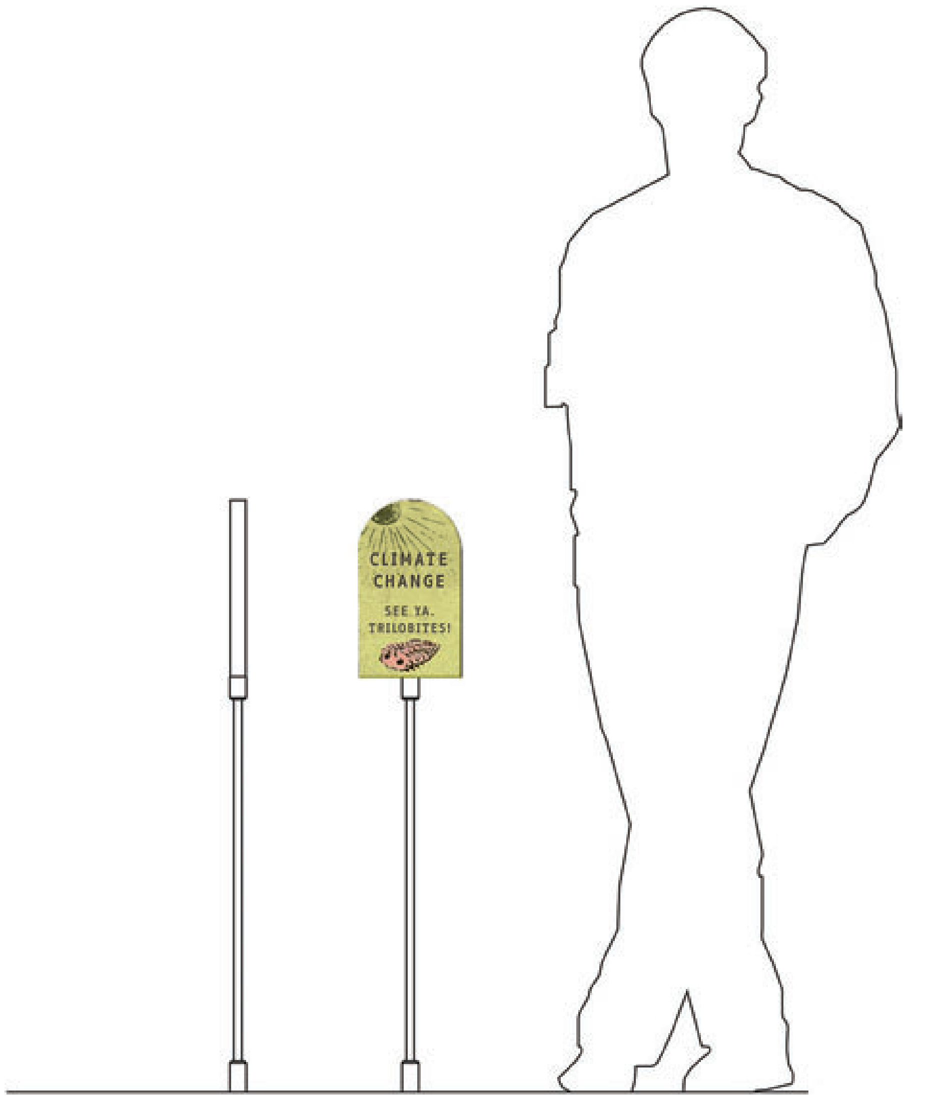






10.6 Evolution Maze





JOGGINS FOSSIL CLIFFS

OPERATING REVENUE & EXPENSE PROJECTIONS

A.L. Arbic Consulting

in association with

Genesis Consulting

April 2006

JOGGINS FOSSIL CLIFFS

OPERTING REVENUE & EXPENSE PROJECTIONS

April 2006

Table of Contents

1.0 ASSUMPTIONS UPON WHICH PROJECTIONS ARE BASED

In order for projections of operating revenues and expenses to be credible, they must be based on clearly stated assumptions of what is being projected. This section of the report provides a summary of those assumptions for the Joggins Fossil Cliffs and Interpretive Centre. The assumptions have been organized into the following sections:

1.1 site and external environment
1.2 facilities
1.3 visitor experience
1.4 operations
1.5 staffing and organizational structure
1.6 attendance projections

All revenue and expense projections will be stated in ***2006 constant dollars***. As such, we have not included a specific inflation factor in our estimates. All projections are assumed to change at the rate of inflation, unless otherwise noted.

1.1 Site and External Environment

1.1.1Site

Key assumptions regarding site features are as follows:

1) A ***purpose-built interpretive centre*** will be constructed in the community of Joggins;

2) ***The location of the Interpretive Centre will be approximately 100' back from the fossil cliffs and roughly equidistant from the Main Street extension and the Dugway***. The main entrance will be about 150' from the Purdy residence and aligned for a direct view of the proposed Dugway tower along the NNE/SSW axis of the building's central hall;

3) The site will include ***exterior interpretive elements*** such as:

   - controlled access to the beach for viewing the fossil cliffs with the purchase of an exploration permit;

   - outdoor interpretive signage strategically located around the site, as well as interpretation of some aspects of the surrounding area including the grindstone quarry.

4) There will be ***prominent directional and promotional signage*** for the cliffs and Centre;

5) There will be ***adequate free parking*** at the Centre to accommodate visitors. This includes appropriate spaces for bus drop offs;

6) The Centre will operate ***a 15-passenger bus/van*** that will be used for dropping off and picking up guided tour participants as needed. It is anticipated that the Centre will secure a corporate sponsorship/donation of this vehicle.

1.1.2 External Environment

Usage and financial performance of heritage facilities reflect not only the features of the site itself but also the external environment in which the facility will operate***.*** The key external environmental factors that will impact on the projections are set out in the following assumptions:

1) The application to designate Joggins as a UNESCO World Heritage Site will be successful;

2) The Bay of Fundy Tourism Partnership, a joint Nova Scotia - New Brunswick market readiness funding and marketing program, will continue to receive provincial support and Joggins will be featured in this initiative, along with other related attractions in the area;

3) During the timeframe projected, there will be no other attractions with a comparable focus developed in the Fundy shore region.

1.2 Facilities

The key elements of the facilities plan that will influence attendance, operating revenues and expenses are as follows:

1) the Interpretive Centre will consist of **12,652** sq. ft. of **gross total interior space;**

2) there will be 3,455 sq. ft. **of exhibition space** in the Interpretive Centre;

3) there will be **1,163** sq. ft. of space suitable for **educational programming, public meetings and rentals**;

4) the Centre's **gift shop** will be **593** sq. ft. and will be accessible without paying admission to the Centre;

5) there will be a **food service** area **of 315** sq. ft. plus **indoor seating** in the lobby area and **outdoor seating** on a patio area. The food service will be concessioned to an outside operator and will be accessible without paying admission to the Centre;

6) the Centre will house an **RCMP community policing office**. This office will not be staffed, but will be used by RCMP personnel or volunteers as needed. For the first year there will be no rent charged for the use of the space. After the first year this arrangement will be revisited with a view toward establishing a rental agreement for a modest sum to cover operating expenses in future years.

1.3 Visitor Experience

The nature and quality of the visitor experience will have the greatest impact on attendance levels and earned income of the Centre. It is assumed that:

1) the visitor experience will take place both ***within the interpretive centre*** and ***throughout the site;***

2) the visitor experience will be based on the master concept of "***the power of the cliffs***";

3) the three essential aspects of the visitor experience will be ***Joggins***, its cultural, historical, geological dimensions; ***fossils***, the scientific and human importance of the Coal Age life and Carboniferous ecosystems; and ***the cliffs***, Joggins' position within the Bay of Fundy ecosystem and the forces that created and shaped the cliffs;

4) the visitor experience will be ***interactive*** and ***high quality***, sufficient to generate positive word of mouth and repeat visitation;

5) the visitor experience will **pervade all parts of the Centre's public spaces.**

1.4 Operations

Key recommendations/assumptions related to the operation of the centre include:

1.4.1 Admission Charges and Other Fees

The following admission and program fees will be charged at the Centre:

1.4.1.1 Admission Charges

Admission Category	Admission Fee
Adult	$7
Child (under 5)	Free
Youth/Student/Seniors	$5
Family (three)	$14
Family (four)	$16
Groups (10 or more)	$4 each
School groups	$2.50 each

1.4.1.2 Guided Tour Fees

It is assumed that a schedule for guided tours will be posted on the Centre's website, allowing visitors to plan their visits to coincide with projected tour times (weather allowing), and that daily tour times will be prominently posted in the Centre's lobby, enabling visitors to quickly and easily make decisions about taking part in tours.

Fees for guided tours of the cliffs are recommended as follows:

Category	2 Hr. Tour	3 Hr. Tour	4 Hr. Tour
Adult	$10	$15	$20
Children (under 5)	-	-	-
Youth/students/seniors	$8	$12	$16
Family (three)	$20	$30	$40
Family (four)	$25	$40	$52

Prices for guided tours include an exploration permit.

The maximum group size will be 12-15 people per guide, depending on the age of tour participants.

Two-hour tours will run from the Centre around coal-mine (hardscrabble) point and back to the Centre by foot, tides and weather allowing. Those taking part in three and four hour tours will be taken from the Centre, dropped off by bus/van at Lower Cove and return to the Centre along the beach by foot, tides and weather allowing. Four-hour tours may include a stop at the Grindstone Quarry.

1.4.1.3 Combination Admission/Guided Tour Fee

To encourage visitors to learn about Joggins both by exploring the Centre's exhibits, as well as by taking part in a guided tour of the cliffs, the following combination packages be offered.

Category	Admission & 2 Hr. Tour	Admission & 3 Hr. Tour	Admission & 4 Hr. Tour
Adult	$15	$20	$24
Children (under 5)	-	-	-
Youth/students/seniors	$11	$15	$19
Family (three)	$30	$40	$48
Family (four)	$37	$50	$60

In addition, school groups may pay $4.00 for a combination interpretive centre admission and a short beach tour.

Appendix A provides a detailed analysis of the percentage of visitors who have been assumed will pay the combination admission/guided tour fee.

1.4.1.4 Fossil Exploration Permit Fee

Visitors wishing to take a self-guided tour of the beach and explore for fossils must purchase a fossil exploration permit. **The cost of purchasing an exploration permit will be $3.00.** As a value-added strategy, the purchase of a fossil exploration permit will also include a copy of the Centre's self-guided tour map of the cliffs.

1.4.1.5 Internet Café

Internet cafés have become a popular way for travelers to stay in touch with friends, family and business at home and to make travel arrangements while they are on the road. The Centre will feature pay-per-use computer terminals that will allow visitors, and members of the local community who do not have internet access, to get on-line for a fee of **20¢ minute.**

1.4.1.6 Coin-Operated Viewing Telescope

To allow visitors to take maximum advantage of the spectacular view of the Bay of Fundy afforded by the Centre's location, the Centre will offer a coin-operated telescope situated at a strategic viewing location on the site.

1.4.2 Memberships

The Centre will offer a membership program, which provides members with the following benefits:

- free admission to the Centre
- complimentary beach permit
- 10% discount at the gift shop
- newsletter
- invitation to events
- 20% discount on programs

Annual membership fees will be as follows:

Membership Category	Annual Membership Fee
Individual	$20
Family	$40

To encourage community involvement in the centre, **residents of the local community will be offered a free membership, to be claimed upon visitation**.[1]

1.4.3 Operating Schedule

The Interpretive Centre and guided beach tours will be available to the public according to the following schedule:

Victoria Day weekend to June 30: open 10:30 to 6:00
Canada Day to Labour Day: open 9:30 to 7:00
Labour Day to Remembrance Day: open 10:30 to 6:00
Off Season: Remembrance Day to Victoria Day: visits and tours by appointment

It is assumed that the facility will open on July 1 for the first year of operations.

1.4.4 Marketing

Multiple strategies will be used to market the Fossil Cliffs Site and Centre to resident, tourist, school and specialty markets, including:

- prominent positioning of the site and centre in provincial tourism marketing;
- placement of promotional ***road signage*** at key points including Highway #104 in both directions, in Parrsboro, Springhill and on Rte. 16 for people coming across the Confederation Bridge from PEI;
- development of ***print material*** to be displayed at visitor information centres, other regional attractions and hotels and ***purchased advertising in key tourism publications***

[1] Local residents are defined as persons whose current primary residence and civic address is in Joggins, River Herbert, Lower River Hebert, Minudie, Lower Cove, Shulie, Strathcona or Maccan Woods and who have resided in one or more of those communities for at least 30 days out of the previous 12 months.

that ***encourage visitors to time their visit to coincide with low tide and plan to spend sufficient time for both a tour of the Centre and a guided tour of the cliffs***;

- use of promotional media such as local and provincial print advertising, local radio advertising and TV public service announcements supplemented by paid advertising spots;

- organization of ***FAM (familiarization) tours*** of the site and Centre to make members of the media and tourism industry aware of the site/centre and the experiences that it offers;

- establishment of partnerships with ***group sales companies*** to attract bus tours to the Centre;

- ***collaboration and joint marketing*** with the Fundy Geological Museum, Bay of Fundy Tourism Partnership, Central Nova Tourist Association, Cape Chignecto Park and the Fundy Shore Tourism Destination Area Committee to promote the "fossil shore," and encourage visitors to visit both the Fundy Geological Museum and the Joggins Fossil Cliffs, including the opportunity for visitors at one site to purchase tickets to the other site at a modest discount.

- creation of a dedicated ***web site*** that includes the opportunity for on-line gift shop sales, ticket and exploration permit sales, tour booking, posting of tide tables and a schedule of guided tour times;

- creation and distribution of a ***teacher's guide*** that highlights the learning opportunities offered at the centre/site and links to curriculum;

- the creation of a ***quarterly email newsletter*** for members and supporters.

1.4.5 Rentals, Functions

It is assumed that the Centre will be promoted to public, private and educational sectors, as well as the local community as a location to hold meetings and other events.

1.4.6 Programs

Visitors to the site and Centre will be offered a range of programs and experiences from which to select, including:

- self-guided tours of the exhibits (included in admission fee);
- guided tours of site and cliffs;
- self-guided tours of the cliffs with the purchase of an exploration permit;
- guided tours of the centre and educational programs for P to 12 school groups, post-secondary school groups and other groups, such as bus tours and community groups;
- two annual events to coincide with peak tourist visitation, such as Canada Day and Labour Day weekends;
- one temporary/changing exhibition per year;
- outreach activities, such as presentations on Joggins at professional conferences and post-secondary institutions.

1.4.7 Other Self-Generated Revenue

In addition to the revenue generated from admission fees and programs, other forms of self-generated revenue will include gift shop sales, food service[2] concession fees (outside operator); internet café; and a coin-operated telescope.

1.4.8 Other Operating Assumptions

Because of its relationship with CREDA, it is assumed that: the Site and Centre will be in a position to realize certain ***economies through bulk purchasing with Cape Chignecto Park*, as well as *less costly insurance fees through CREDA's insurer***. It is further assumed that ***CREDA will manage purchasing and payroll administration*** for the Centre.

1.5 Staffing

1.5.1 Staffing Positions

In order to fulfill its essential conservation, scientific and education mandate as a World Heritage Site, and to maximize the tourism potential and economic benefit of the site to the local community, we recommend the staffing complement outlined below. This staffing complement and commensurate levels of remuneration will ensure that there will be a high-calibre scientific and educational team in place at Joggins, as befits the site's scientific and educational importance. The recommended structure also puts in place a strong management team, which will be required to oversee the day-to-day operations of the centre and site, to work closely with the governing board, and to work toward promoting this Centre as a world-class attraction.

Director

Reporting directly to the Board of Directors, the Director is responsible for overseeing all aspects of the Interpretive Centre and site operations. The Director recommends policies and plans to the Board, implements policies and plans approved by the board and reports on the outcome of these plans and policies. The Director has overall responsibility for human resources management, occupational health and safety and management of the operations of the Centre and site through the staff. The Director is responsible for financial management and seeking out sources of ongoing funding, including both private and public sources. The Director serves as the liaison with all levels of government and the local community, and develops strategies to promote the Centre locally, nationally and internationally.

Geologist

The Geologist is responsible for the security, preservation, documentation and interpretation of Joggins' fossil resources. The Geologist carries out site-specific research, makes that research available to the public and liaises with other researchers and institutions in the scientific community. The Geologist provides curatorial input into the development of exhibitions and educational programs and is responsible for the training of interpretive and collections staff. The Geologist leads tours and other educational programs for post-secondary and professional groups. To enhance the visibility of the site with the larger scientific community, the Geologist publishes scientific papers, attends conferences and conducts lectures on a regular basis.

[2] It is assumed that the food service will offer a limited menu such as soups and sandwiches and hot and cold drinks.

Manager of Programs

The Manager of Programs is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the Centre and site, as well as outreach programs and extension programs. The Manager of Programs develops educational materials to accompany exhibitions and provides input into the development of new/temporary exhibitions.

Educators/Interpreters

The Educators/Interpreters are responsible for advancing the educational mission of the Centre and enhancing the visitor experience by conducting guided tours of the site, by leading workshops and other educational programs for visitors and groups and by answering questions and providing assistance to visitors accessing the beach on an exploration permit. The Educators/Interpreters will help to advance the scientific and research mission of the Centre by assisting in the preliminary identification, cataloguing and preparation of fossil specimens.

Manager of Visitor Services and Marketing

The Manager of Visitor Services and Marketing is responsible for the overall quality of the services offered at the Centre and for ensuring that high standards of customer care are met. The Manager of Visitor Services and Marketing recruits and manages customer service staff (admissions and retail), develops, in conjunction with the Director, and implements the strategic marketing plan for the site and Centre and ensures that the Centre responds to multiple markets and changing visitors demands. The Manager of Visitor Services and Marketing is responsible for overseeing revenue-generation centres including the gift shop, food-service concession, internet cafe and rentals.

Customer Service Assistants

Customer Service Assistants greet visitors, answer general visitor enquiries and introduce visitors to the menu of activities and experiences that can be enjoyed at the Centre/site. Customer Service Assistants process admissions, gift shop transactions and fossil exploration permit purchases, as well as ensuring that gift shop and information displays are well-stocked.

Administrative Assistant

The Administrative Assistant will provide support services for the Centre and Site operations. Anticipated responsibilities include:

- bookkeeping;
- clerical & filing duties;
- processing payment for workshops & programs;
- maintaining a database mailing list;
- program administration including course registration.

It is assumed that an automated phone answering system will be used, enabling this position to be part-time.

Site and Maintenance Manager

The Site and Maintenance Manger is responsible for overseeing all aspects of facility/site maintenance and housekeeping of the physical plant and grounds of the Centre. Through an on-going system, the Site and Maintenance Manager will determine the need for repairs and preventative maintenance, will carry out necessary maintenance and repairs or will oversee the procurement and delivery of contracted services as necessary.

1.5.2 Number of Staff and Compensation Levels

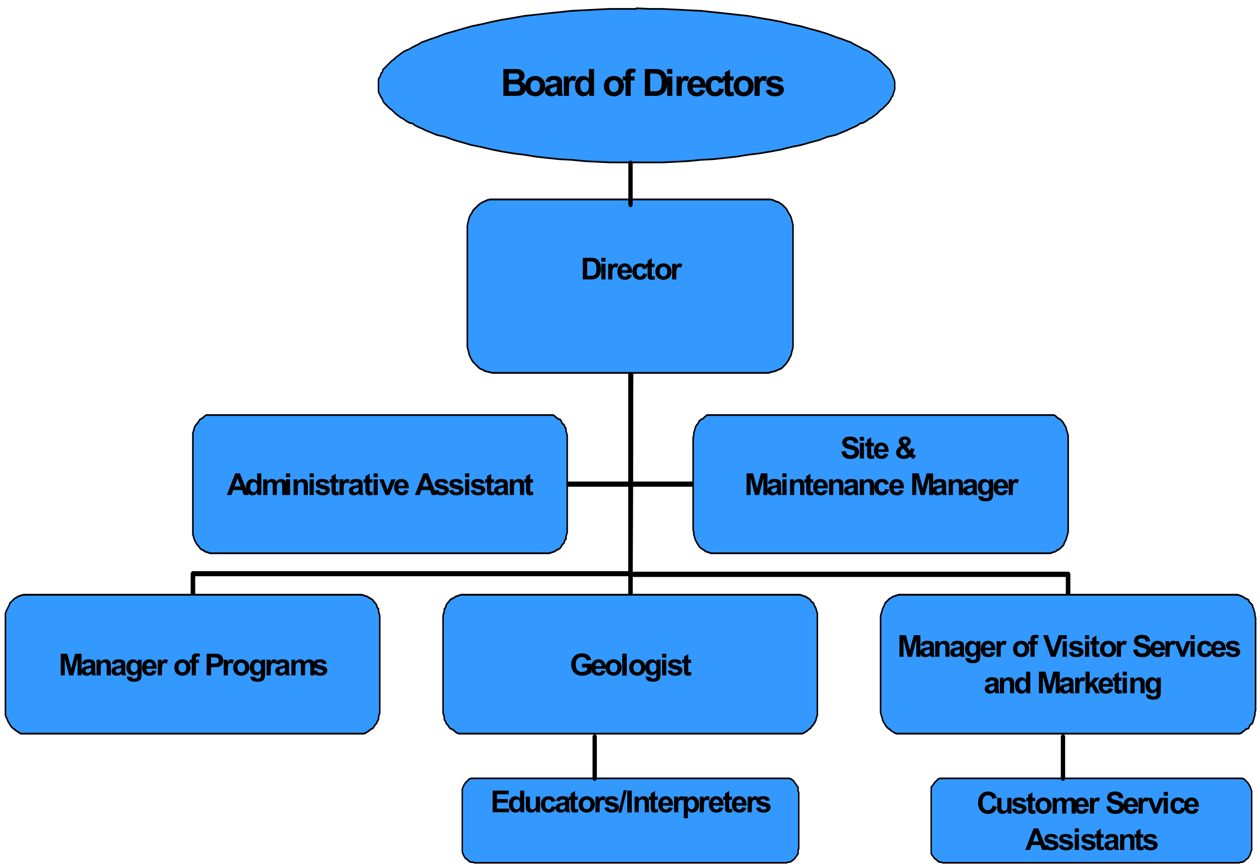
The following chart summarizes the number of staff and compensations levels for the Joggins Fossil Cliffs and Interpretive Centre. It is assumed that there will be opportunities for shared staffing between Joggins Fossil Cliffs and nearby Cape Chignecto Provincial Park. Assumptions regarding shared staffing are as follows:

- Site and Maintenance Manager: 50% Joggins /50% Cape Chignecto
- Manager of Visitor Services and Marketing: 70% Joggins/30% Cape Chignecto
- Manager of Programs: 70% Joggins/30% Cape Chignecto
- Executive Director: 80% Joggins/20% Cape Chignecto

Position	Number	Term of Employment	Compensation	% Paid by Joggins	$ Paid by Joggins
Director	1	full-time	$65,000	80%	$52,000
Geologist	1	full-time	$45,000	100%	$45,000
Manager of Visitor Services & Marketing	1	full-time	$35,000	70%	$24,500
Manager of Programming	1	full-time, seasonal	$25,000	70%	$17,500
Interpreters/Educators	6	full-time, seasonal	4 @ $10/hr. X 38 hrs/week X27 weeks = $41,040 2 @ $10/hr. X 38 hrs/weekX11 weeks = $8,360 Total=$49,400	100%	$49,400
Customer Service Associates	2	full-time, seasonal	$8/hr. X 38 hrs X 25 weeksx2 = $15,200	100%	$15,200
Administrative Assistant	1	part-time, year-round	$12/hr X 20 hrs. X 52 weeks = $12,480	100%	$12,480
Site & Maintenance Manager	1	full-time	$22,500	50%	$11,250
Total Salaries	14	4 full-time, 9 full-time seasonal & 1 part-time year-round	$269,580		$227,330
Benefits @ 13%					$29,553
Total Salaries & Benefits			**$304,625**		**$256,883**

1.5.3 Organizational Chart

Joggins Fossil Cliffs Site and Interpretive Centre
Organizational Chart



2. ATTENDANCE PROJECTIONS

Attendance projections for the Joggins Fossil Cliffs and Interpretive Centre take into account a variety of contextual and market data such as:

1. the size and nature of the potential markets;
2. the marketplace and institutional context in which the centre will operate;
3. the experience of comparable institutions.

2.1 Analysis of Potential Markets

2.1.1 Size of Tourist Market

According to the most recent Nova Scotia Visitor Exit Survey, Nova Scotia attracted approximately **2.2 million non-resident visitors in 2004**.[3] **Of total non-resident visitors, 54% entered the province via Amherst/Tidnish**.

According to the 2004 Nova Scotia Traffic Flow Report, **1% of non-resident visitors to the Province visited the Joggins area**. Applying this percentage to the total number of non-resident visitors to Nova Scotia in 2004 produces a figure of **22,000 non-resident visitors** passing through Joggins.[4]

2.1.2 Origin of Tourist Market

In 2005, Cumberland Regional Economic Development Association conducted a Fundy Shore Visitor information Survey. The survey was conducted over six days at the Nova Scotia Visitor Information Centre in Fort Lawrence. A comparison of this data and the data collected during the 2004 Provincial Visitor Exit Survey suggest both similarities and differences in the profile of visitors to the Fundy Shore compared to the profile of visitors to Nova Scotia as a whole.

Origin of Visitors	Fundy Shore[5]	NS Overall[6]
Atlantic Canada	21%	47%
Ontario	31%	20%
Quebec	4%	5%
Other Canada	7%	6%
New England	5%	5%
Other US	16%	13%
Other International	3%	4%

Although Fundy shore data are based on a smaller sample size, these data would suggest that the Fundy Shore region attracts a ***higher percentage of visitors from Ontario*** and a ***lower percentage of visitors from other parts of Atlantic Canada than the average for the province as a whole***. If confirmed by subsequent research, this finding would have implications on where the Centre should target its marketing efforts.

[3] Prepared on behalf of the Nova Scotia Department of Tourism, Culture & Heritage by Corporate Research Associates, 2005
[4] This figure refers to the percentage of visitors who stopped in the community for more than 30 minutes. 2004 Nova Scotia Visitor Exit Survey.
[5] According to the CREDA Fundy Shore Visitor Information Survey, 2005
[6] According to the 2004 Nova Scotia Visitor Exit Survey

2.1.3 Tourist Party Composition

Party Composition	Fundy Shore	NS Overall
as a couple	34%	44%
as a family with children	39%	16%
alone	6%	25%
With friends or another couple	5%	12%
other	4%	2%

As the data above indicate, 39% of visitors to the Fundy Shore region are* families with children**. ***This finding highlights the importance of the Fossil Cliff Interpretive Centre offering experiences that appeal to a range of interests within families.

2.1.4 Size of Resident Market

Generally speaking, one of the factors influencing the potential success of a visitor attraction is the size and nature of the resident market. Readily accessible and available on a year-round basis, local residents can be most easily and economically made aware of programming. For the purposes of this analysis, we have defined the primary resident market for the Joggins Fossil Cliffs as Cumberland County.

Cumberland County is the ninth largest of Nova Scotia's 18 counties. As the chart below illustrates, the population decreased slightly between 1996 and 2001, as did the majority of counties. Nonetheless, the resident population remained above 30,000 residents.

Size of Resident Market	Cumberland County	Nova Scotia
Population in 2001 (1)	32,605	908,007
Population in 1996 (2)	33,804	909,282
1996 to 2001 population change (%)	-3.5	-0.1

Source: Statistics Canada, 1996 and 2001 Census Data

These data suggest that there is a limited resident population from which to draw visitors. However, the city of Moncton, New Brunswick, which has a population of over 117,000, is only a one hour and fifteen minute drive from Joggins. While technically part of the tourist market, the short distance between Moncton and Joggins virtually makes Moncton part of the resident market for Joggins Fossil Cliffs.

2.1.5 Size of the Primary and Secondary School Market (P-12)

Like most heritage attractions, primary and secondary school groups will represent an important source of visitors for the Joggins Fossil Cliffs Centre. The Joggins area is served by the Chignecto-Central Regional School Board. The school board is divided into four regions, or Families. The Chignecto Family takes in schools in Cumberland County and includes sixteen elementary schools, one junior high school, and seven high schools. The Cobequid Family takes in schools in Colchester County and includes sixteen elementary schools, four middle/junior, and two high schools. The Celtic Family encompasses schools in Pictou County, of which there are fourteen elementary schools, six middle/junior, and three high schools. The Nova Family takes in schools in the Municipality of East Hants, which is one of the fastest growing areas of the province. The Nova Family includes fourteen elementary schools, one middle school, and three high schools.[*]

As the following table illustrates, the potential primary and secondary school market for the Joggings Fossil Cliffs Centre is currently 24,233.

2005 Enrolment	Chignecto Family	Cobequid Family	Nova Family	Celtic Family	Total
Elementary	2,376	3,294	2,747	3,558	11,975
Junior	1,196	1,682	1,427	1,806	6,111
Senior	1,300	1,785	1,163	1,889	6,137
Total	**4,872**	**6,761**	**5,337**	**7,263**	**24,233**

In order to attract visits from the P-12 school market, the Centre's staff should develop curriculum-based school programs for a variety of age levels and promote those programs to local schools. The Centre should also conduct in-service days for teachers in order to familiarize them with the programs and resources that Joggins has to offer.

2.1.6 Postsecondary School Market

Even before the construction of an interpretive centre at Joggins, the fossil cliffs have attracted post-secondary school groups from Canada and the United States. Among universities visiting the cliffs are:

- Dalhousie University
- St. Mary's University
- McGill University
- Mount Allison University
- Colby College
- Fairmont State University
- University of Chicago
- Kansas State University
- Berkeley College

With over 200 geology schools or colleges with geology departments in the United States, and 20 Canadian universities offering geology degrees, there is potential for Joggins Fossil Cliffs to attract visits from a broader number of post-secondary schools. ***The Centre's marketing plan should include specific strategies to market Joggins to the post-secondary market.***

[*] Source: Chignecto-Central School Board

2.1.7 Enthusiast/Professional Market

Those working in or teaching geosciences, as well as serious “rockhounds,” represent a relatively small but important potential market for Joggins. This market is highly motivated to visit sights like Joggins and is likely to spend more time there than would casual visitors. In the United States, the Geological Society of American runs a GeoVenture program that offers geoscience field trip experiences for professionals, rockhounds and their friends; school teachers (K-12); and college students. GeoVentures range from weekend trips (GeoClass), through week-long trips (GeoHostels) to 14 day or longer experiences (GeoTrips).

Discussions with the GSA indicate that Joggins would be considered a good destination for a GeoHostel trip. Trips typically take place during July and August. In order to tap into this market, staff at the Centre will need to submit a proposal to the GSA nine months in advance of the proposal trip time.

In Canada, there are also a number of organizations involved in the delivery of geosciences education programs to industry professionals and teachers, including the Geological Association of Canada and the EdGeo Committee, which coordinates earth science workshops for Canadian teachers. The Canadian Society of Petroleum Geologists also has an outreach program that organizes courses, field trips and other educational initiatives for members. ***Discussions with each of these organizations indicated interest in collaborating with the Joggins Fossil Cliffs Interpretive Centre around the development of educational programs. It is recommended that the Centre’s staff pursue these possibilities in greater detail and develop marketing strategies and programs that appeal to this specialized audience.***

2.2 Institutional Context

The experience of other heritage attractions provides part of the context from which to develop attendance projections for a new heritage attraction like the interpretive centre at Joggins. As such, this section of our report reviews this institutional context.

2.2.1 Experience of Other Provincial Paid-Admission Heritage Attractions

The Nova Scotia Museum (NSM) is a family of 27 museums and heritage sites located throughout the Province. The following table provides a breakdown of visitor data for all sites within the Nova Scotia Museum.

2004-05 Provincial Museum Visitor Statistics	Nova Scotia Museum Sites (26)
Total Attendance	**627,557**
Average Attendance	**24,137**
Visitor Origin:	
% Within County	17%
% Other Nova Scotia	14%
%Other Atlantic Canada	3%
%Other Canada	16%
%US	15%
%Other International	4%
Unknown	32%
Visit Breakdown:	
% Visits by Individuals	62%
% Visits by School Groups	6%
% Visits by Tour Groups	6%
% Visits by Local Groups	1%
% Meeting & Rental Visits	6%
% Research Visits	0%*
% Event and Program Visits	6%
% Other	14%

These statistics provide useful benchmarks for the composition of potential visitors to Joggins.

Attendance: As the above data indicate, **average attendance at all NSM sites was 24,137 visitors in the most recently completed fiscal year*. However, when calculating average attendance at NSM sites attracting over 6,000 visitors, the average annual visitation is 52,720.*[7]**

Visitor Origin: Of those NSM visitors whose origin was known, the **largest percentage of visitors reside in the county in which the site is located**, **followed closely by other parts of Canada and the United States.**

Purpose of visit: The **majority of visits to the NSM are so called "casual visits**," made by those who are not part of an organized group or visiting for a specific reason, such as an event or meeting, although visits by **school groups** and **tour groups** make up an important and, in many cases, growing portion of visitors.

[*] While the average research visits across the system is less than 1%, the Fundy Geological Museum drew 1% of its attendance through research visits.

[7] This includes several Halifax-based sites that attract over 100,000 visitors.

2.2.2 Experience of Selected Cumberland County Attractions

As the following table illustrates, Cumberland County is home to a diverse range of attractions. Although many of these attractions are smaller than what is planned at Joggins, it is nonetheless useful to understand this regional context, which suggests that:

- **the majority of attractions operate on a seasonal basis;**
- the **average admission charge is quite low.** However**, adult admission charges over $6.00 are not without precedent.** In fact, the two attractions with the highest visitation, the Fundy Geological Museum and the Ann Murray Centre, charge $6.00 or more.

Cumberland County Visitor Attractions			
Attraction	**Location**	**Operating Season**	**Adult Admission**
Joggins Fossil Centre	Joggins	June to Sept. 15	$5.00
Age of Sail Heritage Centre	Ward's Brook	June to Sept. 15	$2.00
Amos Seaman School Museum	River Hebert	summer	donation
Anne Murray Centre	Springhill	May to Oct.	$6.00
Cumberland Co. Museum	Amherst	year-round	$3.00
Fundy Geological Museum	Parrsboro	year-round	$6.25
Heritage Models Centre	River Hebert	mid-June to Sept. 30	$3.00
Ottawa House - By-the-Sea	Parrsboro	late-May to mid-Sept	$2.00
Malagash Heritge Museum	Malagash	June 15 to Sept. 15	$2.00
River Hebert Miners Museum	River Hebert	summer	donation
Sringhill Miners' Museum	Springhill	May to Oct.	$4.50
Wallace and Area Museum	Wallace	May 15 to Oct. 1	donation
Wild Blueberry & Maple Centre	Oxford	April to October	donation
Cape Chignecto Park	West Advocate	June to November	$3.00
Total			
Average			**$3.68**

2.2.3 Experience of a Similar Fundy Shore Attraction: Hopewell Rocks

The Hopewell Rocks Ocean Tidal Exploration Site is located on the New Brunswick side of Chignecto Bay. Visitors to the site can learn about tides, geology and human history by visiting the interpretation centre, exploring a series of trails and viewing platforms and walking on the beach though flowerpot rock formations. In 2005, Hopewell Rocks attracted over 180,000 paid visitors to the site, the second highest visitor numbers among attractions in the Province of New Brunswick.

The success of Hopewell Rocks demonstrates the potential for a high quality visitor centre at a unique geological site to attract significant visitor numbers. However, these figures must be viewed within the context of the significant competitive advantages that Hopewell Rocks enjoys:

Location:

- Hopewell Rocks is located along Highway 114, which is the shore road leading to/from Moncton;
- the latest available traffic counts collected at two different points along Highway 114 near Hopewell Rocks recorded 562,100 and 901,550 vehicles annually. By way of comparison, the 2004 traffic counts for Joggins indicated approximately 71,000 vehicles passed through Joggins;
- Hopewell Rocks is located a short distance from Fundy National Park, which is New Brunswick's most visited attraction, with 230,000 visitors in 2004.

Profile and Marketing:

- Hopewell Rocks has been a favourite visitor attraction along the Fundy coast since the mid-1800s. There has been a visitor centre at the site for over 20 years, with a major overhaul completed in 1998.
- New Brunswick has positioned Hopewell Rocks as a lead attraction for the province and to this end has invested heavily in marketing the site. It is frequently featured on the cover of New Brunswick's equivalent of the Doers and Dreamers guide.

The lesson that Joggins can learn from Hopewell Rocks is that aggressive marketing is key to creating the high profile needed to attract significant numbers of visitors.

2.3 Experience of Comparable Institutions

This section of our report contains an analysis of three comparable attractions dedicated to the conservation and interpretation of sites of geological/paleolontological importance. These attractions are:

- Miguasha National Park Interpretive Centre, Miguasha, Quebec
- Dinosaur State Park Exhibit Centre, Rocky Hill, Connecticut
- Royal Tyrrell Museum, Drumheller, Alberta

2.3.1 Profile of Comparables

2.3.1.1 Miguasha National Park Interpretive Centre

Miguasha National Park is located in the Gaspé region of Quebec, on the shores of Chaleur Bay. Like Joggins, Miguasha has a small resident population within an hour drive.

Considered the world's most outstanding illustration of the Devonian Period, or 'Age of Fishes', Miguasha was added to UNESCO’s World Heritage List in 1999.

The first interpretive centre opened at Miguasha in 1978, with the park created in 1985. The current centre features 3,983 sq. ft. of exhibitions, a 1,292 sq. ft theatre, laboratory space, a gift shop and restaurant. Visitors also have access to 3 kms. of interpreted hiking trails and a picnic area.

2.3.1.2 Dinosaur State Park Exhibit Centre

Dinosaur State Park is located a short distance from Hartford Connecticut. The Park and exhibit centre were created in 1968 to protect and interpret one of the largest dinosaur track sites in North America. The Exhibit Center’s geodesic dome encloses five hundred of the tracks, with the remaining 1,500 buried for preservation.

The exhibit centre features more than 55,000 sq. ft. of exhibition space, and a 100-seat theatre. In addition to the Exhibit Centre, the Park also features two miles of nature trails, picnic facilities and the Dinosaur State Park Arboretum, which contain more than 250 species and cultivars of plant families that existed in the Age of Dinosaurs.

2.3.1.3 Royal Tyrrell Museum

The Royal Tyrrell Museum is located in Midland Provincial Park, 6 kilometres from the community of Drumheller, which is approximately 1.5 hours from Calgary.

The 120,000 sq. ft. museum, which opened in 1985, offers over 52,000 sq. ft. of exhibition space. The museum’s facilities also include a large laboratory space, a gift shop operated by the Royal Tyrrell Museum Cooperating Society and a cafeteria with a 160-person capacity that is operated by an outside concessionaire. In 2003, the Museum opened its new, 16,500 sq. ft. ATCO Learning Centre, which houses three classrooms, a hands-on workshop, an outdoor interpretive area and a distance-learning studio to link with students and scientists worldwide.

Other activities and amenities available in the Park include canoeing, kayaking, picnic areas, self-guided tours of the park and the Midland Coal Mining Company Office, hiking trails, including trails leading to mining displays at the original mining sites.

2.3.2 Attendance

As the chart below indicates, attendance levels at the three comparable attractions vary widely. The Royal Tyrrell Museum, which has developed an international reputation for excellence and promotes itself as having the most extensive display of dinosaur fossils in the world, attracts over 300,000 visitors annually. The exhibit centre at Dinosaur State Park is located a short distance from the greater Hartford area, which has an estimated population of 1,184,564. The Centre attracted just over 57,000 visitors on average over the last three years. The interpretive centre at Miguasha National Park, which is a World Heritage Site and like Joggins is located in a rural community over an hour's drive from a major urban centre, attracted an average of 25,497 visitors over the last three years.

The three comparable attractions draw between 5% and 15% of their total visitors from school groups, for an average of 10%. Although the percentage of total visitors drawn from bus tours was not available for Dinosaur State Park Visitor Centre, the other two comparable attractions draw less than 5% of their total visitors from bus tours.

	Miguasha National Park Interpretive Centre	**Dinosaur State Park Exhibit Centre**	**Royal Tyrrell Museum**
Total Building Size (gross sq. ft.)	21,528	55,000 of exhibit space[8]	119,255 sq. ft.
Average Attendance Previous 3 Years	25,497	57,455	342,719
School Groups as % of Total Attendance	10%	15%	5%
Bus Tours as % of Total Attendance	4%	n/a	3%

2.3.3 Governance

Each of the three comparable attractions that was researched is governed by the province/state in which it is located. In the case of the Royal Tyrrell Museum, the Alberta Ministry of Community Development is the governing body. In the case of Miguasha, the site is operated by Parcs Québec/Sepaq (Ministere des resources naturelles Faune et Parcs du Québec) and in the case of Dinosaur State Park, the State of Connecticut is responsible for management of the site and centre.

[8] Total building size was not available.

2.3.4 Sources of Operating Revenue

Although detailed financial information was not available from Dinosaur State Park, the following chart provides a breakdown of operating for Miguasha and the Royal Tyrrell Museum.

Source of Revenue	Miguasha	Royal Tyrrell
% Self-generated	46%	54%
% Donations/Sponsorships	1%	0%
% Government	53%	45%

As is typical for heritage attractions, both Miguasha and the Royal Tyrrell Museum derive a significant percentage of their operating revenues from government sources, ***although Tyrrell generates a higher than average percentage of revenue from earned sources***. Both institutions derive a lower than average percentage of their overall revenue from donations/sponsorships which may be due to the fact that they are operated by provincial governments.[9]

2.3.5 Marketing

The most effective forms of marketing reported by the three comparables included:

- web sites
- word of mouth
- tourist guidebooks
- printed brochures
- joint marketing with other local attractions
- press releases to local newspapers and radio

[9] For a typical breakdown of revenue sources among Canadian heritage institutions, please see page 35 of this report.

2.3.6 Advice for Joggins

Each of the comparables was asked if they had any advice for Joggins Fossil Cliffs. Suggestions included:

- *Set extremely high standards for yourselves, rather than extremely high targets (allow yourselves to 'become' a success rather than open as one).*
- *Be true to your mandate as a UNESCO world heritage site (placing protection of the natural resource before all else).*
- *Show respect and reverence in all that you do in the hopes that it will be imparted to your visitors.*
- *Value innovation.*
- *Educate your visitors to the sensitivity of the resource and do not give them access to the most sensitive resources or areas. If you show them where this material is, do not be surprised if they destroy it.*
- *Gather as much visitor feedback as possible and review it at the management level. Change things that are not common sense from a customer's perspective. Solidify systems and procedures so that service staff have the best opportunity to succeed in providing great customer service.*

2.4 Key Market and Operational Factors

There are a variety of factors that impact the likely attendance for the Joggins Fossil Site and Interpretive Centre, including the following:

2.4.1 Positive Market and Operational Factors

- **Scientific Importance**

Without a doubt, the distinction of the fossil cliffs as a site of international scientific importance is a very positive market factor. Designation as a UNESCO World Heritage Site will make Joggins an even more appealing destination for resident, tourist and educational markets.

- **High Quality Visitor Experience**

The quality of the visitor experience is a definitive factor influencing attendance at heritage attractions. The facilities, exhibitions and visitor experience in the interpretive centre and on the site will be of world-class standards.

- **Proximity to Provincial Gateway**

Joggins is approximately a 20-minute drive from Amherst, the most frequently used point of entry to Nova Scotia, with 54% visitors entering the province via Amherst/Tidnish.

- **Regional Marketing**

In the future, Joggins will benefit from plans to market the Fundy shore as a tourism destination area. The region itself and the other attractions along the shore will in turn benefit from a higher profile as a result of Joggins' World Heritage Site designation.

2.4.2 Negative Market and Operational Factors

- **Location**

While Joggins' proximity to the busiest provincial gateway is an advantage, the vast majority of traffic in the Amherst area, (93%), did not stop in Amherst according to the 2004 Nova Scotia Visitor Exit Study. Additionally, Joggins is located on a secondary highway that does not attract high levels of traffic. Therefore, the Centre and site will not benefit from the type of "drive-by" traffic that they would if they were located on a major travel route.

- **Size of Resident Market**

The resident market for Joggins is small, meaning that the site and Centre must attract a high proportion of their visitors from greater distances.

- **Lack of Tourism Infrastructure**

At the present time in Joggins, there are no hotels or other amenities necessary for attracting and retaining full day or overnight visitors. Interviews with tourism operators indicate that this is a barrier to fully developing the tourist market for Joggins. However, it is reasonable to expect that the local tourism infrastructure will develop over time as more visitors are drawn to the Joggins area with the opening of the interpretive centre.

2.5 Attendance Projections

The attendance projections for the Joggins Fossil Cliffs Site and Centre are based on the following contextual data:

- analysis of potential resident, tourist and educational markets
- the experience of other heritage attractions in Nova Scotia
- the experience of comparable institutions
- the knowledge and experience of the consultants

According to the 2004 Nova Scotia Traffic Flow Report, 1% of non-resident visitors to the Province visited the Joggins area. Applying this percentage to the total number of non-resident visitors to Nova Scotia produces a figure of 22,000 non-resident visitors passing through Joggins.

On average, 28% of tourists in the province are non-resident visitors, while the remaining 72% are Nova Scotians. Applying this ratio to Joggins suggests that an additional 49,428 Nova Scotians pass through Joggins, for a total of 71,428 individuals passing through Joggins annually. Applying the 2004 capture rate of 37% leads to a figure of 26,428 visitors stopping annually in Joggins[10].

It seems reasonable to project that the opening of a new, world-class interpretive centre and subsequent World Heritage Site designation will lead to an increase of at least 15% in traffic flow to the Joggins area. It also seems safe to project that if 37% of those passing through Joggins currently stop for at least 30 minutes, the presence of a new centre and site interpreting the cliffs will result in a higher capture rate, which we have estimated at 52%. The results of this projected increase in traffic flow and higher capture rate leads to an estimate of 42,714 visitors stopping in Joggins annually. Of those people who are projected to stop in Joggins for 30 minutes or more, we estimate that 90% or 38,443 people will visit the Centre or the site.

The following chart summarizes this breakdown:

Year One Visitor Projections

Current Traffic Flow	
Estimated non-resident visitor traffic through Joggins (2004)	22,000
Estimated resident traffic through Joggins (2004)	49,428
Total traffic (2004)	71,428
Capture rate (2004)	37%
Persons stopping in Joggins 30 min. or more (2004)	26,428
Projected Traffic Flow and Visitation Following Interpretive Centre Construction	
Projected % increase traffic (following centre/site development completion)	15%
Projected total traffic through Joggins (following centre/site development completion)	82,142
Projected capture rate (following centre/site development completion)	52%
Projected persons stopping in Joggins 30 min or more	42,714
Projected number of people visiting the centre or site (90% of those stopping)	**38,443**

[10] This figure refers to the percentage of visitors who stopped in the community for more than 30 minutes. 2004 Nova Scotia Visitor Exit Survey.

Because of the novelty and media attention paid to new attractions, visitor numbers are typically higher in the first year and decline slightly in year two. However, because it is anticipated that in its second year of operations, Joggins fossil site will receive world heritage site designation, which will draw considerable attention to the site, we are not projecting a drop in year two attendance, but a 10% increase from year one. This increase will be followed by a slight decrease in year three when the initial novelty and media attention lessen and many interested residents will have visited for the first time. However, after the third year, attendance is projected to gradually increase to stabilized levels as the centre and site begin to develop a higher profile through aggressive marketing and as management develop a better understanding of market preferences and patterns and adjust programming and operations accordingly.

Based on these considerations, the projected five-year visitor numbers for Joggins are as follows:

Projected Five-Year Visitor Numbers for Joggins Fossil Cliffs and Interpretive Centre

	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Visitors to Site	38,443	42,288	40,174	44,191	48,601

Although the attendance projections prepared for the purposes of this report only cover a five-year period, it is anticipated that through aggressive and sustained marketing of Joggins and with the development of the local tourism infrastructure that should accompany construction of the Centre, the long-term visitor numbers for Joggins hold strong potential for growth.

3. OPERATING REVENUE & EXPENSE PROJECTIONS

3.1 Revenue Projections

The main categories of revenue that have been projected for the Joggins Fossil Cliffs are:

- admissions, tours and exploration permits
- memberships
- retail sales
- rentals
- donations
- Internet café
- coin-operated telescope

The bottom line for the projections is the amount of projected revenue minus projected expenses to indicate the additional income required from government sources, other grants and fundraising to break even on operations.

3.1.1. Revenue from Admissions, Tours and Exploration Permits

It is estimated that 80% of visitors to the site will pay admission, take part in a guided tour, or will take part in a self-guided experience that involves the purchase of an exploration permit.[11]

- 50% will pay the admission fee only
- 5% will take part in a guided tour only
- 7.5% will pay a combined fee for admission to the centre as well as a guided tour
- 27.5% will take a self-directed tour and purchase a permit that allows for exploration of the beach
- 10% of visitors will be part of a school group

Based on these calculations and a calculation of average fees found in Appendix A, this leads to the following projections of income from admissions, tours and exploration permits.

Five Year Projected Revenues from Admissions and Tours

	Year 1	Year 2	Year 3	Year 4	Year 5
Interpretive Centre Admissions	$ 78,730	86,605	82,278	95,029	104,512
Guided Tour Fees	$ 12,913	14,205	13,495	15,587	17,142
Interpretive Centre + Guided Tour	$ 29,588	32,547	30,921	35,713	39,277
Exploration Permits	$ 25,372	27,910	26,516	30,625	33,681
School Tours	$ 9,534	10,487	9,963	11,507	12,656
	$ 156,137	**$ 171,754**	**$ 163,174**	**$ 188,461**	**$ 207,268**
Less: Adjustment in Year 1 for Abridged Season	-$ 8,314	-			
Less: HST in admission prices	-$ 19,281	-$ 22,403	-$ 21,284	-$ 24,582	-$ 27,035
	$ 128,542	**$ 149,351**	**$ 141,891**	**$ 163,879**	**$ 180,233**

[11] The remaining 20% will consist of children under the age of five, those attending meetings at the centre and members, who will not pay admission.

3.1.2 Revenue from Memberships

It is not anticipated that the Centre will generate a significant level of revenue from memberships, in part because members of the local community will receive free membership. Nonetheless, the membership program will be a means for building a core group of supporters. Our estimate of revenues from memberships is as follows:

Five Year Projected Revenue from Memberships

	Year 1	Year 2	Year 3	Year 4	Year 5
Memberships					
Individual members	20	24	30	36	40
Rate	$ 20	$ 20	$ 20	$ 20	$ 20
Revenue	$ 400	$ 480	$ 600	$ 720	$ 800
Family members	5	8	10	12	15
Rate	$ 40	$ 40	$ 40	$ 40	$ 40
Revenue	$ 200	$ 320	$ 400	$ 480	$ 600
Total Revenue from Memberships	**$ 600**	**$ 800**	**$ 1,000**	**$ 1,200**	**$ 1,400**

3.1.3 Gift Shop Sales

The following estimate of revenue from retail sales is based on an average expenditure of $2.21 per paid attendee, which is the average expenditure per visitor according to the 2002 Canadian Museums Store Retail Association Retail Industry Report. We are also estimating modest local sales of Joggins Fossil Cliffs clothing and other items otherwise not available in the immediate area.

Five Year Projected Giftshop Sales and Expenses

	Year 1	Year 2	Year 3	Year 4	Year 5
		10%+	5%-	10%+	10%+
Sales at @ $2.21 per paid attendee	$67,966	$74,763	$71,025	$78,127	$85,940
Local sales	$3,000	$3,000	$3,000	$3,000	$3,000
	$70,966	$77,763	$74,025	$81,127	$88,940
Cost of Sales					
Cost of purchases @ 50%	35,483	38,881	37,012	40,564	44,470
Supplies & credit card charges @ 5%	3,548	3,888	3,701	4,056	4,447
	39,031	42,770	40,714	44,620	48,917
Net income from giftshop	**$28,935**	**$31,993**	**$30,311**	**$33,507**	**$37,023**

3.1.4 Annual Gifts and Donations

Although a fundraising feasibility study is not included in the consultants' scope of work, it is anticipated that the Centre will be able to secure modest levels of donations from visitors, community members and key patrons. The strategic placement of a donation box in the lobby of the Centre, with text explaining that all donations will be used for preservation activities, will help to encourage casual donations. Combined with strategies to encourage local businesses and key supporters to make donations in support of conservation and educational activities, we anticipate that the Centre will generate the following income from donations.

Annual Gifts and Donations

	Year 1	Year 2	Year 3	Year 4	Year 5
Donations from visitors, community & key patrons	$ 3,000	$ 4,000	$ 5,000	$ 7,500	$ 10,000

3.1.5 Rentals

Rental income at Joggins will be derived through the rental of space to the RCMP for use as a community policing office, through rent paid by an outside operator of the Centre's café and through rental of the Centre's multipurpose room for meeting space by community and other groups.

Five Year Projections of Rental Income

	Year 1	Year 2	Year 3	Year 4	Year 5
Café @ $250 - $500 /month	3,000	3,000	3,000	4,200	6,000
RCMP Office	-	964	1,012	1,063	1,116
Multipurpose Room/Programming Space	250	250	250	250	250
	$ 3,250	$ 4,214	$ 4,262	$ 5,513	$ 7,366

3.1.6 Internet Café

The internet café will be a value-added service to visitors and members of the community. The following revenue projections are based on an estimate of 5% of paid visitors utilizing the internet café for an average of 15 minutes at a charge of .20/minute.

Five Year Projections from Internet Café

	Year 1	Year 2	Year 3	Year 4	Year 5
Internet Café	**$ 4,613**	**$ 5,074**	**$ 4,821**	**$ 5,303**	**$ 5,833**

3.1.7 Coin-Operated Telescope

Based on revenues generated by the coin-operated telescope at Cape Chignecto Park and Cape D'Or, we are projecting the following revenue from the coin-operated telescope at Joggins.

Five Year Projections of Income from Coin-Operated Telescope

Year 1	Year 2	Year 3	Year 4	Year 5
$ 3,000	**$ 3,300**	**$ 3,135**	**$ 3,449**	**$ 3,793**

3.2 Projected Expenses

Operating expenses for Joggins Fossil Cliffs and Interpretive Centre are projected for the following eight categories:

1. staffing
2. occupancy costs
3. programming
4. exhibitions
5. collections, curatorial
6. marketing
7. administration
8. vehicle operations

3.2.1 Staffing

The single largest operating expense at the centre will be staffing-related costs. Because visitor attractions of this nature are labour-intensive, salaries and benefits typically account for 50 - 65% of total expenses.

Salaries and benefits for the Centre's 4 full-time year-round, 9 full-time seasonal and one part-time year-round employees are projected as follows.

Five Year Projected Salaries and Benefits

	Percentage of Time Spent With Centre	Rates for Full Year	Year 1 abridged public season	Year 2 1%+	Year 3 2%+	Year 4 2%	Year 5 2%
Salaries & Benefits							
Director	80%	$ 52,000	52,000	$ 52,520	$ 53,570	$ 54,642	$ 55,735
Geologist	100%	45,000	45,000	$ 45,450	46,359	47,286	48,232
Manager Visitor Services & Marketing	70%	24,500	24,500	$ 24,745	25,240	25,745	26,260
Manager Programs	70%	17,500	17,500	$ 17,675	18,029	18,389	18,757
Interpreters	100%	49,400	40,280	$ 49,894	50,892	51,910	52,948
Customer Service Assistants	100%	15,200	11,552	$ 15,352	15,659	15,972	16,292
Admin Assistant	100%	12,480	12,480	$ 12,605	12,857	13,114	13,376
Site and Maintenance Manager	50%	11,250	11,250	$ 11,363	11,590	11,822	12,058
Total Salaries		$ 227,330	$ 214,562	$ 229,603	$ 234,195	$ 238,879	$ 243,657
Benefits	13%	29,553	27,893	29,848	30,445	31,054	31,675
Total		$ 256,883	$ 242,455	$ 259,452	$ 264,641	$ 269,934	$ 275,332

3.2.2 Occupancy Costs

Building occupancy costs are generally defined as all costs, excluding salaries, associated with building utilities, repairs and maintenance, security systems and building insurance. Typically in buildings of this type, occupancy costs range from $4.00 to $6.00 per gross sq. ft. and vary according to the extent of environmental controls, weather conditions, the extent of public use and the condition of the building, with new buildings requiring lower maintenance expenditures. Because the centre at Joggins will utilize **green** building technologies in order to reduce on-going occupancy costs, it is assumed that occupancy costs will come in at the lower end of the range, or $4.00/gross sq. ft, of which two-thirds will go toward utilities, and one-third toward maintenance. However, due to the nature of the outdoor experience offered at Joggins, it is anticipated that insurance costs for the site and centre will be comparatively high. As such, we have provided a separate estimate for the insurance portion of occupancy rates. **Projections for insurance costs are only estimates until quotes can be obtained when more detailed planning of the building has been completed.**

Five Year Projected Occupancy Costs

		Year 1	Year 2 1%	Year 3 2%	Year 4 2%	Year 5 2%
Utilities and maintenance	$4/sq foot	$ 51,080	$ 51,591	$ 52,623	$ 53,675	$ 54,749
Insurance		13,500	13,635	13,908	14,186	14,470
		$ 64,580	$ 65,226	$ 66,530	$ 67,861	$ 69,218

3.2.3 Programming and Exhibitions

Programming costs include expenses, exclusive of salaries, associated with public and school programs, special events and non-staff expenditures to cover the cost of one temporary exhibition per year after year 2, as well as routine maintenance to the permanent exhibitions.

These costs are estimated as follows:

Five Year Programming and Exhibitions Expense

	Year 1	Year 2 1%+	Year 3 2%+	Year 4 2%+	Year 5 2%+
Programming	$ 6,000	$ 6,060	$ 6,181	$ 6,305	$ 6,431
Exhibitions	$ -	$ -	$ 5,000	$ 5,100	$ 5,202
	$ 6,000	$ 6,060	$ 11,181	$ 11,405	$ 11,633

3.2.4 Research, Curatorial, Collections Management

The following expenditures are projected for materials and supplies that will be required for research-related activities, as well as the processing and preparation of fossil specimens.

	Year 1	Year 2	Year 3	Year 4	Year 5
		1%+	2%+	2%+	2%+
Curatorial/Research/Collections Management	$ 2,000	$ 2,500	$ 3,000	$ 3,500	$ 4,000

3.2.5 Marketing

The 2005 Fundy Shore Visitor Information Survey administered by CREDA reveled that over half of those surveyed did not know about the scientific importance of Joggins. As such, it will be critically important to "get the word out" about Joggins and the exceptional experience it offers. The following projection of marketing expenses reflects the highest investment in marketing in Year 1, during which marketing materials and a web site will have to be designed for the first time and costs associated with marketing the opening of the centre will be expended. After Year 1 marketing expenses are projected to level off in the range of $30,000.

	Year 1	Year 2	Year 3	Year 4	Year 5
Five Year Projected Marketing Expenses			2% +	2% +	2% +
Website Development & Maintenance	5,000	750	765	780	796
Print advertising	18,000	9,000	9,180	9,364	9,551
Radio	3,000	3,000	3,060	3,121	3,184
TV	3,000	3,000	3,060	3,121	3,184
Brochures	15,000	7,500	7,650	7,803	7,959
Graphic Designer	7,000	-	-	-	-
Partnership advertising	8,000	6,000	6,120	6,242	6,367
Receptions/hosting	1,000	750	765	780	796
	$ 60,000	$ 30,000	$ 30,600	$ 31,212	$ 31,836

3.2.6 Administration

Administrative costs typically account for about 10% to 15% of staffing costs. However, because of the international nature of reporting and meetings associated with world heritage status, we are projecting administrative costs slightly higher than this range, or approximately 23% of staffing costs.

Five Year Projected Administration Expenses

	Year 1	Year 2	Year 3	Year 4	Year 5
		1%+	2% +	2% +	2% +
Audit and legal	7,500	7,575	7,727	7,881	8,039
Bank and credit card charges	2,100	2,121	2,163	2,207	2,251
Board- meetings and travel	15,820	15,978	16,298	16,624	16,956
Dues and fees	2,400	2,430	2,478	2,528	2,578
Office equipment	1,000	1,010	1,030	1,051	1,072
Photocopy and printing	3,000	3,030	3,091	3,152	3,215
Professional Development	2,000	2,020	2,060	2,102	2,144
Professional services	2,500	2,525	2,576	2,627	2,680
Safety equipment and uniforms	2,000	2,020	2,060	2,102	2,144
Supplies, postage and delivery	6,200	6,262	6,387	6,515	6,645
Telephone and communications	6,000	6,060	6,181	6,305	6,431
Travel-staff (conferences, meetings)	7,730	7,807	7,963	8,123	8,285
Total Administration	$ 58,250	$ 58,838	$ 60,015	$ 61,215	$ 62,440

3.2.7 Vehicle Operations

A bus/passenger van will be used to transport guided tour participants for 3 and 4-hour tours 3-6 times per week. It is assumed that the vehicle will not be driven in the off-season and that insurance coverage will be reduced to minimum in the off-season. This leads to the following projection of costs associated with vehicle operation.

Five Year Projections for Vehicle Expenses

	Year 1	Year 2	Year 3	Year 4	Year 5
		1%+	2%+	2%+	2%+
Insurance costs	$ 3,000	$ 3,030	$ 3,091	$ 3,152	$ 3,215
Fuel, maintenance & registration	2,000	2,020	2,060	2,102	2,144
	$ 5,000	$ 5,050	$ 5,151	$ 5,254	$ 5,359

3.3 Summary of Revenue and Expense Projections

The table that follows summarizes our projections of attendance, operating revenue and expenses for the Joggins Fossil Cliffs site and interpretive centre. ***Because it is impossible to project with any certainty potential income from government grants or to project income from fundraising without carrying out a fundraising feasibility study, the bottom line difference between projected revenues and expenses is expressed as the amount of income required from government grants, contributions and fundraising to break even.***

Summary of Five-Year Projected Revenues and Expenses

	Year 1	Year 2	Year 3	Year 4	Year 5
REVENUE					
Admissions and tours	128,542	149,351	141,891	163,879	180,233
Memberships	600	800	1,000	1,200	1,400
Giftshop	70,966	77,763	74,025	81,127	88,940
Annual gifts and donations	3,000	4,000	5,000	7,500	10,000
Rentals	3,250	4,214	4,262	5,513	7,366
Internet	4,613	5,074	4,821	5,303	5,833
Coin Operated Telescope	3,000	3,300	3,135	3,449	3,793
Total Revenue	**$ 213,971**	**$ 244,503**	**$ 234,133**	**$ 267,970**	**$ 297,565**
EXPENSES					
Staffing	242,455	259,452	264,641	269,934	275,332
Operations	64,580	65,226	66,530	67,861	69,218
Giftshop Cost of Sales & Supplies	39,031	42,770	40,714	44,620	48,917
Programming& Exhibitions	6,000	6,060	11,181	11,405	11,633
Curatorial	2,000	2,500	3,000	3,500	4,000
Marketing	60,000	30,000	30,600	31,212	31,836
Administration	58,250	58,838	60,015	61,215	62,440
Vehicle	5,000	5,050	5,151	5,254	5,359
Total Expenses	**$ 477,317**	**$ 469,895**	**$ 481,832**	**$ 495,001**	**$ 508,735**
Additional revenue required from government sources, additional fundraising and contributed sources to break even	**$ 263,345**	**$ 225,393**	**$ 247,699**	**$ 227,030**	**$ 211,170**
% of additional revenue required from government sources, additional fundraising and contributed sources to break even	**55.2%**	**48.0%**	**51.4%**	**45.9%**	**41.5%**

As the table on the previous page indicates, the projected amount of revenue required from government grants, contributions and fundraising ranges from a high of approximately 55% in year one to a low of 41.5% in year five. As the following table illustrates, this is a typical funding mix for heritage attractions, which require, on average, almost 60% of their funding from government sources.

Profile of Canadian Heritage Institutions (excluding nature parks)

Sources of Operating Revenue					
	1993-1994	**1995-1996**	**1997-1998**	**1999-2000**	**2002-2003**
Total Operating Revenues (1000s)	**869,947**	**959,044**	**1,013,019**	**1,116,576**	**1,297,732**
Earned Revenue					
Membership	7,963	9,721	10,846	12,374	16,121
Admission	75,967	91,163	106,081	114,748	126,890
Other earned revenues[1]	111,476	158,169	176,791	227,097	255,218
Total earned revenues	195,406	259,053	293,718	354,219	398,229
Earned Revenue as % of Total	**22.5%**	**27.0%**	**29.0%**	**31.7%**	**30.7%**
Government					
Federal government	233,627	252,358	259,653	268,987	326,205
Provincial government	253,039	252,748	239,313	253,510	272,057
Municipal/Regional government	121,605	120,221	131,719	132,711	177,331
Total Government Revenue	608,271	625,327	630,685	655,208	775,593
Government Revenue as % of Total	**69.9%**	**65.2%**	**62.3%**	**58.7%**	**59.8%**
Institutional/private Revenue[2]	66,270	74,664	88,616	107,149	123,910
Institutional/Private Revenue as a % of Total	**7.6%**	**7.8%**	**8.7%**	**9.6%**	**9.5%**

Statistics Canada: Survey of Heritage Institutions

For the purposes of comparison, the interpretive centre at Miguasha Provincial Park receives 53% of its operating revenue from government sources, while the Royal Tyrrell Museum of Paleontology receives 45% of its operating revenue from government sources.

4. CAPITAL REPLACEMENT

A capital replacement schedule sets out the amount of money that should be saved annually to replace the capital components of a project as their useful life expires.

Based on estimates of the useful life of major capital components of the Joggins Fossil Cliffs Interpretive Centre, as well as their estimated replacement costs, ***it is projected that an annual contribution of $75,000 to a capital replacement fund will be required to cover capital replacements over a 50 year period***. Appendix D provides a detailed capital replacement schedule, which is based on the following assumptions:

All costs and life expectancies are based on available published standards in combination with the experience of cost specialists. These figures are estimates only and should not be considered a substitute for the ongoing assessment of capital assets as the building and site age.

All dollar amounts are expressed in 2006 dollars. No adjustment has been made for inflation.

Additional explanatory notes to various sections of the capital replacement schedule are included in Appendix D.

Appendix A: Detailed Breakdown of Admission & Tour Revenue

APPENDIX A: Detailed Five -Year Projections of Revenue from Interpretive Centre Admissions and Tours

Centre Activity	Attendee Type	Average Fee	% of Total Attendance	Year One Total Paid Attendance	Year One Total Revenue	Year Two Total Paid Attendance (10% increase)	Year Two Total Revenue (no fee change)	Year Three Total Paid Attendance (5% decrease)	Year Three Total Revenue (no fee change)	Year Four Total Paid Attendance (10% increase)	Year Four Total Revenue (fees increase 5%)	Year Five Total Paid Attendance (10% increase)	Year Five Total Revenue (fees@Yr 4 level)
Interpretive Centre Admission	Individual/family	$ 5.17	48.00%	14,762	$ 76,270	16,238	83,898	15,427	79,707	16,969	92,059	18,663	101,246
Interpretive Centre Admission	School Group	$ 2.50	6.00%	1,845	$ 4,613	2,030	5,075	1,928	4,821	2,121	5,568	2,333	6,124
Interpretive Centre Admission	Adult Group	$ 4.00	2.00%	615	$ 2,460	677	2,706	643	2,571	707	2,970	778	3,266
Interpretive Centre & Beach Tour	School Group	$ 4.00	4.00%	1,230	$ 4,921	1,353	5,413	1,286	5,142	1,414	5,939	1,555	6,532
Interpretive Centre & 2 Hour Tour	Individual/family	$ 11.31	4.00%	1,230	$ 13,916	1,353	15,308	1,286	14,543	1,414	16,797	1,555	18,473
Interpretive Centre & 2 Hour Tour	Adult Group	$ 9.00	1.50%	461	$ 4,152	507	4,567	482	4,339	530	5,011	583	5,511
Interpretive Centre & 3 Hour Tour	Individual/family	$ 15.21	1.00%	308	$ 4,677	338	5,145	321	4,888	354	5,645	389	6,209
Interpretive Centre & 3 Hour Tour	Adult Group	$ 12.00	0.50%	154	$ 1,845	169	2,030	161	1,928	177	2,227	194	2,450
Interpretive Centre & 4 Hour Tour	Individual/family	$ 18.50	0.50%	154	$ 2,845	169	3,129	161	2,973	177	3,434	194	3,776
Interpretive Centre & 4 Hour Tour	Adult Group	$ 14.00	0.50%	154	$ 2,153	169	2,368	161	2,250	177	2,598	194	2,858
2 Hour Tour	Individual/family	$ 7.73	2.50%	769	$ 5,943	846	6,537	804	6,210	884	7,173	972	7,889
2 Hour Tour	Adult Group	$ 6.00	0.25%	77	$ 461	85	507	80	482	88	557	97	612
3 Hour Tour	Individual/family	$ 11.75	0.50%	154	$ 1,807	169	1,988	161	1,888	177	2,181	194	2,398
3 Hour Tour	Adult Group	$ 9.00	0.50%	154	$ 1,384	169	1,522	161	1,446	177	1,670	194	1,837
4 Hour Tour	Individual/family	$ 15.58	0.50%	154	$ 2,396	169	2,636	161	2,504	177	2,892	194	3,181
4 Hour Tour	Adult Group	$ 12.00	0.25%	77	$ 923	85	1,015	80	964	88	1,114	97	1,225
Self-directed Exploration Tour	All	$ 3.00	27.50%	8,457	$ 25,372	9,303	27,910	8,839	26,516	9,722	30,625	10,692	33,681
		$ 5.08	**100.00%**	**30,754**	**$ 156,137**	**33,830**	**$ 171,754**	**32,140**	**$ 163,174**	**35,353**	**$ 188,461**	**38,881**	**$ 207,268**
Adjustment for late opening (June 30)*:					**-$ 8,314**								
Total Admissions Revenue not including 15% HST:					**$ 128,542**		**$ 149,351**		**$ 141,891**		**$ 163,879**		**$ 180,233**
***59 fewer tours in this abridged season.**													
Summary by Type of Attendee:													
Total individual/family		$ 6.15	57.0%	17,530	$ 107,854	19,283	$ 118,641	18,320	$ 112,714	20,151	$ 130,181	22,162	$ 143,173
Total school groups		$ 3.10	10.0%	3,075	$ 9,534	3,383	$ 10,487	3,214	$ 9,963	3,535	$ 11,507	3,888	$ 12,656
Total adult groups		$ 7.91	5.5%	1,691	$ 13,378	1,861	$ 14,716	1,768	$ 13,981	1,944	$ 16,147	2,138	$ 17,759
Total self-directedand/or permit only		$ 3.00	27.5%	8,457	$ 25,372	9,303	$ 27,910	8,839	$ 26,516	9,722	$ 30,625	10,692	$ 33,681
		$ 5.08	**100.00%**	**30,754**	**$ 156,137**	**33,830**	**$ 171,754**	**32,140**	**$ 163,174**	**35,353**	**$ 188,461**	**38,881**	**$ 207,268**
Summary by Activity:													
Attending Interpretive Centre only		$ 5.12	50.0%	15,377	$ 78,730	16,915	$ 86,605	16,070	$ 82,278	17,677	$ 95,029	19,441	$ 104,512
Self-directed Tour only		$ 3.00	27.5%	8,457	$ 25,372	9,303	$ 27,910	8,839	$ 26,516	9,722	$ 30,625	10,692	$ 33,681
Attending both Interpretive Centre and Tour		$ 12.03	8.0%	2,460	$ 29,588	2,706	$ 32,547	2,571	$ 30,921	2,828	$ 35,713	3,110	$ 39,277
Taking Tour Only		$ 9.33	4.5%	1,384	$ 12,913	1,522	$ 14,205	1,446	$ 13,495	1,591	$ 15,587	1,750	$ 17,142
School Group- Centre and Beach tours		$ 3.10	10.0%	3,075	$ 9,534	3,383	$ 10,487	3,214	$ 9,963	3,535	$ 11,507	3,888	$ 12,656
		$ 5.08	**100.00%**	**30,754**	**$ 156,137**	**33,830**	**$ 171,754**	**32,140**	**$ 163,174**	**35,353**	**$ 188,461**	**38,881**	**$ 207,268**
Break-down of tour participation:													
total taking 2hr tour		$ 9.65	8.25%	2,537	$ 24,472	2,791	$ 26,920	2,652	$ 25,575	2,917	$ 29,538	3,208	$ 32,486
total taking 3hr tour		$ 12.63	2.50%	769	$ 9,713	846	$ 10,685	804	$ 10,151	884	$ 11,724	972	$ 12,894
total taking 4hr tour		$ 15.45	1.75%	538	$ 8,316	592	$ 9,148	562	$ 8,691	619	$ 10,038	680	$ 11,040
		$ 11.06	**12.50%**	**3,844**	**$ 42,501**	**4,229**	**$ 46,752**	**4,018**	**$ 44,417**	**4,419**	**$ 51,300**	**4,860**	**$ 56,419**

Appendix B: Sample Tour Schedule

APPENDIX B:

Sample Tour Schedule and Interpretive Staffing Plan

Based on the following assumptions:

- ***High tide every 12.5 hours***
- ***Tours end 1.5 hours before high tide and start 1.5 hours after high tide***
- ***One Educator/Interpreter leading tours & 2 monitoring/assisting visitors on the beach every day from Victoria Day to late-June and Labour Day to Remembrance Day***
- ***Two Educators/Interpreters conducting concurrent tours every day from mid-June to Labour Day, one of whom assists/ monitors visitors on beach when not conducting the 2-hour tour***
- ***Two additional Educators/Interpreters monitoring visitors on beach every day from late-June to Labour day***

		Hours of Operation	High tide	Tour Schedule	Total Avail.Time	# tours 2 Hr	3 Hr	4 Hr	Guide/Monitor Staffing Required (TG= tour guide, BM= beach monitor) #1	#2	#3	#4	#5	#6	
May 8-18	9 training days								TG/BM	TG/BM	TG/BM	TG/BM			
19-May	Friday	10:30-6PM	9AM/9:30 PM	11AM-5:30PM	6.5	1		1	TG	BM	BM	Off			
20	Saturday	10:30-6PM	10AM/10:30PM	11:30- 5:30	6	1		1	TG	BM	BM	Off			
21	Sunday	1PM-5PM	11AM/11:30PM	1:30-4:30	3	1			TG	BM	OFF	BM			
22	Monday	10:30-6PM	Noon/12:30 AM	1:30-5:30	4	2			TG	BM	OFF	BM			
23	Tuesday	10:30-6PM	1PM/1:30 AM	2:30-5:30	3	1			TG	OFF	BM	BM			
24	Wednesday	10:30-6PM	2PM/2:30 AM	3:30-5:30	2	1			OFF	OFF	TG/BM	BM			
25	Thursday	10:30-6PM	3PM/3:30 AM	11-1:30; 4:30-5:30	2	1			OFF	TG	BM	BM			
26	Friday	10:30-6PM	4PM/4:30 AM	11-2:30	3.5	1			TG	BM	BM	OFF			
27	Saturday	10:30-6PM	5PM/5:30 AM	11-3:30	4.5	1			TG	BM	BM	Off			
28	Sunday	1PM-5PM	6PM/6:30 AM	1:30-4:30	3	1			TG	BM	OFF	BM			
29	Monday	10:30-6PM	7PM/7:30 AM	11-5:30	6.5	1	1		TG	BM	OFF	BM			
30	Tuesday	10:30-6PM	8PM/8:30 AM	11AM-5:30	6.5	1		1	TG	OFF	BM	BM			
31	Wednesday	10:30-6PM	9PM/9:30 AM	11AM-5:30	6.5	1		1	OFF	OFF	TG/BM	BM			
1-Jun	Thursday	10:30-6PM	10PM/10:30 AM	Noon-5:30	5.5	1	1		OFF	TG	BM	BM			
2	Friday	10:30-6PM	11PM/11:30 AM	1-5:30	4.5	1			TG	BM	BM	OFF			
3	Saturday	10:30-6PM	12PM/12:30PM	2PM-5:30	3.5	1			TG	BM	BM	Off			
4	Sunday	1-5PM	1AM/1:30PM	no tour	2.5				TG	BM	Off	BM			
5	Monday	10:30-6PM	2AM/2:30 PM	11AM-1PM; 4-5:30	2	1			TG	BM	OFF	BM			
6	Tuesday	10:30-6PM	3AM/3:30 PM	11AM-2PM	3	1			TG	OFF	BM	BM			
7	Wednesday	10:30-6PM	4AM/4:30 PM	11AM-3PM	4	2			OFF	OFF	TG/BM	BM			
8	Thursday	10:30-6PM	5AM/5:30 PM	11AM-4PM	5	1	1		OFF	TG	BM	BM			
9	Friday	10:30-6PM	6AM-6:30 PM	11AM-5PM	6	1	1		TG	BM	BM	OFF			
10	Saturday	10:30-6PM	7AM-7:30 PM	11AM-5:30PM	6.5	1		1	TG	BM	BM	Off			
11	Sunday	1PM-5PM	8AM/8:30 PM	1:30-4:30	3	1			TG	BM	Off	BM			
12	Monday	10:30-6PM	9AM/9:30 PM	11AM-5:30PM	6.5	1		1	TG	BM	OFF	BM			
13	Tuesday	10:30-6PM	10AM/10:30PM	11:30- 5:30	6	1	1		TG	OFF	BM	BM			
14	Wednesday	10:30-6PM	11AM/11:30PM	12:30-5:30	5	1	1		OFF	OFF	TG/BM	BM			
15	Thursday	10:30-6PM	Noon/12:30 AM	1:30-5:30	4	2			OFF	TG	BM	BM			
16	Friday	10:30-6PM	1PM/1:30 AM	2:30-5:30	3	1			TG	BM	BM	OFF			
17	Saturday	10:30-6PM	2PM/2:30 AM	3:30-5:30	2	1			TG	BM	BM	Off			
18	Sunday	1PM-5PM	3PM/3:30 AM	no tour	0	0			TG	BM	Off	BM			
19	Monday	10:30-6PM	4PM/4:30 AM	11-2:30	3.5	1			TG	BM	OFF	BM			
20	Tuesday	10:30-6PM	5PM/5:30 AM	11-3:30	4.5	1			TG	OFF	BM	BM	BM	BM	training
21	Wednesday	10:30-6PM	6PM/6:30 AM	11-4:30	5.5	1	1		OFF	OFF	BM	BM	BM	BM	
22	Thursday	10:30-6PM	7PM/7:30 AM	11-5:30	6.5	1		1	OFF	TG	BM	BM	BM	BM	
23	Friday	10:30-6PM	8PM/8:30 AM	11AM-5:30	6.5	1		1	TG	BM	BM	Off	BM	BM	
24	Saturday	10:30-6PM	9PM/9:30 AM	11AM-5:30	6.5	1	1		TG	BM	BM	Off	BM	BM	
25	Sunday	1PM-5PM	10PM/10:30 AM	1:30-5:30	4	1			TG	BM	Off	BM	off	off	
26	Monday	10:30-6PM	11PM/11:30 AM	1-5:30	4.5	1			TG	BM	Off	BM	BM	off	
27	Tuesday	10:30-6PM	12PM/12:30PM	2PM-5:30	3.5	1			TG	OFF	BM	BM	off	BM	
28	Wednesday	10:30-6PM	1AM/1:30PM	3-5:30 PM	2.5	1			OFF	OFF	TG	BM	BM	BM	
29	Thursday	10:30-6PM	2AM/2:30 PM	11AM-1PM; 4-5:30	2	1			OFF	TG	BM	BM	BM	off	
30	Friday	10:30-6PM	3AM/3:30 PM	11AM-2PM	3	1			TG	OFF	BM	OFF	off	BM	

APPENDIX B CON'T:

Sample Tour Schedule and Interpretive Staffing Plan

		Hours of Operation	High tide	Tour Schedule	Total Avail.Time	# tours 2 Hr	3 Hr	4 Hr	Guide/Monitor Staffing Required (TG= tour guide) #1	#2	#3	(BM= beach monitor) #4	#5	#6
1-Jul	**Saturday**	**9:30-7PM**	4AM/4:30 PM	10AM-3PM	5	2	1		TG	TG	BM	OFF	BM	off
2	Sunday	9:30-7PM	5AM/5:30 PM	10AM-4PM	6	2	1		TG	TG	off	BM	BM	BM
3	Monday	9:30-7PM	6AM-6:30 PM	10AM-5PM	7	2	1		TG	OFF	off	TG	BM	BM
4	Tuesday	9:30-7PM	7AM-7:30 PM	10AM-6PM	8	2		1	off	OFF	TG	TG	BM	BM
5	Wednesday	9:30-7PM	8AM/8:30 PM	10AM-6:30 PM	8.5	2		1	off	TG	TG/BM	BM	off	BM
6	Thursday	9:30-7PM	9AM/9:30 PM	10:30AM-6:30PM	8.5	2	1		TG	TG/BM	BM	OFF	BM	off
7	Friday	9:30-7PM	10AM/10:30PM	11:30- 6:30PM	7	2	1		TG	TG	BM	OFF	BM	BM
8	Saturday	9:30-7PM	11AM/11:30PM	12:30-6:30PM	5	2	1		TG	TG	off	BM	BM	BM
9	Sunday	9:30-7PM	Noon/12:30 AM	1:30-6:30PM	5	2			TG	off	off	BM	off	BM
10	Monday	9:30-7PM	1PM/1:30 AM	2:30-6:30PM	3	2			off	off	TG	TG	BM	BM
11	Tuesday	9:30-7PM	2PM/2:30 AM	10AM-12:30PM/3:30-6:30	2	2			off	TG	TG	BM	BM	BM
12	Wednesday	9:30-7PM	3PM/3:30 AM	10-1:30; 4:30-6:30	2	2			TG	TG	BM	OFF	BM	off
13	Thursday	9:30-7PM	4PM/4:30 AM	10-2:30	3.5	2			TG	TG	BM	OFF	BM	off
14	Friday	9:30-7PM	5PM/5:30 AM	10-3:30	4.5	2			TG	TG/BM	off	BM	off	BM
15	Saturday	9:30-7PM	6PM/6:30 AM	10-4:30	5.5	2	1		TG	off	off	TG	BM	BM
16	Sunday	9:30-7PM	7PM/7:30 AM	10-5:30	6.5	2		1	off	off	TG	TG	BM	BM
17	Monday	9:30-7PM	8PM/8:30 AM	10AM-6:30 PM	6.5	2		1	off	TG	TG/BM	BM	off	BM
18	Tuesday	9:30-7PM	9PM/9:30 AM	10:30-AM-6:30	6.5	2	1		TG	TG/BM	BM	OFF	off	BM
19	Wednesday	9:30-7PM	10PM/10:30 AM	11:30-6:30	5.5	2	1		TG	TG/BM	BM	OFF	BM	off
20	Thursday	9:30-7PM	11PM/11:30 AM	1-6:30	4.5	2			TG	TG/BM	off	BM	BM	off
21	Friday	9:30-7PM	12PM/12:30PM	2PM-6:30	3.5	2			TG	off	off	TG/BM	BM	BM
22	Saturday	9:30-7PM	1AM/1:30PM	3-6:30 PM	2.5	2			off	off	TG	TG/BM	BM	BM
23	Sunday	9:30-7PM	2AM/2:30 PM	10AM-12:30PM; 4-6:30	2	2			off	TG	TG/BM	BM	off	BM
24	Monday	9:30-7PM	3AM/3:30 PM	10AM-2PM	3	2			TG	TG/BM	BM	OFF	off	BM
25	Tuesday	9:30-7PM	4AM/4:30 PM	10AM-3PM	4	3			TG	TG/BM	BM	OFF	BM	off
26	Wednesday	9:30-7PM	5AM/5:30 PM	10AM-4PM	5	2	1		TG	TG/BM	off	BM	BM	off
27	Thursday	9:30-7PM	6AM-6:30 PM	10AM-5PM	6	2	1		TG	off	off	TG	BM	BM
28	Friday	9:30-7PM	7AM-7:30 PM	10AM-6PM	6.5	2		1	off	off	TG	TG/BM	BM	BM
29	Saturday	9:30-7PM	8AM/8:30 PM	10AM-6:30 PM	6.5	2		1	off	TG	TG/BM	BM	off	BM
30	Sunday	9:30-7PM	9AM/9:30 PM	10:30AM-6:30PM	6.5	2	1		TG	TG/BM	BM	OFF	off	BM
31	Monday	9:30-7PM	10AM/10:30PM	11:30- 6:30PM	6	2	1		TG	TG/BM	BM	OFF	BM	off
1-Aug	Tuesday	9:30-7PM	11AM/11:30PM	12:30-6:30PM	5	2	1		TG	TG/BM	off	BM	BM	off
2	Wednesday	9:30-7PM	Noon/12:30 AM	1:30-6:30PM	4	3			TG	off	off	TG/BM	BM	BM
3	Thursday	9:30-7PM	1PM/1:30 AM	2:30-6:30PM	3	2			off	off	TG	TG/BM	BM	BM
4	Friday	9:30-7PM	2PM/2:30 AM	10AM-12:30PM/3:30-6:30	2	2			off	TG	TG/BM	BM	off	BM
5	Saturday	9:30-7PM	3PM/3:30 AM	10-1:30; 4:30-6:30	2	2			TG	TG/BM	BM	OFF	off	Bm
6	Sunday	9:30-7PM	4PM/4:30 AM	10-2:30	3.5	2			TG	TG/BM	BM	OFF	BM	off
7	Monday	9:30-7PM	5PM/5:30 AM	10-3:30	4.5	2			TG	TG/BM	off	BM	BM	off
8	Tuesday	9:30-7PM	6PM/6:30 AM	10-4:30	5.5	2	1		TG	off	off	TG/BM	BM	BM
9	Wednesday	9:30-7PM	7PM/7:30 AM	10-5:30	6.5	2	1		off	off	TG	TG/BM	Bm	BM
10	Thursday	9:30-7PM	8PM/8:30 AM	10AM-6:30 PM	6.5	2		1	off	TG	TG/BM	BM	off	BM
11	Friday	9:30-7PM	9PM/9:30 AM	10:30-AM-6:30	6.5	2		1	TG	TG/BM	BM	OFF	off	Bm
12	Saturday	9:30-7PM	10PM/10:30 AM	11:30-6:30	5.5	2	1		TG	TG/BM	BM	OFF	BM	off
13	Sunday	9:30-7PM	11PM/11:30 AM	1-6:30	4.5	2			TG	TG/BM	off	BM	BM	off
14	Monday	9:30-7PM	12PM/12:30PM	2PM-6:30	3.5	2			TG	off	off	TG/BM	BM	BM
15	Tuesday	9:30-7PM	1AM/1:30PM	3-6:30 PM	2.5	2			off	off	TG	TG/BM	Bm	BM
16	Wednesday	9:30-7PM	2AM/2:30 PM	10AM-12:30PM; 4-6:30	2	2			off	TG	TG/BM	BM	off	BM
17	Thursday	9:30-7PM	3AM/3:30 PM	10AM-2PM	3	2			TG	TG/BM	BM	OFF	off	Bm
18	Friday	9:30-7PM	4AM/4:30 PM	10AM-3PM	4	3			TG	TG/BM	BM	OFF	BM	off
19	Saturday	9:30-7PM	5AM/5:30 PM	10AM-4PM	5	2	1		TG	TG/BM	off	BM	BM	off
20	Sunday	9:30-7PM	6AM-6:30 PM	10AM-5PM	6	2	1		TG	off	off	TG/BM	BM	BM
21	Monday	9:30-7PM	7AM-7:30 PM	10AM-6PM	6.5	2	1		off	off	TG	TG/BM	Bm	BM
22	Tuesday	9:30-7PM	8AM/8:30 PM	10AM-6:30 PM	6.5	2		1	off	TG	TG/BM	BM	off	BM
23	Wednesday	9:30-7PM	9AM/9:30 PM	10:30AM-6:30PM	6.5	2		1	TG	TG/BM	BM	OFF	off	Bm
24	Thursday	9:30-7PM	10AM/10:30PM	11:30- 6:30PM	6	2	1		TG	TG/BM	BM	OFF	BM	off
25	Friday	9:30-7PM	11AM/11:30PM	12:30-6:30PM	5	2	1		TG	TG/BM	off	BM	BM	off
26	Saturday	9:30-7PM	Noon/12:30 AM	1:30-6:30PM	4	3			TG	off	off	TG/BM	BM	BM
27	Sunday	9:30-7PM	1PM/1:30 AM	2:30-6:30PM	3	2			off	off	TG	TG/BM	Bm	BM
28	Monday	9:30-7PM	2PM/2:30 AM	10AM-12:30PM/3:30-6:30	2	2			off	TG	TG/BM	BM	off	BM
29	Tuesday	9:30-7PM	3PM/3:30 AM	10-1:30; 4:30-6:30	2	2			TG	TG/BM	BM	OFF	off	Bm
30	Wednesday	9:30-7PM	4PM/4:30 AM	10-2:30	3.5	2			TG	TG/BM	BM	OFF	BM	off
31	Thursday	9:30-7PM	5PM/5:30 AM	10-3:30	4.5	2			TG	TG/BM	off	BM	BM	off

APPENDIX B CON'T:

Sample Tour Schedule and Interpretive Staffing Plan

		Hours of Operation	High tide	Tour Schedule	Total Avail.Time	2 Hr	3 Hr	4 Hr	#1	#2	#3	#4	#5	#6
						# tours			Guide/Monitor Staffing Required TG= tour guide			BM= beach monitor		
1-Sep	Friday	9:30-7PM	6PM/6:30 AM	10-4:30	5.5	2	1		TG	off	off	TG/BM	BM	BM
2	Saturday	9:30-7PM	7PM/7:30 AM	10-5:30	6.5	2		1	off	off	TG	TG/BM	Bm	BM
3	Sunday	9:30-7PM	8PM/8:30 AM	10AM-6:30 PM	6.5	2		1	off	TG	TG/BM	BM	off	BM
4	Monday	9:30-7PM	9PM/9:30 AM	10:30-AM-6:30	6.5	2	1		TG	TG/BM	BM	OFF	off	Bm
5	Tuesday	10:30-6PM	10PM/10:30 AM	11:30-5:30	6	1	1		TG	BM	BM	off		
6	Wednesday	10:30-6PM	11PM/11:30 AM	1-5:30	4.5	2			TG	BM	off	Bm		
7	Thursday	10:30-6PM	12PM/12:30PM	2-5:30	3.5	1			TG	off	off	BM		
8	Friday	10:30-6PM	1AM/1:30PM	3-5:30 PM	2.5	1			TG	off	BM	BM		
9	Saturday	10:30-6PM	2AM/2:30 PM	11-1; 4-5:30	2	1			off	TG	BM	Bm		
10	Sunday	10:30-6PM	3AM/3:30 PM	11-2PM	3	1			off	TG	Bm	off		
11	Monday	10:30-6PM	4AM/4:30 PM	11AM-3PM	4	2			TG	BM	BM	off		
12	Tuesday	10:30-6PM	5AM/5:30 PM	11AM-4PM	5	1	1		TG	BM	off	BM		
13	Wednesday	10:30-6PM	6AM-6:30 PM	11AM-5PM	6	1	1		TG	BM	off	BM		
14	Thursday	10:30-6PM	7AM-7:30 PM	11AM-5:30PM	6.5	1		1	TG	off	BM	BM		
15	Friday	10:30-6PM	8AM/8:30 PM	11AM-5:30 PM	6.5	1		1	TG	off	BM	BM		
16	Saturday	10:30-6PM	9AM/9:30 PM	11AM-5:30PM	6.5	1	1		off	TG	BM	BM		
17	Sunday	10:30-6PM	10AM/10:30PM	11:30- 5:30	6	1	1		off	TG	BM	off		
18	Monday	10:30-6PM	11AM/11:30PM	12:30-5:30	5	1	1		TG	BM	BM	off		
19	Tuesday	10:30-6PM	Noon/12:30 AM	1:30-5:30	4	2			TG	BM	off	BM		
20	Wednesday	10:30-6PM	1PM/1:30 AM	2:30-5:30	3	1			TG	BM	off	BM		
21	Thursday	10:30-6PM	2PM/2:30 AM	3:30-5:30	2	1			TG	off	BM	BM		
22	Friday	10:30-6PM	3PM/3:30 AM	11-1:30; 4:30-5:30	2	1			TG	off	BM	BM		
23	Saturday	10:30-6PM	4PM/4:30 AM	11-2:30	3.5	1			off	TG	BM	BM		
24	Sunday	10:30-6PM	5PM/5:30 AM	11-3:30	4.5	1			off	TG	BM	off		
25	Monday	10:30-6PM	6PM/6:30 AM	11-4:30	5.5	1	1		TG	BM	BM	off		
26	Tuesday	10:30-6PM	7PM/7:30 AM	11-5:30	6.5	1		1	TG	BM	off	BM		
27	Wednesday	10:30-6PM	8PM/8:30 AM	11AM-5:30	6.5	1		1	TG	BM	off	BM		
28	Thursday	10:30-6PM	9PM/9:30 AM	11AM-5:30	6.5	1	1		TG	off	BM	BM		
29	Friday	10:30-6PM	10PM/10:30 AM	Noon-5:30	5.5	1	1		TG	off	BM	BM		
30	Saturday	10:30-6PM	11PM/11:30 AM	1-5:30	4.5	1			off	TG	BM	BM		
1-Oct	Sunday	10:30-6PM	12PM/12:30PM	2PM-5:30	3.5	1			off	TG	BM	off		
2	Monday	10:30-6PM	1AM/1:30PM	3-5:30 PM	2.5	1			TG	BM	BM	off		
3	Tuesday	10:30-6PM	2AM/2:30 PM	11AM-1PM; 4-5:30	2	1			TG	BM	off	BM		
4	Wednesday	10:30-6PM	3AM/3:30 PM	11AM-2PM	3	1			TG	BM	off	BM		
5	Thursday	10:30-6PM	4AM/4:30 PM	11AM-3PM	4	2			TG	off	BM	BM		
6	Friday	10:30-6PM	5AM/5:30 PM	11AM-4PM	5	1	1		TG	off	BM	BM		
7	Saturday	10:30-6PM	6AM-6:30 PM	11AM-5PM	6	1	1		off	TG	BM	BM		
8	Sunday	10:30-6PM	7AM-7:30 PM	11AM-5:30PM	6.5	1		1	off	TG	BM	off		
9	Monday	10:30-6PM	8AM/8:30 PM	11AM-5:30 PM	6.5	1		1	TG	BM	BM	off		
10	Tuesday	10:30-6PM	9AM/9:30 PM	11AM-5:30PM	6.5	1	1		TG	BM	off	BM		
11	Wednesday	10:30-6PM	10AM/10:30PM	11:30- 5:30	6	1	1		TG	BM	off	BM		
12	Thursday	10:30-6PM	11AM/11:30PM	12:30-5:30	5	1	1		TG	off	BM	BM		
13	Friday	10:30-6PM	Noon/12:30 AM	1:30-5:30	4	2			TG	off	BM	BM		
14	Saturday	10:30-6PM	1PM/1:30 AM	2:30-5:30	3	1			off	TG	BM	BM		
15	Sunday	10:30-6PM	2PM/2:30 AM	3:30-5:30	2	1			off	TG	BM	off		
16	Monday	10:30-6PM	3PM/3:30 AM	11-1:30; 4:30-5:30	2	1			TG	BM	BM	off		
17	Tuesday	10:30-6PM	4PM/4:30 AM	11-2:30	3.5	1			TG	BM	off	BM		
18	Wednesday	10:30-6PM	5PM/5:30 AM	11-3:30	4.5	1			TG	BM	off	BM		
19	Thursday	10:30-6PM	6PM/6:30 AM	11-4:30	5.5	1	1		TG	off	BM	BM		
20	Friday	10:30-6PM	7PM/7:30 AM	11-5:30	6.5	1		1	TG	off	BM	BM		
21	Saturday	10:30-6PM	8PM/8:30 AM	11AM-5:30	6.5	1		1	off	TG	BM	BM		
22	Sunday	10:30-6PM	9PM/9:30 AM	11AM-5:30	6.5	1	1		off	TG	BM	off		
23	Monday	10:30-6PM	10PM/10:30 AM	Noon-5:30	5.5	1	1		TG	BM	BM	off		
24	Tuesday	10:30-6PM	11PM/11:30 AM	1-5:30	4.5	1			TG	BM	off	BM		
25	Wednesday	10:30-6PM	12PM/12:30PM	2PM-5:30	3.5	1			TG	BM	off	BM		
26	Thursday	10:30-6PM	1AM/1:30PM	3-5:30 PM	2.5	1			TG	off	BM	BM		
27	Friday	10:30-6PM	2AM/2:30 PM	11AM-1PM; 4-5:30	2	1			TG	off	BM	BM		
28	Saturday	10:30-6PM	3AM/3:30 PM	11AM-2PM	3	1			off	TG	BM	BM		
29	Sunday	10:30-6PM	4AM/4:30 PM	11AM-3PM	4	2			off	TG	BM	off		
30	Monday	10:30-6PM	5AM/5:30 PM	11AM-4PM	5	1	1		TG	BM	BM	off		
31	Tuesday	10:30-6PM	6AM-6:30 PM	11AM-5PM	6	1	1		TG	BM	off	BM		
1-Nov	Wednesday	10:30-6PM	7AM-7:30 PM	11AM-5:30PM	6.5	1		1	TG	BM	off	BM		
2	Thursday	10:30-6PM	8AM/8:30 PM	11AM-5:30 PM	6.5	1		1	TG	off	BM	BM		
3	Friday	10:30-6PM	9AM/9:30 PM	11AM-5:30PM	6.5	1	1		TG	off	BM	BM		
4	Saturday	10:30-6PM	10AM/10:30PM	11:30- 5:30	6	1	1		off	TG	BM	BM		
5	Sunday	10:30-6PM	11AM/11:30PM	12:30-5:30	5	1	1		off	TG	BM	off		
6	Monday	10:30-6PM	Noon/12:30 AM	1:30-5:30	4	2			TG	BM	BM	off		
7	Tuesday	10:30-6PM	1PM/1:30 AM	2:30-5:30	3	1			TG	BM	off	BM		
8	Wednesday	10:30-6PM	2PM/2:30 AM	3:30-5:30	2	1			TG	BM	off	BM		
9	Thursday	10:30-6PM	3PM/3:30 AM	11-1:30; 4:30-5:30	2	1			TG	off	BM	BM		
10	Friday	10:30-6PM	4PM/4:30 AM	11-2:30	3.5	1			TG	off	BM	BM		
11	Saturday	10:30-6PM	5PM/5:30 AM	11-3:30	4.5	1			off	TG	BM	BM		
Total # tours					339	255	54	30						

Open to the Public: 25 weeks, 2 days

Total staffing weeks including training= 27 weeks

Appendix C: Cashflow

Appendix C: Five-Year Cash Flow Projections

Year One: Centre Opens in July	April	May	June	July	August	September	October	November	December	January	February	March	Totall
REVENUE													
Admissions and tours	-	-	-	46,275	51,417	19,281	9,641	1,928	-	-	-	-	128,542
Memberships	-	200	200	200	-	-	-	-	-	-	-	-	600
Giftshop	-	-	-	35,548	28,386	10,645	5,322	1,064	-	-	-	-	70,966
Annual gifts and donations	-	-	-	250	250	150	100	1,250	1,000	-	-	-	3,000
Rentals	250	250	300	250	250	300	300	300	250	250	250	300	3,250
Internet	-	-	-	1,661	1,845	692	346	69	-	-	-	-	4,613
Coin Operated Telescope	-	-	-	1,000	1,200	450	225	45	-	-	-	-	3,000
Total Revenue	$ 250	$ 450	$ 500	$ 75,264	$ 83,348	$ 31,518	$ 15,934	$ 4,657	$ 1,250	$ 250	$ 250	$ 300	$ 213,971
EXPENSES													
Staffing	15,324	15,324	20,904	26,404	29,251	26,404	26,404	20,904	15,324	15,324	15,324	15,324	242,455
Operations	17,757	4,257	4,257	4,257	4,257	4,257	4,257	4,257	4,257	4,257	4,257	4,257	64,580
Giftshop Cost of Sales & Supplies	-	-	-	14,051	15,613	5,855	2,927	585	-	-	-	-	39,031
Programming& Exhibitions	750	750	750	750	750	750	750	750	-	-	-	-	6,000
Curatorial	250	250	250	250	250	250	250	250	-	-	-	-	2,000
Marketing	36,750	6,750	2,750	2,750	2,750	2,750	2,750	2,750	-	-	-	-	60,000
Administration	4,854	4,854	4,854	4,854	4,854	4,854	4,854	4,854	4,854	4,854	4,854	4,854	58,250
Vehicle	-	3,000	400	400	400	400	400	-	-	-	-	-	5,000
Total Expenses	75,685	35,185	34,165	53,798	58,124	45,600	42,672	34,350	24,435	24,435	24,435	24,435	477,316
Cash Surplus(Shortfall)	-$ 75,436	-$ 34,735	-$ 33,665	$ 21,467	$ 25,224	-$ 14,081	-$ 26,738	-$ 29,693	-$ 23,185	-$ 24,185	-$ 24,185	-$ 24,135	-$ 263,345

Year Two	April	May	June	July	August	September	October	November	December	January	February	March	Totall
REVENUE													
Admissions and tours	-	2,987	14,935	44,805	50,780	22,403	11,201	2,240	-	-	-	-	149,351
Memberships	200	200	200	200	-	-	-	-	-	-	-	-	800
Giftshop	-	1,555	7,776	23,329	26,439	11,664	5,832	1,166	-	-	-	-	77,763
Annual gifts and donations	-	-	250	250	250	150	100	2,000	1,000	-	-	-	4,000
Rentals	330	330	380	330	330	380	380	380	330	330	330	384	4,214
Internet	-	101	507	1,522	1,725	761	381	76	-	-	-	-	5,074
Coin Operated Telescope	-	66	330	990	1,122	495	248	50	-	-	-	-	3,300
Total Revenue	$ 530	$ 5,240	$ 24,379	$ 71,427	$ 80,646	$ 35,853	$ 18,142	$ 5,912	$ 1,330	$ 330	$ 330	$ 384	$ 244,503
EXPENSES													
Staffing	15,477	23,669	26,399	29,129	26,399	29,129	26,403	20,930	15,477	15,477	15,477	15,477	259,452
Operations	17,934	4,299	4,299	4,299	4,299	4,299	4,299	4,299	4,299	4,299	4,299	4,299	65,226
Giftshop Cost of Sales & Supplies	-	855	4,277	12,831	14,542	6,415	3,208	642	-	-	-	-	42,770
Programming& Exhibitions	758	758	758	758	758	758	758	758	-	-	-	-	6,060
Curatorial	313	313	313	313	313	313	313	313	-	-	-	-	2,500
Marketing	3,725	3,725	3,725	3,725	3,725	3,725	3,725	3,725	50	50	50	50	30,000
Administration	4,903	4,903	4,903	4,903	4,903	4,903	4,903	4,903	4,903	4,903	4,903	4,903	58,838
Vehicle	-	3,198	337	337	337	337	337	168	-	-	-	-	5,050
Total Expenses	$ 43,110	$ 41,720	$ 45,010	$ 56,294	$ 55,275	$ 49,879	$ 43,945	$ 35,745	$ 24,730	$ 24,730	$ 24,730	$ 24,730	$ 469,896
Cash Surplus(Shortfall)	-$ 42,579	-$ 36,480	-$ 20,631	$ 15,132	$ 25,371	-$ 14,026	-$ 25,803	-$ 29,833	-$ 23,400	-$ 24,400	-$ 24,400	-$ 24,346	-$ 225,392
													-
													-

Year Three	April	May	June	July	August	September	October	November	December	January	February	March	Totall
REVENUE													
Admissions and tours	-	2,838	14,189	42,567	48,243	21,284	10,642	2,128	-	-	-	-	141,891
Memberships	250	250	250	250	-	-	-	-	-	-	-	-	1,000
Giftshop	-	1,480	7,402	22,207	25,168	11,104	5,552	1,110	-	-	-	-	74,025
Annual gifts and donations	-	-	250	250	250	150	100	2,000	2,000	-	-	-	5,000
Rentals	334	384	384	334	334	334	384	385	334	334	334	385	4,262
Internet	-	96	482	1,446	1,639	723	362	72	-	-	-	-	4,821
Coin Operated Telescope	-	63	314	941	1,066	470	235	47	-	-	-	-	3,135
Total Revenue	$ 584	$ 5,111	$ 23,271	$ 67,998	$ 76,700	$ 34,065	$ 17,274	$ 5,743	$ 2,334	$ 334	$ 334	$ 385	$ 234,133
EXPENSES													
Staffing	15,786	24,141	26,926	29,711	26,926	29,711	26,940	21,356	15,786	15,786	15,786	15,786	264,641
Operations	18,293	4,385	4,385	4,385	4,385	4,385	4,385	4,385	4,385	4,385	4,385	4,384	66,530
Giftshop Cost of Sales & Supplies	-	814	4,071	12,214	13,843	6,107	3,054	611	-	-	-	-	40,714
Programming& Exhibitions	1,500	1,500	1,500	364	364	364	363	363	363	1,500	1,500	1,500	11,181
Curatorial	250	250	250	250	250	250	250	250	250	250	250	250	3,000
Marketing	3,793	3,793	3,793	3,793	3,793	3,793	3,793	3,793	64	64	64	64	30,600
Administration	5,001	5,001	5,001	5,001	5,001	5,001	5,001	5,001	5,001	5,001	5,001	5,001	60,015
Vehicle	-	3,263	343	343	343	343	343	172	-	-	-	-	5,151
Total Expenses	$ 44,624	$ 43,147	$ 46,270	$ 56,062	$ 54,905	$ 49,955	$ 44,129	$ 35,931	$ 25,050	$ 26,907	$ 26,907	$ 26,905	$ 481,831
Cash Surplus(Shortfall)	-$ 44,039	-$ 38,036	-$ 22,999	$ 11,934	$ 21,795	-$ 15,890	-$ 26,855	-$ 30,188	-$ 23,515	-$ 26,652	-$ 26,652	-$ 26,600	-$ 247,698

Appendix C Con't : Five-Year Cash Flow Projections

Year Four	April	May	June	July	August	September	October	November	December	January	February	March	Total
REVENUE													
Admissions and tours	-	3,278	16,388	49,164	55,719	24,582	12,291	2,458	-	-	-	-	163,879
Memberships	300	300	300	300	-	-	-	-	-	-	-	-	1,200
Giftshop	-	1,623	8,113	24,338	27,583	12,169	6,085	1,217	-	-	-	-	81,127
Annual gifts and donations	-	-	350	400	400	250	100	3,000	3,000	-	-	-	7,500
Rentals	439	489	489	439	439	489	489	489	439	439	439	436	5,513
Internet	-	106	530	1,591	1,803	795	398	80	-	-	-	-	5,303
Coin Operated Telescope	-	69	345	1,035	1,172	517	259	52	-	-	-	-	3,449
Total Revenue	$ 739	$ 5,864	$ 26,515	$ 77,266	$ 87,116	$ 38,803	$ 19,621	$ 7,295	$ 3,439	$ 439	$ 439	$ 436	$ 267,970
EXPENSES													
Staffing	16,102	24,625	27,466	30,307	27,466	30,307	27,466	21,787	16,102	16,102	16,102	16,102	269,934
Operations	18,659	4,473	4,473	4,473	4,473	4,473	4,473	4,473	4,473	4,473	4,473	4,473	67,861
Giftshop Cost of Sales & Supplies	-	892	4,462	13,386	15,171	6,693	3,347	669	-	-	-	-	44,620
Programming& Exhibitions	1,500	1,500	1,500	401	401	401	401	401	401	1,500	1,500	1,500	11,405
Curatorial	292	292	292	292	292	292	292	292	292	292	292	292	3,500
Marketing	3,864	3,864	3,864	3,864	3,864	3,864	3,864	3,864	75	75	75	75	31,212
Administration	5,101	5,101	5,101	5,101	5,101	5,101	5,101	5,101	5,101	5,101	5,101	5,101	61,215
Vehicle	-	3,327	350	350	350	350	350	176	-	-	-	-	5,254
Total Expenses	$ 45,510	$ 44,074	$ 47,508	$ 58,174	$ 57,117	$ 51,401	$ 45,293	$ 36,763	$ 26,444	$ 27,543	$ 27,543	$ 27,543	$ 495,001
Cash Surplus(Shortfall)	**-$ 44,779**	**-$ 38,210**	**-$ 20,993**	**$ 19,092**	**$ 29,999**	**-$ 12,678**	**-$ 25,672**	**-$ 29,468**	**-$ 23,005**	**-$ 27,104**	**-$ 27,104**	**-$ 27,107**	**-$ 227,031**

Year Five	April	May	June	July	August	September	October	November	December	January	February	March	Total
REVENUE													
Admissions and tours	-	3,605	18,023	54,070	61,279	27,035	13,517	2,703	-	-	-	-	180,233
Memberships	350	350	350	350	-	-	-	-	-	-	-	-	1,400
Giftshop	-	1,779	8,894	26,682	30,240	13,341	6,671	1,334	-	-	-	-	88,940
Annual gifts and donations	-	-	500	500	500	500	500	3,000	4,500	-	-	-	10,000
Rentals	593	593	643	593	593	643	643	643	593	593	593	643	7,366
Internet	-	117	583	1,750	1,983	875	437	87	-	-	-	-	5,833
Coin Operated Telescope	-	76	379	1,138	1,290	569	285	57	-	-	-	-	3,793
Total Revenue	$ 943	$ 6,519	$ 29,373	$ 85,083	$ 95,885	$ 42,963	$ 22,053	$ 7,825	$ 5,093	$ 593	$ 593	$ 643	$ 297,565
EXPENSES													
Staffing	16,424	25,118	28,016	30,914	28,016	30,914	28,014	22,220	16,424	16,424	16,424	16,424	275,332
Operations	19,032	4,562	4,562	4,562	4,562	4,562	4,562	4,562	4,562	4,562	4,562	4,561	69,218
Giftshop Cost of Sales & Supplies	-	970	4,092	14,675	16,632	7,330	3,669	734	-	-	-	-	40,917
Programming& Exhibitions	1,500	1,500	1,500	439	439	439	439	439	438	1,500	1,500	1,500	11,833
Curatorial	333	333	333	333	333	333	333	333	333	333	333	333	4,000
Marketing	3,929	3,930	3,929	3,930	3,929	3,929	3,930	3,930	100	100	100	100	31,836
Administration	5,203	5,203	5,203	5,203	5,203	5,203	5,203	5,203	5,203	5,203	5,203	5,203	62,440
Vehicle	-	3,394	357	357	357	357	357	179	-	-	-	-	5,359
Total Expenses	$ 46,422	$ 45,019	$ 48,793	$ 60,415	$ 59,472	$ 53,076	$ 46,508	$ 37,601	$ 27,061	$ 28,123	$ 28,123	$ 28,122	$ 508,735
Cash Surplus(Shortfall)	**-$ 45,479**	**-$ 38,500**	**-$ 19,420**	**$ 24,668**	**$ 36,413**	**-$ 10,113**	**-$ 24,455**	**-$ 29,776**	**-$ 21,968**	**-$ 27,530**	**-$ 27,530**	**-$ 27,479**	**-$ 211,169**

Appendix D: Capital Replacement Schedule

APPENDIX D: CAPITAL REPLACEMENT SCHEDULE

Additional Explanatory Notes to Capital Replacement Schedule

- **Architectural:**

The estimated useful life of these components is based on experience and has been compared to CSA Standard S478-95 Guideline on Durability in Buildings. Where there are discrepancies with the standard, the figures have been derived from industry publications. The building structure and foundations are assumed to have an indefinite lifespan, requiring little or no maintenance. CSA S478-95 describes the maintenance of these items as "little/none, significant if failure." They are designed to last for the anticipated service life of the building.

- **Mechanical:**

Plumbing, piping, valves and fittings, (including roof drains, floor drains, cleanouts, etc.) are expected to last the life of the building. Periodically valves will fail and/or leak; the water quality dictates the longevity of the piping systems.

- **Electrical:**

The life of electrical equipment is often triggered by a decision to add to, relocate or modify electrical elements, only to find that spare parts are no longer available. It is at this point that components are replaced simply because they cannot be modified to suit the new intent.

- **Site and Landscape:**

Signage with graphics (interpretive panels, warning or orientation signs, etc.) could be expected to have a lifespan of 5-10 years depending upon exposure to elements not including vandalism or other deliberate "weathering." Interpretive panels angled to the viewer (like drafting boards) have a shorter lifespan, 4 to 8 years, due to sun fading. Interpretive content may need to be refreshed from time to time aside from exposure deterioration.

Playground equipment could be expected to last 25-30 years although it is usually subject to periodic annual replacement of sections due to breakage, plough damage, etc.

Gravel roads will require annual mild re-grading and some additional new gravel to dress minor subsidence. This repair should not be significant if roads are not frequently used in winter and early spring. Paved parking areas and concrete surfaces should last 20-25 years with only minor repairs before needing resurfacing or other more significant repairs. Stone paved inlays and other specialized paving will require slightly more annual or bi-annual maintenance to prevent deterioration, but should last indefinitely if cared for properly and if minor repairs are carried out promptly.

Landscaping will require on-going maintenance and replacement of dead materials, in the area of 5-15% replacement per year (decreasing annually). Unlike building construction, which has progressively greater levels of maintenance as the building ages, site work has the greatest levels of maintenance in the first few years. After that point, plants are more established, more durable, larger (shadowing out weeds, etc.) and less susceptible to vandalism (larger, stouter limbs, etc.). Any minor subsidence that is going to appear in gravel roads or loose laid paving like stone will take place in 1-2 years and should be addressed at that point in order to prevent further deterioration or more expensive repairs.

- **Permanent Exhibits**

There are no set rules on determining the lifespan of permanent exhibits. Some require replacement within 7 years, while others last 20 years or more, depending on materials and levels of use. For the purposes of this capital replacement schedule, we have assumed a gradual replacement of permanent exhibits of a 10-20 year period.

Joggins Fossil Cliffs Interpretive Centre Capital Replacement Schedule									
					Replacement Period:				
		Yrs 1-5	**Yrs 6-10**	**Yrs 11-15**	**Yrs 16-20**	**Yrs 21- 25**	**Yrs 26- 30**	**Yrs 31- 40**	**Yrs 41- 50**
		$	$	$	$	$	$	$	$
Architectural									
Division 4	Re-point Stone Veneer Wall				80,000				
Division 5	Disassemble, move to new foundations, reassemble dugway tower								70,000
	Replace stair lowering motor		5,000						
	Replace lower stair				15,000				
Division 6	Replace dugway tower decking (larch/hemlock)								15,000
	Replace wood (larch/hemlock) siding								24,000
	Replace Hardiboard Siding								70,000
	Replace architectural millwork					60,000			
Division 7	Replace roof membrane and green roof material					220,000			
	Replace flashings						11,500		
Division 8	Replace aluminum curtain wall framing system								51,800
	Replace glazing units							28,500	
	(Assumes new glazing technology for energy savings)								
	Replace exterior steel and aluminum doors						33,500		
	Replace interior wood doors								36,500
Division 9	Replace carpet tile			4,600					
	Replace porcelain tiles								12,200
	Replace ceiling tiles								10,200
	Repaint interior walls		11,300						
	Replace glass floor panels			30,000					
Division 10	Replace washroom partitions						6,700		
	Replace moveable partitions						14,700		
	Replace food service counter closure						12,700		
	Replace fixed food service equipment								21,000
	Replace motorised food service equipment				15,100				
Mechanical	Grilles, Registers and Diffusers						8,000		
	Ductwork						70,000		
	Dampers						1,000		
	Centrifugal Fans					2,500			
	Rooftop Exhaust Fans				2,000				
	DX Coils				10,000				
	Electric Heating Coils				10,000				
	Air-Cooled Condensers/Heat Pumps				15,000				
	Molded Pipe Insulation				10,000				
	Base-Mounted Pumps				5,000				
	Pipe-Mounted Inline Pumps		5,000						
	Sump Pumps		2,000						
	Electric Motors				5,000				
	Electric Controls				5,000				
	Electronic Controls			50,000					
	SCR's (Electric Coils)			2,000					
	Electric Domestic Hot Water Heaters		700						
	Plumbing Fixtures							20,000	
	Plumbing Fixture Trim				5,000				
	Portable Fire Extinguishers			1,000					
	Electric Force Flow Heaters			2,000					
	Plumbing Piping							50,000	
	Sprinkler Heads & Piping							75,000	
Electrical	Lighting Fixtures						50,000		
	Wiring Devices (switches & receptacles)				20,000				
	Starters and Drives					5,000			
	Distribution Equipment					20,000			
	Dimming Equipment				10,000				
	Fire Alarm Equipment				15,000				
	Communications		15,000						
	Wire and Cable								30,000
Site and Landscape									
	Media signage	10,000							
	Interpretive panels- fabrication and installation		51,000		61,000		51,000	61,000	51,000
	NSDOT roadway signage					25,000			
	Playground Equipment					12,000			
	Rest area furnishings		6,000						
	Fencing		5,000						
	Paved parking/concrete surfaces					32,000			
Interpretation & Exhibit		-	332,667	332,667	332,667	-	99,800	329,340	568,860
CAPITAL REPLACEMENT REQUIRED PER EACH INDICATED PERIOD:		$ 10,000	$433,667	$ 422,267	$ 615,767	$ 376,500	$ 358,900	$ 563,840	$ 960,560
ACCUMULATED CAPITAL REPLACEMENT COST:		$ 10,000	$443,667	$ 865,933	$ 1,481,700	$ 1,858,200	$ 2,217,100	$ 2,780,940	$ 3,741,500
INDICATED ANNUAL CAPITAL RESERVE REQUIRED: $75,000									
ACCUMULATED CAPITAL RESERVE @$75,000 per year*:		$ 375,000	$750,000	$1,125,000	$ 1,500,000	$ 1,875,000	$ 2,250,000	$ 3,000,000	$ 3,750,000

Special Places Protection Act

CHAPTER 438

OF THE

REVISED STATUTES, 1989

amended 1990, c. 45; 1994-95, c. 17; 2004, c. 6, s. 31; 2005, c. 28

An Act to Provide for the Preservation, Regulation and Study of Archaeological and Historical Remains and Palaeontological and Ecological Sites

Short title

1 This Act may be cited as the Special Places Protection Act. *R.S., c. 438, s. 1.*

Purpose of Act

2 The purpose of this Act is to

(a) provide for the preservation, protection, regulation, exploration, excavation, acquisition and study of archaeological and historical remains and palaeontological sites which are considered important parts of the natural or human heritage of the Province;

(b) provide for the preservation, protection, regulation, acquisition and study of ecological sites which are considered important parts of the natural heritage of the Province and, notwithstanding the generality of the foregoing, preserve, regulate, acquire and study those ecological sites that

(i) are suitable for scientific research and educational purposes,

(ii) are representative examples of natural ecosystems within the Province,

(iii) serve as examples of ecosystems that have been modified by man and offer an opportunity to study the natural recovery of ecosystems from such modification,

(iv) contain rare or endangered native plants or animals in their natural habitats,

(v) provide educational or research field areas for the long-term study of natural changes and balancing forces in undisturbed ecosystems; and

(c) promote understanding and appreciation among the people of the Province of the scientific, educational and cultural values represented by the establishment of special places. *R.S., c. 438, s. 2.*

Interpretation

3 In this Act,

(a) "Committee" means the Advisory Committee on the Protection of Special Places;

(aa) "heritage object" means an archaeological, historical or palaeontological object or remain but does not include such an object to which the Treasure Trove Act applies;

(b) "Minister" means the member of the Executive Council assigned responsibility for this Act;

(c) "Museum" means the Nova Scotia Museum;

(d) "registered owner" means an owner of land whose interest in the land is defined and whose name is specified in an instrument in the registry of deeds, and includes a person shown as a tenant of land on the last revised assessment roll;

(e) "special places" means those places referred to in Section 2. *R.S., c. 438, s. 3; 1990, c. 45, s. 1; 2005, c. 28, s. 1.*

Act binds Crown

4 (1) This Act binds Her Majesty in right of the Province.

(2) repealed 1990, c. 45, s. 2.

R.S., c. 438, s. 4; 1990, c. 45, s. 2.

Advisory Committee on Protection of Special Places

5 (1) There is hereby established a committee to be known as the Advisory Committee on the Protection of Special Places.

(2) The Committee shall be appointed by the Minister and shall be composed of

(a) one person employed by the department for which the Minister has responsibility, who is the chair of the Committee;

(b) three persons who are representative of

(i) the Department of Environment and Labour,

(ii) the Department of Tourism, Culture and Heritage, and

(iii) the Department of Natural Resources; and

(c) up to six other persons who may include persons recognized as experts in fields pertinent to this Act and persons who represent aboriginal interests.

(3) Members of the Committee may be appointed for such terms as the Minister determines.

(4) repealed 2005, c. 28, s. 2.

(5) Members of the Committee shall be eligible for re- appointment.

(6) A member of the Committee shall not receive any remuneration for being a member thereof, but shall be reimbursed for actual expenses incurred in connection therewith. *R.S., c. 438, s. 5; 2005, c. 28, s. 2.*

Duties and powers

6 The Committee shall be responsible to the Minister and shall have power to

(a) make recommendations to the Minister concerning the administration, classification and acquisition of special places;

(b) conduct research with respect to existing and possible future special places;

(c) recommend regulations to the Minister with respect to management plans and other matters related to ecological sites;

(d) conduct research concerning the possible removal from designation of existing special places;

(e) ensure that, if a special places designation is being considered that appears to effect the operation of some other public Act, the persons charged with the administration of that Act have the opportunity to make representations to the Committee before any recommendations are made to the Minister;

(f) do any other thing which the Minister may assign the Committee with respect to assisting him in the proper administration of this Act. *R.S., c. 438, s. 6.*

Designation of protected site

7 (1) The Minister, with the approval of the Governor in Council, may designate any land within the Province, including land covered with water, that has outstanding archaeological, historical or palaeontological significance as a protected site.

(2) A designation made pursuant to subsection (1) shall contain a description of the land sufficient to identify it and a copy of the designation shall be deposited in the registry of deeds for the registration district in which the land is situated.

(2A) Every designation of a protected site shall be published in one edition of the Royal Gazette and the effective date of such designation shall be the date of the publication of the aforesaid designation in the Royal Gazette.

(2B) Such publication shall contain a description of the protected site sufficient to identify the boundaries of same.

(3) The Minister may place appropriate signs or other devices at a protected site indicating that the land is a protected site, but no sign or device is required to be placed at a site.

(4) Where the land to be so designated is privately owned,

(a) the Minister shall cause notice of the intention to designate to be served upon each registered owner not less than thirty days prior to designation;

(b) the owner may comment upon the proposed designation within the period of time specified by the Minister; and

(c) no person shall be entitled to any damages for compensation for injurious affection as a result of the designation of land or land covered with water. *R.S., c. 438, s. 7; 1990, c. 45, s. 3.*

Termination of designation

7A (1) Where it appears to the Committee that the continued designation of land as a protected site is inappropriate, the Committee may recommend to the Minister that the designation be terminated.

(2) Before making a recommendation pursuant to subsection (1), the Committee shall give notice of the proposed recommendation in a newspaper circulating in the Province giving at least thirty days for receipt by the Committee of written submissions by the public and, where the land is privately owned, the notice shall be served on the registered owner of the land.

(3) The Committee shall not make a recommendation pursuant to subsection (1) until thirty days following the deadline for receipt of written submissions pursuant to subsection (2).

(4) Upon receipt by the Minister of a recommendation pursuant to this Section to terminate a designation, the Minister may, with the approval of the Governor in Council, terminate the designation.

(5) Where the Minister terminates the designation of land, the Minister shall cause notice of the termination to be deposited in the registry of deeds for the registration district in which the land is situate and, where the land is privately owned, to be sent to the registered owner of the land. *1990, c. 45, s. 4.*

Heritage research permit

8 (1) No person shall carry out explorations or make excavations on any land in the Province, including land covered with water, for the purpose of seeking heritage objects, without a heritage research permit.

(2) The Minister, or a person authorized by the Minister, may issue heritage research permits authorizing archaeological, historical or palaeontological explorations and excavations in the Province.

(3) A heritage research permit shall be subject to the following:

(a) the application must be made on a form approved by the Minister;

(b) the applicant must be competent to conduct heritage research as proposed on the form provided;

(c) the permit holder must submit a report on the work done to the Minister within the time specified on the permit and in such detail as the Minister requires; and

(d) the permit holder must deliver possession of all heritage objects recovered, while excavating pursuant to the heritage research permit, to the Museum or to any other public institution which the Minister may designate, which objects become the property of the Province.

(4) Notwithstanding clause (d) of subsection (3), the Museum or other public institution designated by the Minister pursuant to said clause (d) may return any heritage object received to the person who recovered it, subject to such conditions as to the care and disposition of the object as the Museum or other institution, as the case may be, determines. *R.S., c. 438, s. 8; 1990, c. 45, s. 5.*

Effect of permit

9 A permit issued under this Act does not

(a) authorize the permit holder to enter upon lands or remove heritage objects therefrom without the consent of the owner or person entitled to grant consent; or

(b) relieve the permit holder from compliance with any enactment, regulation or law relating to excavations on land. *R.S., c. 438, s. 9.*

Cancellation of permit

10 The Minister may cancel a permit at any time and the permit shall, upon cancellation, cease to be in force. *R.S., c. 438, s. 10.*

Seizure of heritage object

11 Where a heritage object has been recovered from any site in the Province by a person who is not a holder of a permit or by a permit holder in contravention of his permit, the Minister or a person authorized by him may seize the heritage object and deliver it to the Museum, which object becomes the property of the Province. *R.S., c. 438, s. 11; 1994-95, c. 17, s. 1.*

Prohibition where no permit

12 Notwithstanding the issue of a licence pursuant to the Treasure Trove Act, no person shall

(a) excavate or otherwise alter a protected site or remove any objects from a protected site unless he is the holder of a permit;

(b) knowingly destroy, desecrate, deface or alter archaeological or historical remains or a palaeontological site whether designated or not unless he holds a heritage research permit to excavate the specific site. *R.S., c. 438, s. 12; 1990, c. 45, s. 6.*

Stop order

13 (1) When, in the opinion of the Minister, any special place, whether designated or not, is threatened with destruction by reason of commercial, industrial or other development or activity, the Minister may order the development or activity to cease in whole or in part for thirty days and, upon the recommendation of the Minister, the Governor in Council may continue the order until a site survey and, if necessary, a site investigation and salvage is carried out under the direction of the Museum.

(2) When such a development or activity is carried out by a government department or agency or a developer, the Governor in Council may require that funds be provided by that department, agency or developer to cover the costs of site survey, investigation and salvage.

(3) Where a site survey, investigation or salvage is ordered, it shall be carried out in such a manner that it will not cause undue hardship on the agency, owner or person responsible for the development or activity. *R.S., c. 438, s. 13; 1990, c. 45, s. 7.*

Designation of ecological site

14 (1) The Minister, with the approval of the Governor in Council, may on Crown land or on private land with the consent of the owner, including land covered with water, designate certain areas of the Province as ecological sites.

(2) The Minister may formulate a management plan for an ecological site at any time and may seek the assistance of the Committee when so doing.

(3) Every designation of an ecological site shall be published in one edition of the Royal Gazette and the effective date of such designation shall be the date of the publication of the designation in the Royal Gazette.

(4) Such publication shall contain a description of the ecological site sufficient to identify the boundaries of same.

(5) The Minister may place appropriate signs or other devices at an ecological site indicating that the land is a protected site, but no sign or device is required to be placed at a site.

(6) The ecological sites shall be designated by a description of the lands sufficient to identify them and such designation shall be registered as soon as possible by the Minister in the registry of deeds office for the registration district in which the lands are situated.

(7) Before the registration of the aforesaid designation, the Minister shall forthwith by registered mail give notice to the registered owner or owners of the lands so designated.

(8) A designation of an ecological site

(a) runs with the land to which it applies and binds all successors in title to the land or any estate in the land unless the designation is terminated pursuant to this Act; and

(b) is not affected by any tax deed conveying the land to which it applies.

(9) Subsection (8) applies to all designations of ecological sites whether made before or after the coming into force of that subsection. *R.S., c. 438, s. 14; 1990, c. 45, s. 8; 2004, c. 6, s. 31; 2005, c. 28, s. 3.*

Termination of designation

14A (1) Where it appears to the Committee that the continued designation of land as an ecological site is inappropriate, the Committee may recommend to the Minister that the designation be terminated.

(2) Before making a recommendation pursuant to subsection (1), the Committee shall give notice of the proposed recommendation in a newspaper circulating in the Province giving at least thirty days for receipt by the Committee of written submissions by the public and, where the land is privately owned, the notice shall be served on the registered owner of the land.

(3) The Committee shall not make a recommendation pursuant to subsection (1) until thirty days following the deadline for receipt of written submissions pursuant to subsection (2).

(4) Upon receipt by the Minister of a recommendation pursuant to this Section to terminate a designation, the Minister may, with the approval of the Governor in Council, terminate the designation.

(5) Where the Minister terminates the designation of land, the Minister shall cause notice of the termination to be deposited in the registry of deeds for the registration district in which the land is situate and, where the land is private land, to be sent to the registered owner of the land. *1990, c. 45, s. 9.*

Management of designated Crown land

15 Crown lands designated as ecological sites shall be under the administration and control of the Minister. *R.S., c. 438, s. 15.*

Ecological research permit

16 (1) The Minister, or a person authorized by the Minister, may issue ecological research permits authorizing ecological research or other ecological activities within the designated ecological sites.

(2) Such permits so issued shall be subject to the following:

(a) an application for a permit must be made on a form approved by the Minister;

(b) the applicant must be competent to conduct ecological research or other ecological activities as proposed on the form provided;

(c) the permit holder must submit a report on the work done or activities carried on to the Minister within the time specified on the permit; and

(d) the permit may be made subject to such conditions as the Minister, or a person authorized by the Minister, may prescribe in order to protect the designated ecological site or some part thereof from any such proposed research or activities, and, if the lands are privately held, such research or activities must be carried on with the written consent of the landowner.

(3) The Minister may cancel the permit at any time and the permit shall, upon cancellation, cease to be in force. *R.S., c. 438, s. 16; 1990, c. 45, s. 10.*

Ecological research permit

17 After the designation of an ecological site, no person shall carry on any activity which may alter any part of the terrain or of the vegetation or carry on any acts which may disturb the fauna or the flora within the designated site, unless such person has first obtained an ecological research permit from the Minister, or a person authorized by the Minister. *R.S., c. 438, s. 17; 1990, c. 45, s. 11.*

Prohibition on disposal or grant of rights

18 (1) The Province, upon the designation of an ecological site upon Crown lands, and notwithstanding the provision of any other special or general statute, shall not grant, lease or otherwise dispose of lands that comprise such a site.

(2) Any grant of the Province of any rights under any other statute, including, but not so as to restrict the generality thereof, the mining rights, fishing and game rights, forestry rights and water rights, shall be forbidden on any ecological site designated and any grant purported to be made shall be null and void. *R.S., c. 438, s. 18.*

Restriction on expropriation

19 Notwithstanding any general or special Act, including the provisions of the Expropriation Act, no expropriation power can be exercised within the limits of a designated ecological site without the express authorization of the Minister, in addition to any other authorization necessary to carry out such expropriation power. *R.S., c. 438, s. 19.*

Regulations

20 (1) The Governor in Council, upon the recommendation of the Minister, may make regulations for the protection, preservation and use of special places on Crown lands and with respect to special places on private lands with the further consent of the landowner and, generally and without restricting the generality thereof, may make regulations

(a) establishing management plans for designated ecological sites;

(b) for the classification of ecological sites and the uses to which each classification can be put;

(c) for the control of entry onto a special place and the control of activities within such places;

(d) respecting the control, regulation, restriction or prohibition of any kind of use, development or occupation of the land or of any of the natural resources in a special place;

(e) respecting the sign, plaques and markers to be placed at a special place;

(f) determining measures, including financial incentives, to encourage the identification, preservation and protection of special places;

(g) respecting generally any other matter or thing necessary or incidental to the protection of special places.

(2) The exercise by the Governor in Council of the authority set forth in this Section shall be regulations within the meaning of the Regulations Act. *R.S., c. 438, s. 20; 1990, c. 45, s. 12.*

Service of notice

21 (1) Service of any notice required to be made by this Act shall be sufficient if served upon the person by registered mail at his last known address.

(2) Where a person upon whom service should be made cannot be identified or his address is not known, service shall be sufficient if notice is affixed in a

conspicuous place on the land and a copy is delivered to any occupant of the land. *R.S., c. 438, s. 21.*

Offence and penalty

22 (1) Every person who contravenes any provision of this Act or who, being the holder of a permit, fails to comply with any term or condition of any permit issued under this Act is guilty of an offence and is liable on summary conviction to a penalty not exceeding ten thousand dollars.

(2) Where a corporation is convicted of an offence against this Act, the maximum penalty that may be imposed upon the corporation is one hundred thousand dollars and not as provided in subsection (1). *R.S., c. 438, s. 22; 1990, c. 45, s. 13.*

Existing designations and permits preserved

23 Notwithstanding the repeal of the former Historical Objects Protection Act, every designation made and permit issued under that Act remains good and valid. *R.S., c. 438, s. 23.*

Joggins Fossil Cliffs Protected Site Designation

made under Section 14 of the

Special Places Protection Act

R.S.N.S. 1989, c. 438

N.S. Reg. 53/2006

In the matter of Chapter 8 of the Acts of 1970,

the *Historical Objects Protection Act*

- and -

In the matter of the designation of the certain lands at or near Joggins in the County of Cumberland and Province of Nova Scotia as a Protected Site

Whereas Section 2 of Chapter 8 of the Acts of 1970, the *Historical Objects Protection Act* provides that the Minister of Education may designate any land within the Province that has archeological, historical or palaeontological significance as a protected site.

And whereas that certain piece or area of land commonly known as the Fossil Cliffs, situate and being at or near Joggins in the County of Cumberland and Province of Nova Scotia is land having such significance.

Now therefore pursuant to the power vested in me by Section 2 of the *Historical Objects Protection Act*, I, the undersigned Minister of Education, do hereby designate as a protected site under the said *Historical Objects Protection Act* that certain piece or area of land commonly known as the Fossil Cliffs, situate and being at or near Joggins, in the County of Cumberland and Province of Nova Scotia, and being more particularly described as follows:

Beginning at point “A” on the ordinary high water line of Chignecto Bay, said point being a distance of fifteen hundred feet northerly and in a direct line from the intersection of the north wall of the government wharf at Joggins, with the aforementioned ordinary high water line of Chignecto Bay;

From thence easterly in a direct line to point “B” on the crest of the Fossil Cliffs so-called;

Thence in a northeasterly direction to point “C”, five thousand two hundred eighty feet, along the crest line of the aforementioned Fossil Cliffs so-called;

Thence westerly in a direct line up to point “D” on the ordinary high water line of Chignecto Bay;

Thence southwesterly along the ordinary high water line of Chignecto Bay to the place of beginning as shown on Plan No. E-5-4 recorded in the Crown Land Records Office, Department of Lands and Forests, Halifax, Nova Scotia, a copy of which is annexed hereto, and marked Schedule “A”.

Sgd.: *Peter Nicholson*

Feb 24/1972

Minister of Education

Schedule “A”

[The plan contained in Schedule “A” is not available in this format. Contact the Registry of Regulations for more information or to obtain a copy.]

Beaches Act

CHAPTER 32

OF THE

REVISED STATUTES, 1989

amended 1993, c. 9, s. 9

An Act to Preserve and Protect the Beaches of Nova Scotia

Short title

1 This Act may be cited as the *Beaches Act.* R.S., c. 32, s. 1.

Dedication of beaches

2 (1) The beaches of Nova Scotia are dedicated in perpetuity for the benefit, education and enjoyment of present and future generations of Nova Scotians.

Purpose of Act

(2) The purpose of this Act is to

(a) provide for the protection of beaches and associated dune systems as significant and sensitive environmental and recreational resources;

(b) provide for the regulation and enforcement of the full range of land-use activities on beaches, including aggregate removal, so as to leave them unimpaired for the benefit and enjoyment of future generations;

(c) control recreational and other uses of beaches that may cause undesirable impacts on beach and associated dune systems. R.S., c. 32, s. 2.

Interpretation

3 In this Act,

(a) "beach" means that area of land on the coastline lying to the seaward of the mean high watermark and that area of land to landward immediately adjacent thereto to the distance determined by the Governor in Council, and includes any lakeshore area declared by the Governor in Council to be a beach;

(b) "Minister" means the Minister of Lands and Forests;

(c) "peace officer" includes a member of the Royal Canadian Mounted Police, a police officer appointed by a city, incorporated town or municipality of a county or district and a conservation officer as defined in the *Crown Lands Act, Forests Act* and *Wildlife Act*;

(d) "vehicle" means a vehicle propelled or driven otherwise than by muscular power, whether or not the vehicle is registered pursuant to the *Motor Vehicle Act*, and includes an airplane;

(e) "vessel" means a means of conveyance of a kind used on water and includes an accessory to the vessel. R.S., c. 32, s. 3.

Administration

4 (1) The administration, management and control of beaches shall be under the direction of the Minister.

Natural Resources Advisory Council

(2) The Minister may refer matters relating to beaches to the Natural Resources Advisory Council established pursuant to the *Natural Resources Advisory Council Act* and the Council shall advise the Minister on such matters.

Other services

(3) The Minister may utilize, upon such terms and conditions as the Minister deems fit, the services of such persons as the Minister considers necessary for the efficient carrying out of the purpose of this Act and the regulations.

Agreements

(4) The Minister may, for the effective management of beaches, enter into agreements with the Government of Canada or an agency thereof, with a provincial or municipal government or an agency thereof or with a person for the purposes of this Act or the regulations.

Agreements to manage or preserve land

(5) Without restricting the generality of subsection (4), the Minister may enter into an agreement with the owner or occupier of land adjacent to a beach to manage or preserve that land so that it complements the beach.

Acquisition of land

(6) The Minister, with the consent of the Governor in Council, may acquire land or an interest in land to provide public access to and from a beach and to provide facilities there.

Authorized services

(7) The Minister may authorize lifeguard and other services on a beach.

Studies and research

(8) The Minister may undertake studies and carry out research on beaches in the Province.

Educational programs

(9) In an effort to create greater public awareness and understanding of the beaches in the Province, the Minister may promote educational programs that emphasize the importance of conserving beaches and using them for recreational and other purposes in such a manner as to maintain their environmental integrity. R.S., c. 32, s. 4; 1993, c. 9, s. 9.

Determination of beach area

5 (1) The Governor in Council, on the recommendation of the Minister, may determine what area of land to the landward of mean high watermark and immediately adjacent thereto and what lakeshore area is a beach within the meaning of this Act.

Notice of beach area

(2) When the Governor in Council determines pursuant to subsection (1) that an area of land to the landward of mean high watermark is a beach, the Minister shall

(a) publish a notice containing a description of the beach in the Royal Gazette and in a newspaper circulated in the county or counties to which the beach is contiguous;

(b) deposit a description and plan of the beach in the office of the registrar of deeds for the registration district in which the beach is situate, signed either by him or the Deputy Minister of Lands and Forests or by a Nova Scotia Land Surveyor;

(c) give notice to the owner of the beach if the owner is known, by serving upon him or by mailing by registered post addressed to him at his last known place of abode, a notice containing a description of the beach and notifying him that the beach is a beach under this Act; and

(d) post signs about the beach indicating that it is a beach and that no sand, gravel, stone or other material may be removed from it without the consent of the Minister.

Evidence of sign as prima facie proof

(3) Evidence that a sign has been posted is *prima facie* proof that the sign has been posted pursuant to clause (d) of subsection (2).

Certified description as prima facie proof

(4) A description and plan of a beach, appearing to be certified by the Minister or the Registrar of Crown Lands appointed pursuant to the *Crown Lands Act*, shall be received as evidence without proof of the signature of the Minister or Registrar of Crown Lands and the designation of any lands on the plan as a beach is *prima facie* proof that the lands so designated are a beach. R.S., c. 32, s. 5.

Prohibited removal of sand

6 (1) No person shall wilfully take or remove any sand, gravel, stone or other material from a beach without the permission of the Minister.

Ballast for lobster pot

(2) Nothing in this Section shall prevent or restrict a fisherman from removing from a beach rocks for ballast for his lobster pots. R.S., c. 32, s. 6.

Powers of peace officer

7 (1) A peace officer may

(a) search without a warrant and seize a vehicle including an off-highway vehicle, vessel or other property where the peace officer has reasonable and probable grounds to believe that an offence has been committed pursuant to this Act or any other enactment, if the offence is committed on a beach, and may detain the same for a period not exceeding twenty-four hours where the peace officer has reasonable and probable grounds to believe the seizure and detention is necessary to prevent the continuation or repetition of the offence;

(b) order a person removing or displacing sand, gravel, stone or other material from a beach without a permit or lawful authorization to return it to the general area from where it was removed;

(c) arrest without warrant a person a peace officer finds committing an offence pursuant to this Act or the regulations or any other enactment if the offence is committed on a beach;

(d) exercise all the powers of a peace officer as defined in the *Criminal Code* (Canada).

Costs of impounding and storing

(2) Where a vehicle, vessel or other property is seized and detained pursuant to this Act, the costs of impounding and storing it shall be paid by the person to whom the seized property is to be released before it is released.

Duty of registered owner to identify operator

(3) Where the registered owner of the seized property wilfully fails to identify the person in charge of the vehicle or vessel at the time at which it is operated in violation of a provision of this Act or the regulations within forty-eight hours of a demand by a peace officer, the registered owner is guilty of an offence.

Liability of registered owner

(4) The registered owner of a vehicle or vessel is liable to incur the penalties provided for a violation of this Act or the regulations unless, at the time of the violation, the vehicle or vessel was in the possession of a person without the registered owners consent, either expressed or implied.

Presence of registered owner

(5) Where the registered owner of a vehicle or vessel is present on or in the vehicle or vessel at the time of the violation of a provision of this Act or the regulations by another person operating that vehicle or vessel, the registered owner, as well as the operator, is guilty of the offence.

Summary Proceedings Act

(6) Where not inconsistent with this Act, the *Summary Proceedings Act* and forms authorized thereunder applies *mutatis mutandis* to all prosecutions and proceedings pursuant to this Act.

Offence

(7) Any person who fails to comply with an order made pursuant to clause (b) of subsection (1) is guilty of an offence. R.S., c. 32, s. 7.

Prohibited activities

8 (1) No person shall, while on a beach,

(a) be impaired by alcohol or drugs;

(b) act in a noisy or disorderly manner;

(c) create a disturbance;

(d) pursue a course of conduct that is detrimental to the safety of other beach users or their enjoyment of the beach and its facilities;

(e) wilfully destroy property and other natural resources found on or adjacent to a beach;

(f) dump or deposit garbage or other material on a beach other than in a receptacle so provided;

(g) engage in any other activity prohibited by regulation.

Order by Minister

(2) Where there is reasonable and probable grounds to believe that a person has violated or is about to violate any provision of this Act or the regulations, or that the entry upon or remaining within a beach by any person may be detrimental to the safety of other beach users or their enjoyment of the beach, the Minister or a person authorized to act on the Ministers behalf may, without notice or hearing, issue a verbal or written order prohibiting that person from entering upon or being within a beach specified in the order for a period specified therein.

Duty to observe order

(3) Any person having knowledge of an order made pursuant to subsection (2) shall observe that order, and in the event the person is within a beach when the order is made, shall leave forthwith. R.S., c. 32, s. 8.

Offence

9 Every person contravening any provision of this Act or of the regulations shall be guilty of an offence, and every violation in connection with a separate taking

or removing of sand, gravel, stone or other material from a beach shall be a separate offence. R.S., c. 32, s. 9.

Penalty

10 (1) Any person who violates this Act is liable upon summary conviction to a penalty of not more than two thousand dollars and in default of payment thereof to imprisonment for not more than ninety days.

Additional orders

(2) In addition to any penalty imposed, the court may order a person convicted of an offence pursuant to this Act to restore the beach as nearly as possible to the condition it was in before the offence was committed and pay an amount equal to twice the market value of any aggregate or other property, damaged or removed. R.S., c. 32, s. 10.

Permission for removal of sand

11 The Minister, upon such terms and conditions as the Governor in Council from time to time prescribes, may grant permission for the removal of sand, gravel, stone or other material from a beach. R.S., c. 32, s. 11.

No compensation entitlement

12 No person affected by this Act shall be entitled to compensation for any restriction, encumbrance or use or lack of use, of any nature or kind whatsoever, of a beach that may result or results from the enacting of this Act. R.S., c. 32, s. 12.

Regulations

13 The Governor in Council may make regulations

(a) for the preservation, control and management of beaches;

(b) for the granting of leases, licences and permits authorizing the removal of sand, gravel, stone or other material from beaches and determining the fees and charges for such leases, licences and permits;

(c) providing for the removal from a beach, by specified persons or persons in specified trades or occupations, of quantities of sand, gravel, stone or other material in such amount as he determines;

(d) exempting any beach from the operation of this Act and the regulations hereto;

(e) to preserve and protect flora and fauna located on a beach;

(f) to restrict or regulate traffic by vehicles, vessels or pedestrians on a beach;

(g) to restrict or regulate certain activities on a beach;

(h) to prevent the disposal of garbage on a beach;

(i) prescribing a minimum penalty of not less than fifty dollars and a maximum penalty of not more than two thousand dollars for offences contrary to the regulations;

(j) respecting the management or preservation of lands adjacent to a beach in accordance with an agreement made pursuant to Section 4 or where the lands are owned or occupied by Her Majesty in right of the Province;

(k) defining any word or expression used in this Act but not defined herein;

(l) respecting such other matters as he deems necessary for the carrying out of the intent and purposes of this Act. R.S., c. 32, s. 13.

Regulations Act

14 The exercise by the Governor in Council of the authority set forth in Section 13 shall be regulations within the meaning of the *Regulations Act*. R.S., c. 32, s. 14.

Beaches Regulations

made under Section 13 of the
Beaches Act
R.S.N.S. 1989, c. 32
O.I.C. 89-580 (May 16, 1989), N.S. Reg. 70/89
as amended by O.I.C. 2004-138 (March 30, 2004, effective April 1, 2004), N.S. Reg. 47/2004

Citation
1 These regulations may be cited as the "Beaches Regulations".

Definitions
2 In the Act and these regulations

(a) "Act" means the *Beaches Act*;

(b) "beach attendant" means a person appointed pursuant to Section 3;

(c) "develop" means the construction of a path, trail or road on a beach or the erection or placement on a beach of a building, structure or other manmade feature not indigenous to the site;

(d) "Department" means the Department of ~~Lands and Forests~~ [Natural Resources];

(e) "Minister" means the Minister of ~~Lands and Forests~~ [Natural Resources];

(f) "mean high water mark" means

(i) the line on the seashore reached by the average of the mean high tides of the sea between the spring and neap tides in each quarter of a lunar revolution during the year excluding only extraordinary catastrophes or overflows, or

(ii) the line on the shore of a lake or river usually reached by the water after the great flow of the spring has abated and the lake or river is in its ordinary state, and

(iii) for the purposes of determining the boundaries of a parcel of land at a place in respect to which there is no record of tides extending at least over one year, the visible high water mark, that is, the point fixed by signs on the ground such as the state of vegetation and accumulation of debris;

(g) "structure" includes a building, camp, trailer, tent, houseboat, raft, wharf, post, fence or wall.

Administration
3 The Minister may appoint a person, including a casual employee of the Department, as a beach attendant to perform on one or more beaches such duties as may be assigned from time to time by the Department.

Management of lands adjacent to a beach
4 The Minister may enter into a management agreement with the owner or occupier of land adjacent to a beach.

Removal of beach aggregate
5 (1) The Minister may issue a permit to a person for the removal for personal or domestic purposes approved by the Department of sand, stone or other material from a beach, provided the permit states

(a) the purpose for which the material is to be used;

(b) the amount of material to be removed;

(c) the type of material to be removed;

(d) the location from which the material is to be removed;

(e) the means by which the material is to be removed;

(f) the period of time during which the material is to be removed; and

(g) the condition in which the beach is to be left after the material is removed.

(2) The fee to be charged by the Minister for a permit for the removal of sand, gravel, stone or other material from a beach shall be as follows:

(i) an administration fee of $20.00 for 10 cubic yards or less when used for personal or domestic purposes approved by the Department,
Clause 5(2)(i) amended: O.I.C. 2004-138, N.S. Reg. 47/2004.

(ii) an administration fee of $20.00 plus a charge of $.50 per cubic yard/$.65 per cubic metre or $.34 per ton/$.37 per tonne for more than 10 cubic yards when used for personal or domestic purposes.
Clause 5(2)(ii) amended: O.I.C. 2004-138, N.S. Reg. 47/2004.

Development of a beach
6 No person shall develop a beach without the prior written authorization and approval of the Minister.

Restricted activities
7 Except as provided in the Act or with a permit from the Minister, no person shall, while on a beach,

(a) wilfully remove, deface or injure any natural object, tree, shrub, plant or grass;

(b) wilfully remove, deface, damage or destroy a signboard, sign or notice placed on a beach or adjacent to a beach;

(c) wilfully remove or displace any rock, mineral, fossil, sand, gravel or other aggregate or object of natural curiosity or interest;

(d) display a sign or advertisement;

(e) sell or offer for sale an article or service or thing or carry on a business;

(f) alter, damage or destroy any watercourse; or

(g) leave a fire unattended until it is completely extinguished.

Domestic animals
8 (1) No person who owns or is in control of a domestic animal shall permit it to be at large on a beach where a sign or notice is posted by the Department that domestic animals are to be kept on a leash.

(2) For the purpose of subsection (1), a domestic animal is deemed to be at large unless the animal is on a leash which does not exceed six feet in length and which is hand-held or securely tied and restricts the animal from running loose.

(3) Except with a permit from the Minister, which will prescribe appropriate restrictions relative to time, area and conditions, no person shall ride or walk a horse on a beach.

(4) No person who owns or is in control of a domestic animal shall fail to clean up any animal excrement or mess left on a beach by that animal.

Vehicles
9 (1) Except with a permit from the Minister, it shall be an offence to have or use a vehicle on a beach.

(2) Subsection (1) does not apply to a vehicle used to launch a vessel on a beach.

Vessels
10 Except with a permit from the Minister, no person shall operate a vessel in

excess of five miles per hour within 200 feet of a beach when another person is known by the operator of the vessel to be present on the beach.

Production of permit
11 Every person issued a permit under the Act or [these] regulations shall produce the same for inspection when requested to do so by the Minister, a peace officer or beach attendant.

Signs/notices
12 (1) The Minister may cause to be marked or erected a sign, notice, map or other device to permit, restrict or prohibit an activity on a beach.

(2) It shall be an offence for a person to fail to comply with a sign, notice, map or other device erected pursuant to subsection (1).

Penalty
13 A person convicted of any violation of the[se] regulations shall incur a penalty of not less than fifty dollars nor more than two thousand dollars.

Repeal of old regulations
14 Regulations made by Order in Council 76-622 dated the 25th of May, 1976, are rescinded as and from the 17th day of May, 1989.

Effective date of new regulations
15 These regulations shall come into force on and after the 17th day of May, 1989.

Mineral Resources Act

CHAPTER 18

OF THE

ACTS OF 1990

amended 1992, c. 14, s. 61; 1992, c. 37, ss. 1, 2; 1994, c. 36; 1995-96, c. 8, s. 20; 2001, c. 6, s. 118; 1999 (2nd Sess.), c. 12

Mineral Resources Act

Short title

1 This Act may be cited as the Mineral Resources Act. *1990, c. 18, s. 1.*

Purpose of Act

1A The purpose of this Act is to support and promote responsible mineral resource management consistent with sustainable development while recognizing the following goals:

(a) providing a framework for efficient and effective mineral rights administration;

(b) encouraging, promoting and facilitating mineral exploration, development and production;

(c) providing a fair royalty regime; and

(d) improving the knowledge of mineral resources in the Province. *1999 (2nd Sess.), c. 12, s. 1.*

Interpretation

2 In this Act,

(a) "assessment work" means bona fide work that conforms to the regulations and is submitted for credit as work to prove the existence, extent and value of a mineral deposit and includes work carried out pursuant to a special licence;

(aa) "assessment work report" means a report respecting assessment work or a prospector's statement;

(ab) "bulk sampling" means the obtaining of a sample of mineral-bearing material for the purpose of developing a suitable method of mining or treatment and includes grade and reserve estimation, metallurgical testing, product testing and market evaluation;

(b) "claim" means a claim of forty acres or 16.188 hectares, more or less, applied for or held in accordance with this Act;

(c) "Crown" means Her Majesty in right of the Province;

(d) "Crown lands" means lands that are Crown lands within the meaning of the Crown Lands Act;

(e) "Department" means the Department of Natural Resources;

(f) "Deputy Minister" means the Deputy Minister of Natural Resources;

(g) "excavation registration" means a registration submitted pursuant to Section 101;

(h) "exploration licence" means a licence by which the holder thereof is granted, pursuant to Section 28, the right to search and prospect for minerals within an area designated in the licence;

(ha) "geothermal resource" means a substance, including steam, water and water vapour, that is found anywhere below the surface of the earth and that derives an added value from the natural heat of the earth present in, resulting from or created by the earth;

(hb) "geothermal resource area" means an area designated by the Governor in Council pursuant to this Act;

(i) "holiday" includes a day or portion of a day designated pursuant to the Civil Service Act as a holiday;

(j) "lease" means a mineral lease granted pursuant to Section 56 or a special lease granted pursuant to Section 22;

(k) "legal representative" means the executor, administrator, guardian, trustee, liquidator, receiver or other person upon whom an interest in a mineral right has devolved by operation of law, legal process or order of a court of competent jurisdiction;

(l) "lessee" means the holder of a lease or the legal representative acting on behalf of the holder;

(la) "letter of authorization" means an authorization granted pursuant to Section 102;

(m) "licence" means an exploration licence or special licence;

(n) "licensee" means the holder of an exploration licence or a special licence;

(o) to (q) repealed 1999 (2nd Sess.), c. 12, s. 2.

(r) "mine" does not include bulk sampling but does include

(i) an opening upon, or excavation in, or working of, the ground for the purpose of mining, opening up or proving a mineral, gypsum, limestone or mineral-bearing substance,

(ii) an ore body, mineral deposit, stratum, soil, rock, stone, bed or earth, clay, sand, gravel or place where mining is being or may be carried on,

(iii) the ways, works, machinery, plant, bunkhouses, cook-houses, latrines, wash-houses and other buildings, structures and roadways below or above ground belonging to or used in connection with a mine, and

(iv) a quarry, excavation or opening in the ground made for the purpose of searching for, or removal of, a mineral, gypsum, limestone or mineral-bearing substance that, for the purpose of this Act, is taken as such;

(s) "mineral" means a natural solid inorganic or fossilized organic substance and a substance prescribed to be a mineral, but does not include

(i) ordinary stone, building stone or construction stone,

(ii) sand, gravel, peat, peat moss or ordinary soil,

(iii) gypsum,

(iv) limestone, except that which is vested in the Crown, and

(v) oil or natural gas,

unless declared to be a mineral by the Governor in Council;

(sa) "mineral lease" means a mineral lease issued pursuant to Section 56;

(t) "mineral right" means a licence or lease;

(u) "mineral right holder" means a person whose name appears in the records of the Registrar as having a mineral right;

(v) "mining" includes a method of working whereby the soil, earth, rock, stone, mineral, gypsum, limestone or a mineral-bearing substance may be disturbed, whether previously disturbed or not, or removed, washed, sifted, roasted, smelted, refined, crushed, dissolved, precipitated, separated or dealt with for the purpose of obtaining a mineral, gypsum or limestone for sale or barter;

(va) to (x) repealed 1999 (2nd Sess.), c. 12, s. 2.

(y) "Minister" means the Minister of Natural Resources;

(ya) "non-mineral registration" means a registration pursuant to subsection (2) of Section 90;

(z) "officer" includes the Registrar, an engineer, geologist in the public service and a person designated by the Minister to carry out an inspection, investigation or other function pursuant to this Act;

(aa) "peace officer" means a peace officer as defined in the Criminal Code (Canada);

(ab) and (ac) repealed 1999 (2nd Sess.), c. 12, s. 2.

(ad) "person" includes a partnership or a company;

(ae) "prescribed" means prescribed by the regulations;

(af) "private land" means all land other than Crown land;

(ag) repealed 1999 (2nd Sess.), c. 12, s. 2.

(ah) "production" means the winning, taking or carrying away for sale or exchange of a mineral, mineral-bearing substance, gypsum, limestone, tailings or any product thereof, except for the purpose of assaying, sampling or metallurgical testing;

(ai) "record" means a book, map, chart, plan, file and a micrographic, electronic or other storage means for recording events, transactions, documents or information;

(aia) "registrant" means the holder of a non-mineral registration;

(aj) "Registrar" means the Registrar appointed pursuant to this Act;

(aja) "safe" and "safety" means public safety but does not include occupational health and safety;

(ak) "special lease" means a special lease issued pursuant to Section 22;

(al) "special licence" means a special licence issued pursuant to Section 22;

(am) "surface rights permit" means a permit issued pursuant to this Act authorizing entry upon, or passage over, specified private lands;

(an) "tailings" means the residue discarded, set aside or impounded during production;

(ao) "tract" means mineral tract comprising sixteen claims, as prescribed;

(ap) "work credit" means credit given for assessment work performed upon a licence. *1990, c. 18, s. 2; 1992, c. 14, s. 61; 1992, c. 37, s. 1; 1994, c. 36, s. 1; 1999 (2nd Sess.), c. 12, s. 2.*

Application of Act

3 This Act applies to every person who searches and prospects for, mines or produces a mineral, or any substance declared, pursuant to Section 5, to be a mineral, and to every person specifically mentioned herein, including a person who produces gypsum or limestone. *1990, c. 18, s. 3.*

Title to minerals

4 (1) All minerals are reserved to the Crown and the Crown owns all minerals in or upon land in the Province and the right to explore for, work and remove those minerals.

(2) Every grant of Crown lands made on or after the twenty-second day of April, 1910, shall, whether the same is so expressed therein or not, be construed and held to reserve to the Crown all the minerals in or upon the land so granted and the right to explore for, work and remove those minerals.

(3) Every grant of Crown lands made at any time on or before the twenty-second day of April, 1910, shall, whether the same is so expressed therein or not, and notwithstanding the provisions of such conveyance or of any enactment or law, be construed and held to have reserved to the Crown all the minerals in or upon the land so granted and the right to explore for, work and remove those minerals.

(4) Every person who has acquired Crown lands by conveyance or prescription is deemed not to have acquired the minerals in or upon the Crown lands or the right to explore for, work and remove those minerals and no person is entitled to acquire minerals or such right by conveyance or prescription. *1990, c. 18, s. 4.*

Declaration as mineral

5 (1) Where it is made to appear to the Governor in Council that a non-living substance formed by the processes of nature that occurs on or under the surface of the earth

(a) has a higher economic value or use than that to which it has formerly been put;

(b) that had formerly been classified as gypsum, limestone or building material, has a higher economic value or use than has gypsum, limestone or building material; or

(c) should in the public interest be treated as a mineral,

the Governor in Council may, by regulation, declare the substance or any deposit of it to be a mineral.

(2) A copy of a declaration made pursuant to subsection (1) shall be published in the Royal Gazette and in such other manner as the Governor in Council directs.

(3) A regulation made pursuant to subsection (1) may apply to all lands or such lands as may be prescribed. *1990, c. 18, s. 5.*

Consequences of declaration

6 Where the Governor in Council has made a declaration pursuant to clause (b) of subsection (1) of Section 5, the substance or the deposit of the substance referred to in the regulation is deemed, for the purposes of this Act and the Crown Lands Act, always to have been a mineral, notwithstanding the terms of any grant from the Crown or any conveyance, instrument, enactment or law. *1990, c. 18, s. 6.*

Former owner's rights

7 Where the Governor in Council has made a regulation pursuant to subsection (1) of Section 5, the person who, but for the regulation was the owner of the substance, has the right during the period of six months immediately following the publication of the regulation, in priority to all other persons, to apply for and obtain a mineral right pursuant to this Act for, or with respect to, the substance. *1990, c. 18, s. 7.*

Application for compensation

8 (1) A person engaged in mining activities regulated pursuant to this Act and claiming an interest in a substance declared to be a mineral pursuant to Section 5 may apply for compensation to the Expropriations Compensation Board and is subject to the provisions of the Expropriation Act.

(2) No compensation shall be paid in respect of an application pursuant to subsection (1) made one year from the date a regulation is made pursuant to Section 5. *1990, c. 18, s. 8.*

Geothermal resource area

8A (1) The Governor in Council may

(a) designate areas to be known as geothermal resource areas;

(b) determine that Section 4 applies to the geothermal resources in a geothermal resource area as if the geothermal resources were a mineral and may further determine which other provisions of this Act apply to geothermal resources in those areas;

(c) modify a provision of this Act to permit its application to geothermal resources;

(d) generally adapt the provisions of this Act to existing circumstances with respect to geothermal resources in geothermal resource areas.

(2) Where, pursuant to subsection (1),

(a) an area is designated as a geothermal resource area and Section 4 is determined to apply to the geothermal resources in a geothermal resource area as if the geothermal resources were a mineral; or

(b) there is a modification or adaptation of any other provision of this Act with respect to a geothermal resource in a geothermal resource area,

no person affected by the designation, determination, modification or adaptation shall be entitled to compensation of any nature or kind whatsoever.

(3) The exercise of the authority contained in subsection (1) shall be regulations within the meaning of the Regulations Act. *1992, c. 37, s. 2.*

Supervision of Act and regulations

9 The Minister has the general supervision and management of this Act and the regulations. *1990, c. 18, s. 9.*

Personnel

10 (1) Such persons as are necessary for the administration of this Act and the regulations shall be appointed in accordance with the Civil Service Act.

(2) Notwithstanding subsection (1), the Minister may engage, upon such terms and conditions as the Minister deems fit, the services of such professional and technical persons and experts to advise the Minister as the Minister deems necessary for the efficient carrying out of this Act and the regulations.

(3) Notwithstanding anything in the Civil Service Act, the Minister may employ any person to investigate the mineral resources of the Province, or to perform any work in connection with this Act, and may pay any such person for such services at the rate agreed upon out of the Consolidated Fund of the Province. *1990, c. 18, s. 10.*

Officers

11 The Minister may appoint such officers as the Minister considers necessary who shall perform such duties as are assigned to them by the Minister, this Act or the regulations. *1990, c. 18, s. 11.*

Designated employee

12 The Minister may designate an employee in, or an officer of, the Department to perform administrative functions or powers of the Minister pursuant to this Act or the regulations. *1990, c. 18, s. 12.*

Powers of Deputy Minister

13 The Deputy Minister has and may exercise any and all of the powers by this Act or by the regulations conferred upon any officer appointed pursuant to Section 11 or Section 12. *1990, c. 18, s. 13.*

Powers of Minister

14 (1) The Minister may

(a) extend, upon application and for good cause shown, the time fixed or allowed for the doing of anything or the taking of any proceeding pursuant to this Act; or

(b) cancel, revoke or rescind a mineral right where money is due and owing to the Crown by the mineral right holder.

(2) An extension may be ordered pursuant to subsection (1) although the application for the same is not made until after the expiration of the time fixed or allowed and may require payment by the applicant to a person aggrieved by such extension. *1990, c. 18, s. 14.*

Security

15 (1) Notwithstanding anything in this Act, the Minister may require cash, security or negotiable bonds for any purpose consistent with the proper administration of this Act.

(2) Unless otherwise prescribed, security given pursuant to this Act shall be in the form of money, cash, negotiable bonds or other security acceptable to the Minister.

(3) The Minister, upon application by a person and upon being satisfied that the condition of a bond or other security has been broken, may make an order assigning the bond to a person to be named in the order, and that person or that person's executors or administrators may sue on the bond in that person's own name as if the bond had been originally given to that person and recover thereon as trustee for all persons interested the full amount recoverable in respect of any breach of a condition of the bond. *1990, c. 18, s. 15.*

Restriction on Government employees and ministers

16 (1) No person holding an office or employment with the Government shall, while holding such office or employment, directly or by any other person, acquire or hold any mineral right in the Province without the consent of the Governor in Council.

(2) Notwithstanding subsection (1), a member of the Executive Council, the Minister, the Deputy Minister or an individual holding an office or employment with the Government engaged in any activities related to this Act shall not, while holding such office or employment, directly or indirectly, by himself or by any other person, acquire or hold any mineral right in the Province.

(3) No employee of or person under contract to the Department, or person employed pursuant to subsection (3) of Section 10, and no former employee of, or person formerly under contract to, the Department shall divulge or use any confidential information including any information, the confidentiality of which is

protected by enactment or information, the release or use of which creates a benefit to the person who uses or divulges the same, unless the release or use of such information

(a) has been authorized by each person to whom it pertains;

(b) is required for the enforcement and administration of this Act or the regulations; or

(c) is permitted by the expiration of the confidentiality period provided by the enactment.

(4) A person who contravenes this Section is guilty of an offence and in addition to any penalty imposed is subject to disciplinary action including loss of office or employment with the Government. *1990, c. 18, s. 16.*

Powers of entry

17 Every officer or person designated by the Minister and their assistants, when engaged in duties pursuant to this Act or geoscientific activities, may at any reasonable time enter upon and pass over the land of any person by any reasonable means doing as little damage as possible and no action lies against that officer or person, the assistants, the Minister or the Province for any act done pursuant to this Section except actual damage. *1990, c. 18, s. 17; 1999 (2nd Sess.), c. 12, s. 3.*

Registrar

18 The Minister may designate a person to be the Registrar. *1990, c. 18, s. 18.*

Registrar's office and records

19 (1) The Registrar shall have an office at the City of Halifax and at such other place as may be prescribed.

(2) The Registrar shall keep at the office, in the manner prescribed, such records as are required by this Act and the regulations.

(3) All information contained in records and copies of records that are required pursuant to this Act to be kept by the Registrar, and an accurate reproduction of such information, is admissible in evidence as proof of the contents therein if certified as correct by the Registrar.

(4) The Registrar shall maintain a record of mineral rights and non-mineral registrations that is conclusive as to the matters entered therein.

(5) The Registrar shall maintain a record of applications for mineral rights and non-mineral registrations properly filed with the Registrar in which shall be entered particulars of the disposition of each application and such other matters as may be prescribed.

(6) The Registrar shall maintain a record wherein are entered the names of mineral right holders and registrants.

(7) All instruments that are required to be filed pursuant to this Act shall be filed with the Registrar who shall enter the same in the Registrar's records in the manner prescribed.

(8) Upon payment of the prescribed fee, an interested person may, subject to the provisions of subsection (9), during office hours inspect records of mineral rights and non-mineral registrations and records of names of mineral right holders and registrants and may obtain copies of applications for mineral rights and non-mineral registrations.

(9) Notwithstanding the Freedom of Information and Protection of Privacy Act, departmental notations, other than the application number and date stamp, not forming part of a document, leases and other instruments of a confidential nature and filed for information purposes only pursuant to subsection (7), options and financial information shall be held in confidence by the Registrar unless the Registrar is directed to release the same by the order of a court of competent jurisdiction or by the Minister who may direct such information to be released in connection with procedures to and for the provisions of this Act and the regulations with respect to the information contained in the portion of the record ordered to be released and upon such notice to the parties concerned as the Minister deems appropriate.

(10) The office of the Registrar shall be open every day that is not a holiday, a Saturday or a Sunday at ten o'clock in the forenoon and close at four o'clock in the afternoon.

(11) Where the time limited for the filing or recording of a document or for the doing of any act or thing at the office of the Registrar pursuant to this Act expires or falls on a day on which the office is closed, the time so limited extends to, and such filing, recording or other act may be done on the day next following on which the office is open.

(12) A certificate purporting to be signed by the Registrar is prima facie proof of the contents of documents filed in the office of the Registrar. *1990, c. 18, s. 19; 1999 (2nd Sess.), c. 12, s. 4.*

Transfer of exploration licence

20 The Registrar is responsible for the transfer of an exploration licence in the manner set out in this Act. 1990, c. 18, s. 20.

Restriction on lands and requirement for mineral right

21 (1) Lands within the Province may, from time to time, be restricted from any or all prospecting, exploration, development or mining for such periods of time and in such a manner as may be prescribed.

(2) No person shall search and prospect for minerals except pursuant to a mineral right.

(3) Notwithstanding subsection (2), a person who searches and prospects for minerals in a preliminary way with the intent of acquiring a mineral right where such searching and prospecting is restricted to outcrop and float examination, line flagging, geological and topographical mapping, rock, water, and overburden sampling and geophysical surveys is not required to obtain a licence pursuant to subsection (2) provided that person

(a) is, in the case of an individual, of the age of majority;

(b) except as otherwise prescribed, registers with the Registrar in the manner set forth in the regulations and pays the prescribed fee in the prescribed manner;

(c) has the consent of the owner, occupant who has authority to give consent, or tenant of the surface rights, or in the case of Crown lands, the consent of the Minister; and

(d) conducts the preliminary non-disturbance surface work on lands which are open for application for a licence, and which are not restricted pursuant to the regulations.

(4) No person, including a person searching or prospecting pursuant to subsection (3), shall carry out any exploration, development or production of minerals on a claim or claims held pursuant to a licence or lease unless the person is the mineral right holder or does so with the authority of the mineral right holder. *1990, c. 18, s. 21; 1994, c. 36, s. 2; 1999 (2nd Sess.), c. 12, s. 5.*

Withdrawal of lands and special licences and leases

22 (1) The Minister may withdraw any lands in the Province from being subject to application for an exploration licence for all or certain minerals.

(2) Lands withdrawn from being subject to application for an exploration licence may be explored and mined pursuant to a special licence or special lease

granted for all or certain minerals by the Minister with the approval of the Governor in Council.

(3) A special licence or special lease may contain such terms and conditions as are approved by the Governor in Council.

(4) Except as provided in subsection (3), a special licence or special lease is subject to this Act and the regulations.

(5) The Minister may offer by tender the right to obtain a special licence upon all or part of the lands withdrawn pursuant to subsection (1) and the provisions of Section 34 apply mutatis mutandis.

(6) No application for a special licence shall be accepted for areas upon which another application for a special licence is under consideration.

(7) Where the Minister intends to grant a special licence or special lease in respect of lands subject to an existing mineral right or a non-mineral registration, the Minister shall

(a) give the mineral right holder or registrant an opportunity to be heard;

(b) impose such terms and conditions, pursuant to subsection (3), as are necessary to minimize interference with the existing mineral right or non-mineral registration.

(8) The Minister shall not grant a special licence or special lease if, in the Minister's discretion, the Minister deems that it would not be in the best interest of the Province to do so.

(9) The Minister may reopen for application for an exploration licence any lands withdrawn pursuant to subsection (1) for all or certain minerals. *1990, c. 18, s. 22; 1999 (2nd Sess.), c. 12, s. 6.*

Exception

23 Notwithstanding Section 30 but subject to subsection (6) of Section 22, the Minister may accept an application for a special licence or a special lease granted pursuant to subsection (2) of Section 22 for an area already applied for or under a mineral right or registration. *1990, c. 18, s. 23; 1999 (2nd Sess.), c. 12, s. 7.*

Application for licence

24 (1) An individual of the age of majority or a corporate person may, in the manner prescribed, apply for a licence as prescribed.

(2) An application for a licence shall be in the prescribed form and shall specify the claim or claims applied for as designated on the official maps of the Department.

(3) The Registrar shall cause an application to be inscribed with the precise time and date at which the application is received at the office of the Registrar. *1990, c. 18, s. 24; 1994, c. 36, s. 3; 1999 (2nd Sess.), c. 12, s. 8.*

Required information

25 (1) Every person shall, within fifteen days of that person's first application for a mineral right, file in the office of the Registrar documentation in the prescribed form that contains the following information:

(a) if an individual or sole proprietorship,

(i) the individual's name or proprietorship's name,

(ii) the individual's address in the Province,

(iii) the individual's address, if any, outside of the Province, and

(iv) the name and address of the agent resident in the Province;

(b) if a partnership or syndicate,

(i) the name of the partnership or syndicate,

(ii) the names of all partners or members of the syndicate,

(iii) the addresses of all partners or members of the syndicate in the Province,

(iv) the addresses, if any, of all partners or members of the syndicate outside the Province,

(v) the name and address of the agent resident in the Province,

(vi) a copy of the certificate of partnership or syndicate registration or other registration confirming registration for the Province;

(c) if a body corporate,

(i) the name of the corporation,

(ii) the names and addresses of the president, secretary and other officers and directors of the corporation,

(iii) the mode of incorporation,

(iv) the date of incorporation,

(v) a copy of the certificate of incorporation or registration,

(vi) the location of the head office,

(vii) the name and address of the agent resident in the Province,

(viii) the principal office of the corporation in the Province, and

(ix) repealed 1999 (2nd Sess.), c. 12, s. 9.

(x) any information that the Registrar may require.

(2) Service upon the agent referred to in subclause (iv) of clause (a), subclause (v) of clause (b) or subclause (vii) of clause (c) of subsection (1) shall be deemed to be sufficient service upon the individual or proprietorship, the partnership or syndicate and the members thereof and the corporation, respectively.

(3) Every mineral right holder shall advise the Registrar in writing, within thirty days, of a material change affecting the information required by subsection (1). *1990, c. 18, s. 25; 1999 (2nd Sess.), c. 12, s. 9.*

Contents of application

26 (1) An application for a mineral right, any other application and a transfer or assignment of a claim or of a right or interest acquired pursuant to this Act shall contain, or have endorsed thereon,

(a) the place of residence and post office address of the applicant, transferee or assignee;

(b) where not a resident in the Province, the name, residence and post office address of a person resident in the Province upon whom service may be made; and

(c) such other information as may be prescribed.

(2) The address provided pursuant to subsection (1) is the address for service and, unless otherwise provided for by this Act, service may be made by forwarding by prepaid registered mail to such address.

(3) No application, transfer or assignment shall be accepted unless it conforms with subsection (1) and the regulations.

(4) The name of the agent upon whom service may be made may be changed by filing in the office of the Registrar a memorandum setting forth the name, residence in the Province and post office address of the new agent.

(5) The last address of a person on file with the Registrar is the address for service of all notices and documents pursuant to this Act.

(6) Unless otherwise provided in this Act, a notice or document required by this Act to be given shall be given in the manner prescribed. *1990, c. 18, s. 26.*

Duty to accept application

27 The Minister, where satisfied that the requirements pursuant to subsection (1) of Section 32 have been met, shall accept an application for an exploration licence. *1990, c. 18, s. 27.*

Exploration licence

28 (1) Where the Registrar is satisfied that the application is complete and complies with this Act and the regulations, the Registrar shall issue an exploration licence.

(2) The Registrar may issue an exploration licence for part of the lands applied for, with the approval of the Minister, or refuse an application if it is not in accordance with Section 30, subsection (1) of Section 32 and Section 46. *1990, c. 18, s. 28.*

Duties of Registrar upon issuing exploration licence

29 When the Registrar issues an exploration licence pursuant to Section 28, the Registrar shall cause appropriate entries to be made in the records maintained by the Registrar and shall forward the licence to the applicant in the manner prescribed. *1990, c. 18, s. 29.*

Restriction on acceptance of application

30 No application for an exploration licence shall be accepted for areas that are subject to an exploration licence, special licence, non-mineral registration, lease, special lease or application for any of them, unless the applicant holds the mineral right or non-mineral registration. *1990, c. 18, s. 30; 1999 (2nd Sess.), c. 12, s. 10.*

Refund of fees

31 Where an application is refused or rejected, the Registrar shall refund the fees submitted with the application in the amount and manner prescribed. *1990, c. 18, s. 31.*

Dispute

32 (1) Subject to subsection (2), where the right to issue a licence for a claim or claims is in dispute, no application shall be accepted for a licence of the claim or claims until the dispute is disposed of by the decision of an authority that is competent to deal with the dispute.

(2) Where an appeal lies from a decision referred to in subsection (1), no application shall be accepted until after the time limited for taking the appeal expires, or where an appeal is taken, after the dispute is disposed of by the highest authority to which an appeal is taken.

(3) Notwithstanding Section 27, where, in the opinion of the Minister, the acceptance of an application for an exploration licence is not in the best interests of the Province or would hinder mineral development, the Minister may reject or defer the application. *1990, c. 18, s. 32; 1999 (2nd Sess.), c. 12, s. 11.*

Investigation by Minister

33 (1) Where a person whose application is deferred pursuant to subsection (3) of Section 32 makes a request to the Minister within fifteen days of the deferral, the Minister or a person designated by the Minister shall conduct an investigation regarding that person's entitlement to an exploration licence.

(2) If, upon investigation, the Minister refuses to accept the application for an exploration licence, the Minister shall report the refusal to the Governor in Council and the Governor in Council may confirm the refusal, or direct that the application be accepted, in whole or in part, and upon such terms and conditions as the Governor in Council determines. *1990, c. 18, s. 33.*

Tenders for competing applications

34 (1) Where two or more persons submit applications for an exploration licence for a common claim or claims and the Registrar is unable to determine which application was received first, the Registrar shall, after giving notice in the manner and within the time prescribed, request the applicants to submit tenders, in the manner and within the time prescribed, for the right to obtain the exploration licence.

(2) Subject to subsection (3) of Section 32, where tenders have been submitted pursuant to subsection (1), the Registrar, within the time prescribed, shall issue an exploration licence to the applicant who

(a) undertakes to perform on the claim or claims the greatest amount of assessment work in excess of the amount of assessment work required by the regulations; and

(b) deposits with the Registrar security in an amount determined by the Minister and within a time fixed by the Registrar.

(3) If no tender is submitted which, in the opinion of the Registrar, is acceptable or if the security required pursuant to subsection (2) is not deposited, the claim or claims is deemed to be available for application at the end of normal office hours of the last day fixed for the deposit of the security and applications may be submitted therefor on the next business day.

(4) In respect of an exploration licence issued pursuant to subsection (2), the amount of assessment work committed in the successful tender by the applicant shall be the amount of assessment work the applicant is required to perform.

(5) The security required pursuant to clause (b) of subsection (2) shall be returned upon the completion of all assessment work undertaken pursuant to clause (a) of subsection (2) within the time and manner acceptable to the Registrar.

(6) Failure to complete the assessment work pursuant to clause (a) of subsection (2) results in the forfeiture of the security deposited pursuant to clause (b) of subsection (2). *1990, c. 18, s. 34; 1999 (2nd Sess.), c. 12, s. 12.*

Form of exploration licence

35 An exploration licence shall be in the prescribed form. *1990, c. 18, s. 35.*

Location of claims

36 A licence shall specify the location by claims and tracts as designated on the official maps of the Department. *1990, c. 18, s. 36; 1994, c. 36, s. 4.*

Coterminous claims

37 An exploration licence may include any number of coterminous claims not exceeding eighty but licences shall not be granted for portions of claims. *1990, c. 18, s. 37.*

Rights conferred

38 Subject to Sections 39, 40 and 100, the rights conferred by a licence are, and are limited to, prospecting and searching for minerals, extracting minerals for test

purposes and applying for a mineral lease for all or a part of the area held under a licence. *1990, c. 18, s. 38; 1994, c. 36, s. 5; 1999 (2nd Sess.), c. 12, s. 13.*

Prohibited entry or working of private land

39 No mineral right holder, legal representative of the mineral right holder or a person acting on behalf of the mineral right holder shall enter upon, pass over or work private land for the purpose of gaining access to and working the mineral right except with the consent of the owner or tenant or pursuant to Section 100. *1990, c. 18, s. 39; 1994, c. 36, s. 6; 1999 (2nd Sess.), c. 12, s. 14.*

Prohibited entry or working of Crown lands

40 No mineral right holder, legal representative of the mineral right holder or person acting on behalf of the mineral right holder shall enter upon and work Crown lands except with the consent of the Minister or of a person designated by the Minister and upon such terms and conditions as are specified by the Minister. *1990, c. 18, s. 40; 1994, c. 36, s. 7; 1999 (2nd Sess.), c. 12, s. 15.*

Expiry and renewal of exploration licence

41 (1) An exploration licence expires one year from the date of its issue, unless renewed or extended pursuant to subsection (7) of Section 100.

(2) An exploration licence may be renewed only once each year.

(3) A renewal is effective for one year from the day next after which the exploration licence would have expired but for the renewal. *1990, c. 18, s. 41; 1994, c. 36, s. 8.*

Statistical reports

42 A person searching, prospecting or mining and an operator of a mine as herein defined or quarry as defined in the Metalliferous Mines and Quarries Regulations Act or any replacement of that Act or amendment thereto within the Province shall be required to file with the Department during each year statistical reports containing such information as is prescribed. *1990, c. 18, s. 42; 1999 (2nd Sess.), c. 12, s. 16.*

Reports of work done

43 (1) Subject to Section 45, a report detailing all the work done or caused to be done during the year of the licence, including assessment work and other related work and a statement of expenditure in the prescribed form shall be submitted on or before the anniversary date of the licence.

(2) The licensee may, at any time, submit a report in the prescribed form as to the work done or caused to be done by the licensee. *1990, c. 18, s. 43; 1994, c. 36, s. 9; 1999 (2nd Sess.), c. 12, s. 17.*

Entitlement to renewal of exploration licence

44 (1) The Registrar shall renew an exploration licence where a licensee

(a) files an application for renewal in the prescribed form; and

(b) pays the prescribed fee,

and either

(c) has performed the prescribed assessment work in a manner acceptable to the Minister and has filed the prescribed assessment work report in a form acceptable to the Registrar;

(d) has sufficient work credits; or

(e) provides the required payment in lieu of assessment work on or before the day upon which the exploration licence is due to expire.

(2) repealed 1994, c. 36, s. 10.

1990, c. 18, s. 44; 1994, c. 36, s. 10.

Time extension

45 (1) Notwithstanding Sections 43 and 44 and for good cause shown, the Registrar may grant a single extension of time for filing the assessment work report for a period of time and upon the terms and conditions determined by the Registrar where

(a) the Registrar is satisfied that the licensee has performed the assessment work to the required amount; and

(b) the licensee files a statement of expenditures indicating the nature and value of the assessment work performed.

(2) Where the licensee submits an assessment work report that is acceptable to the Registrar and filed within the time provided by the extension, the Registrar shall renew the exploration licence for one year from the date next after the licence or renewal thereof was due to expire.

(3) Notwithstanding subsection (1) of Section 41, where the assessment work report is not filed within the extension period, the licence expires at the end of that period. *1990, c. 18, s. 45.*

Restriction on right to apply

46 (1) An application for a claim or claims that were contained in an exploration licence that has expired or has been forfeited, abandoned or surrendered shall not be accepted by the Registrar for a period of ninety days following the date of the expiry, forfeiture, abandonment or surrender unless the Registrar is satisfied that the applicant is not the licensee who held the exploration licence immediately preceding the date of expiry, forfeiture, abandonment or surrender nor a person acting on behalf of, associated with or having a community of interest with the licensee.

(2) For the purpose of subsection (1), when an extension has been provided pursuant to Section 45, the ninety-day period shall be from the date of the expiry of the extension.

(3) For the purpose of this Section,

(a) a corporation and a person or one of several persons by whom the corporation is directly or indirectly controlled;

(b) corporations controlled directly or indirectly by the same persons;

(c) persons connected by blood relationships, marriage or adoption; or

(d) persons connected by partnership or engaged in joint ventures,

have a community of interest. *1990, c. 18, s. 46; 1999 (2nd Sess.), c. 12, s. 18.*

Renewal of exploration licence

47 (1) Notwithstanding Section 46, the Registrar may renew an exploration licence that has expired when

(a) the requirements of subsection (1) of Section 44 have been met; and

(b) the claim or claims subject to the exploration licence has not been applied for by or issued to another person.

(2) Payment in lieu of assessment work required by clause (e) of subsection (1) of Section 44 does not constitute satisfaction of assessment work pursuant to this Section. *1990, c. 18, s. 47; 1999 (2nd Sess.), c. 12, s. 19.*

Application of excess credits

48 (1) Where assessment work in excess of the prescribed assessment work required is performed during an exploration licence year and proved to the satisfaction of the Registrar, the Registrar shall apply the excess work credits against the assessment work requirement for subsequent terms of renewal.

(2) A report of acceptable assessment work shall be filed before

(a) the end of the licence year in which the assessment work was conducted; or

(b) the expiration of an extension pursuant to Section 45 in respect of that year,

whichever is the later.

(3) Except as prescribed, if a report of assessment work that is acceptable is filed after the period defined in subsection (2), the assessment work may be credited at one half the value of assessment work reported in compliance with subsection (2).

(4) Acceptable assessment work that is a ground or airborne regional survey may be credited with such percentage of value of that assessment work as is prescribed and subsection (3) does not apply to the assessment work. *1990, c. 18, s. 48; 1994, c. 36, s. 11.*

Certificate of compliance

49 The Registrar, if satisfied that the prescribed assessment work has been performed or the prescribed payment in lieu thereof has been made, shall grant a certificate of compliance of the licence in the prescribed form and the certificate in the absence of fraud or mistake is final and conclusive evidence of the renewal of the licence. *1990, c. 18, s. 49; 1994, c. 36, s. 12.*

Effect of delay

50 Notwithstanding Section 41, where evidence of assessment work performed is submitted to the Registrar within the required period or the Registrar requires the licensee to revise information submitted for assessment credit, the licence does not lapse because of any delay that may occur in the consideration of the evidence or in making an investigation that may be deemed necessary. *1990, c. 18, s. 50; 1994, c. 36, s. 13.*

Work on coterminous claims and reference in report to licence

51 (1) Where a licence has two or more coterminous claims, the required amount of assessment work for all of the claims may be performed on one or more of the claims.

(2) Reports of assessment work to be filed and certificates issued pursuant to Section 49 shall indicate the licence upon which the assessment work was performed. *1990, c. 18, s. 51; 1994, c. 36, s. 14.*

Payments in lieu of work

52 (1) Where the amount of acceptable assessment work performed is insufficient and there are not adequate work credits for the renewal of an exploration licence, the licensee may make a payment in lieu of assessment work where

(a) a payment in lieu is made not more than once in the first five-year period of the exploration licence and not more than once in each five-year period thereafter;

(b) the payment is in the amount of the deficiency in the prescribed assessment work for that year but in no case is less than the assessment work requirement for one claim for that year; and

(c) the payment is calculated on a per claim basis.

(2) Where a payment in lieu of assessment work is made pursuant to subsection (1), it shall be refunded if in the following year the licensee performs and submits the prescribed assessment work plus the amount of the deficiency for the previous year.

(3) The refund shall be the total value of that portion of assessment work done and approved that can be applied in total satisfaction of the assessment work requirements for individual claims within the area licensed. 1990, c. 18, s. 52.

Integration of anniversary dates

53 A licensee holding two or more exploration licences with different anniversary dates may apply to the Registrar to integrate their anniversary dates and the Registrar may assign a common anniversary date for the exploration licences and amend the exploration licences accordingly if

(a) the exploration licences whose anniversary dates are to be integrated are not first year licences;

(b) there is no payment in lieu of assessment work outstanding pertaining to the exploration licences whose anniversary dates are to be integrated; and

(c) the anniversary dates are not being integrated for the purpose of extending the time for doing ~~assesssment~~ [assessment] work or making a payment in lieu of assessment work,

and the provisions of Section 37 apply. *1990, c. 18, s. 53.*

Conversion to single licence

54 (1) Notwithstanding Section 83, where any two or more coterminous exploration licences have been held for one or more years and none of the licences is in good standing by reason only of a payment in lieu of assessment work, the Registrar may accept, upon application, a surrender of the coterminous exploration licences and may, upon payment of the prescribed fee, issue one exploration licence for the whole or any single coterminous portion of the claims that were contained in the surrendered exploration licences.

(2) An exploration licence issued pursuant to subsection (1) shall assume the year of the oldest of the exploration licences from which it is derived and the Registrar shall select the month and the day to be used to determine the anniversary date of the new exploration licence.

(3) On or before the anniversary date of a new exploration licence issued pursuant to subsection (1), the licensee shall file assessment work acceptable to the Registrar or apply work credits to meet the requirement for the claims comprising the new exploration licence based on the year of the new exploration licence determined in accordance with subsection (2).

(4) Work requirements for each new exploration licence issued pursuant to subsection (1) shall be those work requirements of the oldest of the exploration licences surrendered pursuant to subsection (1).

(5) Each exploration licence issued pursuant to subsection (1) shall not itself, or combined with others, be subject to further regrouping for a period of one year following the issue of the exploration licence.

(6) Work credits applying to any exploration licences that have been regrouped pursuant to subsection (1) may be applied to the new exploration licence.

(7) The licensee may not re-apply, within a period of ninety days of the regrouping, for an exploration licence covering a claim surrendered for the purpose of regrouping. *1990, c. 18, s. 54; 1994, c. 36, s. 15.*

Execution and date of licence

55 Every exploration licence or renewal thereof shall be executed on the part of the Crown by the Registrar and shall bear the date of the day upon which the application therefor was accepted. *1990, c. 18, s. 55.*

Requirement for mineral lease

55A (1) No person shall carry out production of a mineral except in accordance with a mineral lease.

(2) For greater certainty, subsection (1) does not apply to the production of gypsum or limestone that has not been declared a mineral pursuant to Section 5. *1999 (2nd Sess.), c. 12, s. 20.*

Prerequisites to issue and term of lease

56 (1) Subject to Section 22, where the holder of a licence

(a) files with the Registrar an application in the prescribed form;

(b) provides the prescribed information in the prescribed form and manner;

(c) satisfies the Minister that the applicant has delineated a mineral deposit within the proposed lease area;

(d) provides a written undertaking to commence production within two years of obtaining the lease;

(e) repealed 1999 (2nd Sess.), c. 12, s. 21.

and

(f) pays the first year's rent in advance,

the Minister shall issue a lease.

(2) A lease shall be for a term of twenty years subject to compliance with this Act.

(3) A lease may be issued for any number of coterminous claims as approved by the Minister. *1990, c. 18, s. 56; 1994, c. 36, s. 16; 1999 (2nd Sess.), c. 12, s. 21.*

Rights under lease

57 A lease gives the exclusive right to all or specified minerals in or upon the leased area for the term of the lease, subject to the payment of royalties and to all other conditions contained in this Act. *1990, c. 18, s. 57.*

Formalities and issue and filing of lease

58 (1) A mineral lease in the prescribed form shall be made in duplicate, one to be issued to the lessee and the other to be filed and registered in the office of the Registrar who shall enter it in the Registrar's records in the manner prescribed.

(2) A certificate of such registration, with the day and year thereof, shall be inscribed on the duplicate delivered to the lessee.

(3) A lease shall be executed by the lessee under seal and on the part of the Crown by the Minister under seal. *1990, c. 18, s. 58; 1994, c. 36, s. 17; 1999 (2nd Sess.), c. 12, s. 22.*

Prohibition

59 No mineral right holder or registrant shall enter upon or conduct any surface excavation, surface mining or other surface work upon any private lands until the mineral right holder or registrant has obtained the right to enter upon or conduct the same by agreement with the owner or pursuant to this Act. *1990, c. 18, s. 59; 1999 (2nd Sess.), c. 12, s. 23.*

Renewal of lease

60 (1) A lessee who is bona fide working the lease and is in compliance with this Act and who applies to the Minister at least six months prior to the expiration of the term of the lease is entitled to a renewal thereof for an additional twenty years upon the terms and conditions in force at the time of renewal.

(2) Where a mineral lease has expired, the Minister shall withdraw, pursuant to Section 22, for thirty days from the date the mineral lease expired, the area formerly held under the lease and give the lessee the exclusive right to apply for and obtain an exploration licence in the manner set out in Section 24.

(3) No other applications for an exploration licence for the area withdrawn pursuant to subsection (2) shall be considered during the thirty-day period referred to in subsection (2).

(4) The exploration licence referred to in subsection (2) shall bear the month and day of the day following the expiration of the mineral lease.

(5) The assessment work required for the exploration licence referred to in subsection (2) shall be that prescribed for an exploration licence that had its commencement at the date of issue of the original exploration licence that was converted to the mineral lease.

(6) Where the lessee does not apply for and obtain an exploration licence pursuant to subsection (2), the Minister may

(a) accept applications by tender for the right to obtain an exploration licence, in which case the provisions of subsections (2), (3) and (4) of Section 34 apply mutatis mutandis; or

(b) reopen the area for application pursuant to Section 22.

(7) Where any question arises as to the assessment work required in subsection (5), the decision of the Minister on the question is final. *1990, c. 18, s. 60; 1994, c. 36, s. 18; 1999 (2nd Sess.), c. 12, s. 24.*

Keeping and inspection of records and accounts

60A Every lessee shall keep on the premises named in the lease, records, accounts, correspondence and documents that shall at all reasonable times be open to inspection and examination and be produced upon request of any person authorized by the Minister, in which records shall be entered a clear and distinct statement of

(a) all mineral-bearing substances processed at the premises;

(b) the sources of the minerals or mineral-bearing substances processed;

(c) the quantity and analysis of the minerals or mineral-bearing substances processed;

(d) the quantity and analysis of the concentrate recovered;

(e) the quantity and analysis of tailings and waste discharges;

(f) the quantity and analysis of all products sold and the name and address of the buyer; and

(g) any other information as prescribed or required by the Minister. *1999 (2nd Sess.), c. 12, s. 25.*

Work report

61 A lessee or registrant shall submit annually, on or before the first day of March in each year, reports in such a manner and form as are prescribed containing such information as is prescribed. *1994, c. 36, s. 19; 1999 (2nd Sess.), c. 12, s. 26.*

Work credits

62 (1) Notwithstanding Section 48, upon application for a lease, the applicant may direct that all or any portion of the work credits accumulated on the existing exploration licence or special licence be applied to the claims that are to be included in the proposed lease area.

(2) If any work credits are applied to the lease pursuant to subsection (1) they retain their value until the termination of the lease or any replacement thereof and may be applied to a licence acquired pursuant to subsection (5) of Section 65.

(3) Notwithstanding subsections (1) and (2), there shall be

(a) no requirement to conduct assessment work on a lease; and

(b) no work credits granted for activity conducted pursuant to a lease. *1990, c. 18, s. 62; 1994, c. 36, s. 20; 1999 (2nd Sess.), c. 12, s. 27.*

Payment of rentals

63 Rentals at the prescribed rate shall be paid annually on or before the anniversary date of a lease for the ensuing year. *1990, c. 18, s. 63.*

Conversion to single lease

64 (1) Subject to this Act and upon application by the lessee of two or more leases and the surrender thereof, the Minister may issue one lease for the whole or any smaller portion of the coterminous claims covered by the surrendered leases and may include in the lease an additional coterminous claim or claims to which the lessee holds a valid mineral right and subsection (1) of Section 79 does not apply.

(2) A lease issued pursuant to subsection (1) assumes the year of the oldest of the leases from which it is derived and the Registrar shall select the month and the day to be used to determine the anniversary date of the lease. *1990, c. 18, s. 64; 1994, c. 36, s. 21; 1999 (2nd Sess.), c. 12, s. 28.*

Review of lease

65 (1) The Minister shall review a lease where

(a) the lessee fails to commence production or significant development work leading to production within two years of obtaining the lease;

(b) the lessee fails to submit the prescribed annual reports;

(c) the lessee wishes to surrender the lease; or

(d) the lessee commences production in accordance with this Act and the annual report required by Section 42 indicates that no production or development work has occurred within the previous twelve months.

(2) For the purpose of the review pursuant to subsection (1), the lessee shall provide all relevant information required by the Minister in the manner and at the times the Minister requests.

(3) Following the review, the Minister shall declare that

(a) the lease continue for a period of two years from the date of the review or until the lease expires, whichever occurs first;

(b) the lease is forfeited; or

(c) the application to surrender the lease has been accepted.

(4) Where the Minister allows the lease to continue for two years pursuant to clause (a) of subsection (3), the Minister shall review the lease at the end of that two years and make another declaration pursuant to subsection (3).

(5) Where the lease expires pursuant to clause (a) of subsection (3) or where the Minister declares the lease forfeited pursuant to clause (b) of subsection (3), the Minister shall provide the lessee and the Registrar with a written declaration of the expiration or forfeiture of the lease and the lessee has thirty days from the date of the declaration to apply for and obtain an exploration licence or, subject to Section 22, a special license, as the case may be, for the area held pursuant to the forfeited or expired lease during which time no other applications for the area shall be accepted.

(6) The licence referred to in subsection (5) shall bear the month and day of the day following the termination of the lease.

(7) The assessment work required is that prescribed for an exploration licence that had its commencement at the date of issue of the original exploration licence that was converted to the lease or, in the case of a special licence, the amount of assessment work required is that approved by the Governor in Council or the Minister, as the case may be.

(8) The licensee shall, within twelve months of the issuance of the licence, submit assessment work for, or apply existing work credits to, the year referred to in subsection (7).

(9) Where the lessee does not apply for a licence pursuant to subsection (5), the Minister may reopen the area for application pursuant to Section 24. *1990, c. 18, s. 65; 1994, c. 36, s. 22; 1999 (2nd Sess.), c. 12, s. 29.*

Order to cease operations

66 The Minister may order the lessee to cease all operations pending the outcome of a review pursuant to Section 65 or an investigation. *1990, c. 18, s. 66.*

Effect of breach of lease or non-compliance

67 (1) Where an investigation shows to the satisfaction of the Minister that the lessee has breached a term or condition of the lease, the Minister may

(a) declare the lease forfeited;

(b) grant the lessee thirty days to comply with the terms or conditions of the lease; or

(c) make such order or decision as the Minister deems just and equitable.

(2) The Minister shall notify the lessee of the decision by prepaid registered mail.

(3) Where the lessee does not comply with

(a) the terms and conditions of the lease within the thirty days granted pursuant to clause (b) of subsection (1); or

(b) an order or decision of the Minister made pursuant to clause (c) of subsection (1),

the Minister may declare the lease to be forfeited and direct the Registrar to make the appropriate entry in the records. *1990, c. 18, s. 67.*

Forfeiture of lease

68 The Minister shall declare a lease forfeited where a lessee

(a) repealed 1999 (2nd Sess.), c. 12, s. 30.

(b) fails to perform the obligations under the lease;

(c) is a corporation that becomes dissolved;

(d) obtains the lease by misrepresenting any material fact;

(e) fails to pay royalties within thirty days of the due date; or

(f) fails to pay rent within thirty days of the due date. *1990, c. 18, s. 68; 1999 (2nd Sess.), c. 12, s. 30.*

Effect of forfeiture of lease

69 Where the Minister declares a lease forfeited,

(a) the Minister shall provide the lessee with a written declaration of the forfeiture stating the reasons for the forfeiture; and

(b) the lessee and all lienholders cease to have any interest in the lease or mine. *1990, c. 18, s. 69.*

Application for right in land

70 (1) Whenever a lessee requires land, or a right or interest in land, for a mine or any purpose connected with or incidental to a mine and no agreement can be made for the acquisition thereof, or a right-of-way or easement in respect to the land, the lessee may present an application to the Minister stating that

(a) the lessee is the lessee under a certain lease;

(b) the lessee requires certain land or some right or interest therein, of which a plan and description is attached, for one or more of the above purposes in connection with the area covered by the lease;

(c) a person named is the owner of the land, and the lessee is willing to make an arrangement with the owner for the acquisition of the land, right or interest, stating the nature of the proposed agreement and the price that the lessee is willing to pay, but the owner is unwilling to accept; and

(d) the lessee requests that the Minister make an order that the right or interest in the lands required by the lessee be vested in the lessee.

(2) The application shall be accompanied by the deposit with the Minister of such sum as directed for costs or expenses that may be ordered to be paid by the lessee to the owner where the Minister requires the deposit.

(3) Upon application, the Minister may, by a vesting order, vest in the lessee the property right claimed by the lessee or such other right as the Minister may determine.

(4) A vesting order issued by the Minister shall be filed at the registry of deeds for the registration district in which the land to which the order relates is situate and the filing thereof is deemed to be a deposit of expropriation documents pursuant to the Expropriation Act.

(5) Upon the filing of a vesting order by the Minister, the lessee named in the order is and is deemed to be the expropriating authority within the meaning of the Expropriation Act. *1990, c. 18, s. 70; 1999 (2nd Sess.), c. 12, s. 31.*

Expropriation Act

71 In connection with the proceedings pursuant to Section 70,

(a) the Expropriation Act applies mutatis mutandis to the expropriation;

(b) notwithstanding Section 4 of the Expropriation Act, whenever the provisions of that Act conflict with the expropriation provisions of this Act, the expropriation provisions of this Act prevail;

(c) the lessee is deemed to be the statutory authority for the purpose of the Expropriation Act;

(d) the Minister is deemed to be the approving authority for the purpose of the Expropriation Act. *1990, c. 18, s. 71.*

Restriction on use of right

72 Every mineral right holder who has acquired any property, right or interest pursuant to this Act or through an agreement with the owner subject to the terms of the agreement shall, if the property, right or interest is less than fee simple, use the same for some purpose connected with mining and for no other purpose and shall use the same in such manner as is least injurious to the owner of the land. *1990, c. 18, s. 72.*

Interpretation of Sections 74 to 81

73 In Sections 74 to 81,

(a) "lessee" includes the lessee who held the lease immediately preceding its forfeiture, surrender, abandonment or expiry, or the legal representative of the lessee;

(b) "property" means the real and personal property of the lessee that is associated with the mine. *1990, c. 18, s. 73.*

Liability of lessee

74 Notwithstanding the surrender, abandonment, forfeiture or expiry of a lease, the lessee remains liable for any terms and conditions of the lease including, without restricting the generality of the foregoing, those related to reclamation,

rentals, royalties, maintenance of buildings and structures and safety, until such terms and conditions have been fulfilled. *1990, c. 18, s. 74.*

Reclamation

75 (1) The area disturbed by the former mining operations, including the area upon which waste rock and tailings were deposited, shall be reclaimed to the satisfaction of the Minister by the lessee within twelve months of the cessation of production or such greater time as may be determined by the Minister.

(2) The cash or bond provided by the lessee is forfeited to the Department if reclamation has not been completed in accordance with subsection (1).

(3) Any unforfeited cash or bond provided by the lessee shall be retained until the area described in subsection (1) is inspected by an officer and the lessee is notified in writing by the Minister that the lessee is relieved from the obligation to maintain security for the purpose of reclamation. *1990, c. 18, s. 75.*

Maintenance of property

76 (1) The lessee or property owner shall maintain the property in a safe condition and shall not permit the property to become unsightly.

(2) Where the Minister determines that the condition of the property constitutes a danger to the health or safety of a person or constitutes an unsightly premise, the Minister may cause work required to make the property safe or to remove or remedy the unsightliness thereof to be performed at the expense of the Province.

(3) Where the Minister causes work to be done pursuant to subsection (2), the cost of the work is a debt due and owing to the Crown by the lessee or owner of the property and forms a charge upon the property.

(4) Nothing in this Section, nor any work done pursuant to subsection (2), relieves the lessee or owner of the property from liability for the maintenance of the property in such manner as to prevent danger to public health, safety or property. *1990, c. 18, s. 76.*

Disposition of property from lease

77 In connection with the disposition of property from a lease and dating from the time of surrender, abandonment, forfeiture or expiry,

(a) the lessee

(i) shall not, without the written authorization of the Minister, alienate or remove from the Province any of the property within the first six months, and

(ii) shall, following the receipt of authorization pursuant to subclause (i), remove the property within the six months following the date of the authorization;

(b) the Minister may, at any time, subject to Section 120, acquire all or any property for the Province;

(c) compensation to the lessee

(i) shall be payable pursuant to clause (b) and the procedure set forth in the Expropriation Act, in respect of the acquisition of land applies mutatis mutandis, subject to the deduction of an amount owed to the Province by the lessee pursuant to this Act and the regulations, and

(ii) shall not be payable when the Minister has acquired property pursuant to clause (b). *1990, c. 18, s. 77; 1999 (2nd Sess.), c. 12, s. 32.*

Effects of non-payment

78 Where a rental or royalty or money in respect of a lease is owed to the Province, the lessee shall not, without prior written authorization of the Minister, sell, transfer, set over, assign, sublet or otherwise dispose of the property including minerals, and the amount owed is a debt due to the Crown and forms a charge upon the property. *1990, c. 18, s. 78.*

Offer of mineral right

79 (1) Where a lease is surrendered, abandoned, forfeited or expires, a mineral right to that area may be offered by the Minister for tender or sale at public auction or otherwise disposed of, upon such terms and conditions as the Minister determines.

(2) The issuance of a mineral right to the subsequent mineral right holder does not confer upon that mineral right holder any right respecting property acquired by the Province pursuant to Section 77. *1990, c. 18, s. 79.*

Decision of Minister final

80 Where any question arises as to whether a lease is surrendered, abandoned, forfeited or expired, or whether the mine has been abandoned, the decision of the Minister on the question is final. *1990, c. 18, s. 80; 1999 (2nd Sess.), c. 12, s. 33.*

Reversion to Crown

81 Where a lease expires or is forfeited, abandoned, surrendered or otherwise terminated and no renewal is sought pursuant to this Act,

(a) all minerals in and upon the area formerly held under lease absolutely revert to the Crown; and

(b) any mineral stockpiles upon which no royalty has been paid absolutely become the property of the Crown. *1990, c. 18, s. 81.*

Remedies of Minister

82 Nothing contained in this Act prevents the Minister from having or using any remedy available to recover possession of the mineral rights contained in any area, claim or claims covered by a lease. *1990, c. 18, s. 82; 1999 (2nd Sess.), c. 12, s. 34.*

Surrender

83 (1) Subject to the approval of the Minister pursuant to Section 65, a mineral right holder or registrant may surrender all or a specified part of the area comprised within the mineral right or non-mineral registration by notice in writing to the Registrar, together with the original mineral right or non-mineral registration.

(2) Where the original mineral right or non-mineral registration referred to in subsection (1) is lost, the Registrar may accept an affidavit verifying the fact of such loss in place of the original.

(3) Upon receipt of the notice of surrender by the Registrar, all or a specified part of the mineral right or non-mineral registration expires and the Registrar shall provide the mineral right holder or registrant with written notice of the expiry.

(4) Where there has been a partial surrender, the Registrar shall amend the mineral right or non-mineral registration in accordance with the surrender and return it to the mineral right holder or registrant. *1990, c. 18, s. 83; 1994, c. 36, s. 23; 1999 (2nd Sess.), c. 12, s. 35.*

Liability of holder

84 The surrender of a mineral right or non-mineral registration does not relieve a mineral right holder or a registrant from any terms, conditions or obligations of the mineral right or non-mineral registration and the provisions of this Act that existed at the time of such surrender. *1990, c. 18, s. 84; 1999 (2nd Sess.), c. 12, s. 36.*

Restriction on transfer of exploration licence

85 (1) An exploration licence shall not be transferred without the written consent of the Registrar.

(2) Where the holder of an exploration licence or the holder's legal representative

(a) submits an application in the prescribed form;

(b) pays the prescribed fee; and

(c) provides the information requested by the Registrar,

the Registrar may consent to the transfer.

(3) No special licence or special lease or lease or non-mineral registration, shall be transferred without the written consent of the Minister. *1990, c. 18, s. 85; 1994, c. 36, s. 24; 1999 (2nd Sess.), c. 12, s. 37.*

Formalities of transfer of mineral right

86 A transfer of a mineral right or non-mineral registration shall be in the prescribed form and shall be signed by the transferor or by the legal representative of the transferor. *1990, c. 18, s. 86; 1999 (2nd Sess.), c. 12, s. 38.*

Filing of transfer or assignment

87 (1) A mineral right holder shall file with the Registrar, a summary, as prescribed, of an agreement that results or may result in a transfer or assignment of a mineral right, part of a mineral right or any interest in a mineral right.

(1A) A registrant shall file with the Registrar a summary, in the prescribed form and containing such information as is prescribed, of an agreement that results or may result in a transfer or assignment of a non-mineral registration, part of a non-mineral registration or any interest in a non-mineral registration.

(2) Notwithstanding the Freedom of Information and Protection of Privacy Act, a document filed pursuant to subsection (1) or (1A) that has been marked "confidential" shall be held in confidence by the Registrar.

(3) A transfer or an assignment of a mineral right or non-mineral registration or an agreement that results or may result in the transfer or assignment of a mineral right or non-mineral registration is ineffective against a person who, for valuable consideration and without notice of the transfer, assignment or agreement, acquires an interest in the mineral right or non-mineral registration, unless a notice of the transfer, assignment or agreement is filed with the Registrar in the

prescribed manner and in the prescribed form. *1990, c. 18, s. 87; 1999 (2nd Sess.), c. 12, s. 39.*

Effect of instrument

88 (1) Where in an application for a mineral right or for a non-mineral registration or in a transfer of a mineral right or non-mineral registration an interest is sought to be created or to be transferred to more than one person, the instrument shall operate as if it were expressed to be conveyed to the person first named therein upon the trusts set out in subsections (2) and (3) and the Registrar shall, for the purpose of this Act, treat the person first named as the owner of the mineral right.

(2) A mineral right holder holds the mineral right in trust for the persons who own the right, including himself.

(2A) A registrant holds a non-mineral registration in trust for each person who owns the right, including the registrant.

(3) The persons whose names appear on an application for a mineral right or non-mineral registration, or in a transfer of a mineral right or non-mineral registration shall prima facie be deemed to be the owners of the mineral right or non-mineral registration held for them in trust pursuant to this Section.

(4) A trust created by this Section is ineffective against a person who, for valuable consideration and without notice of the trust, acquires an interest in a mineral right or non-mineral registration unless a caveat, in the prescribed form, which gives notice of the trust is filed with the Registrar in the prescribed manner. *1990, c. 18, s. 88; 1999 (2nd Sess.), c. 12, s. 40.*

Restriction on production of gypsum or limestone

89 No person shall, except in accordance with a non-mineral registration, carry out production of gypsum or limestone that has not been declared to be a mineral pursuant to Section 5. *1999 (2nd Sess.), c. 12, s. 41.*

Issue of permit by Minister

90 (1) repealed 1999 (2nd Sess.), c. 12, s. 42.

(2) Where an applicant for a non-mineral registration required by Section 89 files with the Registrar

(a) an application for a non-mineral registration in the prescribed form;

(b) the prescribed documentation;

(c) a written undertaking to commence production;

(ca) evidence that satisfies the Minister that the applicant has delineated a deposit of gypsum or limestone that has not been declared a mineral pursuant to Section 5 within the proposed non-mineral registration area; and

(d) evidence of the applicant's right to the gypsum or limestone including a right to surface access,

the Minister shall issue a non-mineral registration in the prescribed form.

(3) The holder of a non-mineral registration required by Section 89 is not bound by

(a) Section 96;

(b) subsections (1), (2), (3), (4) and (5) of Section 99;

(c) Sections 108 to 152; and

(d) Section 155. *1990, c. 18, s. 90; 1994, c. 36, s. 26; 1999 (2nd Sess.), c. 12, s. 42.*

Duties of holder

91 The holder of a lease or non-mineral registration shall provide the Registrar with written notification

(a) where it is anticipated that production will be suspended for a period greater than sixty days;

(b) immediately following a production suspension of sixty days; or

(c) where it is intended to resume production. *1990, c. 18, s. 91; 1999 (2nd Sess.), c. 12, s. 43.*

Rights of holder and duty of Minister

92 (1) Subject to this Act, a non-mineral registration gives the registrant the right to carry on the production of gypsum or limestone that has not been declared a mineral pursuant to Section 5 within the area designated in the non-mineral registration and shall be limited to such area as may be required for the purpose of the mine.

(2) repealed 1999 (2nd Sess.), c. 12, s. 44.

(3) Where the Minister issues a non-mineral registration, the Minister shall cause it to be forwarded to the applicant and file a duplicate with the Registrar who shall enter it in the Registrar's records in the manner prescribed.

(4) repealed 1999 (2nd Sess.), c. 12, s. 44.

1990, c. 18, s. 92; 1999 (2nd Sess.), c. 12, s. 44.

93 repealed 1999 (2nd Sess.), c. 12, s. 45.

Review of permit

94 (1) The Minister shall review a non-mineral registration when the registrant

(a) fails to commence production or significant development work leading to production within two years of obtaining the non-mineral registration;

(b) fails to submit the prescribed annual information reports;

(c) wishes to surrender the non-mineral registration; or

(d) commences production in accordance with this Act and the annual report required pursuant to this Act indicates that no production has occurred within the previous twelve months.

(2) Upon reviewing the non-mineral registration, the Minister may

(a) continue the non-mineral registration for such period of time and upon such terms and conditions as the Minister deems appropriate; or

(b) cancel the non-mineral registration.

(c) repealed 1999 (2nd Sess.), c. 12, s. 46.

(3) Where the Minister continues the non-mineral registration pursuant to clause (a) of subsection (2), the Minister shall review the non-mineral registration at the end of the period during which the non-mineral registration was continued and, upon the review, the Minister may exercise any of the powers set out in subsection (2).

(4) Where, following the review, the Minister is of the opinion that the continuation of the non-mineral registration is not justified, the Minister shall declare the non-mineral registration cancelled and the Registrar, at the direction of the Minister, shall mark the record of the non-mineral registration "Cancelled", amend the record accordingly and forthwith send notification to the registrant of

the cancellation and the reasons therefore. *1990, c. 18, s. 94; 1999 (2nd Sess.), c. 12, s. 46.*

Notice of cancellation of non-mineral registration

95 The Minister may declare a non-mineral registration cancelled not less than thirty days after giving the registrant written notice of a failure to submit the prescribed annual information reports unless the registrant remedies the deficiency before the non-mineral registration is cancelled. *1999 (2nd Sess.), c. 12, s. 47.*

Investigation of mining operation

96 (1) In this Section, "inefficient mining" means the extraction or recovery of a mineral or minerals in a manner that, in the opinion of the Minister,

(a) and (b) repealed 1999 (2nd Sess.), c. 12, s. 48;

(c) unduly affects the ability of the mineral deposit to be mined; or

(d) produces less than an optimum recovery of minerals.

(2) Whenever it is represented to or comes to the knowledge of the Minister that the lessee is conducting inefficient mining, the Minister may order an investigation to determine if the mining operation should be altered or modified to permit the more economical and efficient prosecution of the work.

(3) Following the investigation, the Minister may order such modifications or alternatives as the Minister deems necessary to correct the situation.

(4) The Minister shall serve the lessee with notice of the order.

(5) Where the Minister has served the order, the lessee shall have thirty days to comply with the order or such further time as may be provided in the order.

(6) Where the lessee does not comply with the order pursuant to subsection (5), the Minister may declare the lease forfeited. *1990, c. 18, s. 96; 1999 (2nd Sess.), c. 12, s. 48.*

Security

97 (1) The applicant for a lease, non-mineral registration, an excavation registration or letter of authorization

(a) shall post cash, a negotiable bond or other security, in the case of an application for a lease, non-mineral registration or letter of authorization; or

(b) may be required by the Minister to post cash, a negotiable bond or other security in the case of an application for an excavation registration,

in a form satisfactory to the Minister and in an amount determined in accordance with the regulations to provide for the reclamation of the area that may be disturbed by the activities of the lessee, registrant or holder of an excavation registration or letter of authorization or an agent or assignee of the lessee, registrant or holder of an excavation registration or letter of authorization.

(2) The security required pursuant to subsection (1) is forfeited to the Minister if

(a) in the case of a bond, it is not renewed at least thirty days before its expiry date and reclamation is not completed; or

(b) reclamation has not been completed to the satisfaction of the Minister within the prescribed time.

(3) Subject to Section 120, the security forfeited to the Minister pursuant to subsection (2) may be employed, in whole or in part, under the direction of the Minister to reclaim the area of mining activity and the balance of unexpended funds, if any, shall be returned to the payor. *1990, c. 18, s. 97; 1994, c. 36, s. 28; 1999 (2nd Sess.), c. 12, s. 49.*

98 repealed 1999 (2nd Sess.), c. 12, s. 50.

Termination of mining operations

99 (1) The lessee shall provide the Minister with six months notice in writing of the lessee's intent to permanently terminate mining operations.

(2) Failure to comply with this Section constitutes an offence and is punishable by a fine not exceeding twenty thousand dollars or by imprisonment not exceeding two years less one day.

(3) Where the lessee is required through no fault of the lessee to suddenly and permanently terminate mining operations, the lessee, the legal representative of the lessee or any creditor of the lessee shall forthwith notify the Minister.

(4) Where in the opinion of the Minister it is appropriate, the lessee shall be required to maintain access to the mine for a period of up to thirty days from the date upon which notice was given pursuant to subsection (3).

(5) The costs incurred in maintaining access to the mine from the date upon which operations terminate until the time referred to in subsection (4)

(a) shall be borne by the lessee or the legal representative of the lessee; or

(b) may be paid by the Minister and thereafter shall be recovered from the lessee or the legal representative of the lessee or any of them and form a charge upon the property.

(6) Not later than one month prior to the intended permanent closure of a mine, or within such period as the Minister may determine, the lessee or registrant or legal representative of the lessee or registrant or any of them shall furnish a summary report containing the prescribed information on the workings of the mine, including the reason for the closure, the nature and amount of any mineral remaining in the mine and such existing maps and plans as the Minister may request. *1990, c. 18, s. 99; 1999 (2nd Sess.), c. 12, s. 51.*

Surface rights permit

100 (1) A licensee who is unable to obtain an agreement with the owner or tenant of private lands for the right to

(a) pass over private lands for the purpose of gaining access to the lands covered by the licence or any part thereof; or

(b) pass over, enter upon or work the lands covered by the licence or any part thereof,

may apply to the Minister, after notice to the owner or tenant, for a surface rights permit to pass over, enter upon and work such lands.

(2) The Minister, after hearing the parties, may grant a surface rights permit upon such terms and conditions as the Minister determines, and the Minister may determine the amount of any compensation to be paid to such owner or tenant and the manner and time of payment of the same.

(3) Where the owner or tenant of the private land cannot be located, the Minister may grant a surface rights permit on the terms and conditions determined by the Minister.

(4) The Minister may order the applicant for a surface rights permit to give security for payment of the compensation and may prohibit, pending the determination of the proceeding or until the compensation is paid or secured, further passage over, entry upon or work by such licensee, the licensee's legal representative or any person acting on behalf of the licensee.

(5) Where there are several owners or tenants of the lands sought to be entered upon or passed over and there are, in the opinion of the Minister, special difficulties in effecting service of any notice pursuant to this Section, the Minister may order substituted service in such manner as the Minister may determine.

(6) There is no appeal from the granting by the Minister of a surface rights permit, from the Minister's determination as to the amount of compensation, from any order for security or from any order or decision or ruling in respect thereto.

(7) Where a licensee is delayed in the performance of work on the land covered by the licence by refusal of the owner or tenant of the land to permit the licensee to pass over, enter upon or work the lands and the Minister has granted the licensee a surface rights permit pursuant to this Section, the time within which the licensee is required to perform work under the licence shall be extended by a period equal to the delay resulting from the owner's or tenant's refusal to permit the licensee to pass over, enter upon and work the land.

(8) A surface rights permit granted pursuant to this Section is a decision made by the Minister and may be made a rule or order of the Supreme Court in accordance with Section 172. *1990, c. 18, s. 100; R.S., c. 240, s. 10; 1992, c. 16, s. 39; 1994, c. 36, s. 30.*

Excavation registration

101 (1) A licensee shall submit and have recorded an excavation registration in the manner and form prescribed before commencing

(a) trenching or pitting to prescribed depths;

(b) trenching, pitting or stripping by mechanized means;

(c) underground exploration including shaft sinking, driving of adits, declines, drifts, levels, cross cuts, raises or winzes or the reopening, rehabilitation or dewatering of any such workings;

(d) bulk sampling for the removal of less than one hundred tonnes of mineral-bearing material; or

(e) other prescribed work.

(2) No work shall be commenced pursuant to subsection (1) until the licensee deposits with the Department cash or a bond in the amount and in the form acceptable to the Minister. *1990, c. 18, s. 101; 1999 (2nd Sess.), c. 12, s. 52.*

Bulk sampling

102 (1) A licensee shall obtain a letter of authorization in the manner and form prescribed before commencing bulk sampling for the purpose of extracting one hundred tonnes or more of mineral-bearing material.

(2) The letter of authorization shall be for such term as the Minister determines but shall not exceed the term of the licence or any renewals of the licence.

(3) No work shall be commenced pursuant to subsection (1) until the licensee deposits with the Minister cash or a bond in the amount and in the form acceptable to the Minister. *1999 (2nd Sess.), c. 12, s. 53.*

103 to 106 repealed 1999 (2nd Sess.), c. 12, s. 53.

Interpretation of Sections 108 to 152

107 In Sections 108 to 152,

(a) "allowance for depreciation" means an allowance for the undepreciated value of depreciable assets not exceeding one hundred per cent at the end of each fiscal year for the first three years of a mining operation and an amount not exceeding thirty per cent of the undepreciated value at the end of each year thereafter until the undepreciated value of the assets is wholly allowed;

(b) "allowance for processing" means an allowance by way of return on capital employed in the secondary crushing, grinding, concentrating, chemical extraction, smelting, refining or packaging of output in the Province equal to eight per cent of actual cost borne by the operator of the processing assets and added thereto a further allowance by way of return on capital employed by the operator in respect of assets that were necessary to the servicing and management of the processing activities equal to twenty-five per cent of that amount allowed by way of return on capital for processing assets, but the total to be deducted as an allowance for processing shall not be in excess of sixty-five per cent of net income before deducting the allowance for processing;

(c) "depreciable asset" means the assets in use in the Province by the operator resulting from

(i) the expenses incurred and substantiated by the operator in the exploration for an ore body to the date a lease is acquired if such expense is incurred in relation to assessment work as prescribed and has not been used as a deduction in the calculation of royalties payable by another mining operation in the Province, but where an operator has a mining operation during a fiscal year in which exploration expenses have been incurred, those expenses shall be considered an operating expense of a mine consistent with clause (i) of Section 124,

(ii) the expenses incurred by the operator in the development of a mine from the date the lease is acquired to the date production of the mine begins, if such expense is essential to the production of output from a mine, is approved by the

Mine Assessor and has not been used as a deduction in the calculation of royalties,

(iii) the expenditures for the purchase and installation of mining, milling, power, plant and equipment essential to the production of the output of a mine, and all other expenditures that are, in the opinion of the Mine Assessor, essential for the purpose mentioned in this clause and are not deducted from net income or specifically prohibited pursuant to this Act,

(iv) equipment leased at its fair market value less any amount of buy out, if any, at the effective lease date;

(d) "fiscal year" means the fiscal period, not exceeding twelve months, for which the accounts of the business of an operator have been or are ordinarily prepared and accepted for purposes of assessment pursuant to this Act and, subject to Section 111, in the absence of such an established practice the fiscal period shall be that adopted by the operator;

(e) "Mine Assessor" means an officer designated by the Minister to administer the royalty provisions of this Act and the regulations;

(f) "mining operation" means the extraction of minerals from, or in any mine, and its transportation from the point of egress from the mine including primary crushing and processing to the sale of output;

(g) "operator" means, where used in relation to any mine, the mineral right holder, the mineral right holder's legal representative and, in the case where there is no mineral right holder, the owner or tenant of the property or premises where the mine is situated, and includes a lessee;

(h) "output" means the minerals and mineral products taken, gained or derived from a mining operation or a mine;

(i) "processing assets" means any depreciable asset of an operator that is a building or part of a building in which only secondary crushing, grinding, concentrating, chemical extraction, smelting, refining or packaging activities take place and all equipment that is used solely for secondary crushing, grinding, concentrating, smelting, refining and packaging and is maintained on an available for use basis but does not include those used for primary crushing, to carry ore or output or necessary to the servicing and management of processing assets. *1990, c. 18, s. 107; 1994, c. 36, s. 31.*

Deemed single mine

108 (1) Where mining is conducted in more than one location by the same person or under the same general management or control or jointly controlled by

persons not dealing at arm's length, or the net income of which accrues to the same person are, for the purpose of determining whether that person pays a royalty, deemed to be one mine.

(2) Where mining is carried on by two or more affiliated or associated corporations under the same general control, or the net income of which accrues for the benefit of the same shareholders, the income from the various operations shall be combined and dealt with as the net income of one and the same operator.

(3) Where mining is conducted by two or more operators, each operator is deemed not to be dealing at arm's length with the other.

(4) For the purpose of this Act,

(a) a corporation and a person or one of several persons by whom the corporation is directly or indirectly controlled;

(b) corporations controlled directly or indirectly by the same persons; or

(c) persons connected by blood relationship, marriage or adoption,

are deemed not to be dealing with each other at arm's length. *1990, c. 18, s. 108.*

Allowances proportioned

109 Where the operator provides secondary crushing, grinding, concentrating, chemical extraction, smelting, refining, packaging or otherwise processes any output other than that derived from a mining operation controlled by the operator in the Province, the allowance for processing and the indirect expenses incurred shall be proportioned on the same basis as the operator's output from a mining operation controlled by the operator in the Province is to the total output processed at the facility during the fiscal year. *1990, c. 18, s. 109.*

Deemed cost and deemed receipt of amount

110 (1) An expense or depreciable asset resulting from a non-arm's length transaction is deemed not to exceed the cost of the service supplied or the value of the depreciable asset as approved by the Mine Assessor.

(2) Any operator who has provided services or transferred assets not at arm's length is deemed to have received an amount not less than the cost of such service or the value of the asset at the time of the transfer as approved by the Mine Assessor. *1990, c. 18, s. 110.*

Change in fiscal year

111 No operator shall change the operator's fiscal year without first notifying the Mine Assessor and receiving the approval of the Mine Assessor. *1990, c. 18, s. 111.*

Removal from Province

112 (1) Except for testing, no person shall remove from the Province to any place outside of Canada for processing any output from a mine in the Province without first obtaining the consent of the Minister.

(2) Where the operator files

(a) all smelter or sales contracts or agreements; and

(b) such information as requested by the Mine Assessor,

the Minister may approve the removal from the Province of any ore, mineral or mineral-bearing substance.

(3) Where approval is not obtained pursuant to subsection (1), the Governor in Council may order that the amount of the royalty payable by the operator of the mine be increased to up to three times the amount of the royalty that the operator would otherwise be required to pay. *1990, c. 18, s. 112; 1995-96, c. 8, s. 20.*

Royalties

113 All output, whether gained under authority as may be granted pursuant to this Act or not, is subject to such royalties to the Crown for the use of the Province as are imposed pursuant to this Act and the regulations and the operator shall pay the royalty to the Crown at the times and in the manner set out in this Act and the regulations. *1990, c. 18, s. 113.*

Deemed separate fund and deemed trust

114 (1) The royalty payable by an operator shall be deemed to be held separate from and form no part of the operator's money, assets or estate, whether or not the amount of the royalty has in fact been kept separate and apart from the operator's money, assets or estate.

(2) Every person subject to pay royalties pursuant to this Act is deemed to hold the same in trust for Her Majesty in right of the Province and for the payment over of the same in the manner and at the time provided pursuant to this Act and the regulations, whether or not the amount therefor has in fact been held separate and apart by that person, and the amount, from the moment the output is severed until the royalty is paid, forms a lien and charge on all the estates and interests in the output, slimes and tailings, and all other assets of the mine, or

any of the proceeds thereof, and the lien is deemed to be a mortgage or secured debenture and is payable in priority to all other liens, charges or mortgages in respect of the output, slimes, tailings and all other assets of the mine, or any of the proceeds thereof.

(3) The lien referred to in subsection (2) is not a charge against a parcel registered pursuant to the Land Registration Act until a certificate evidencing the lien has been recorded in the register of the parcel. *1990, c. 18, s. 114; 2001, c. 6, s. 118.*

Circumstances requiring payment of royalty

115 Where it has been found that a mine has been in operation and the operator of the mine or owner of the property or premises where the mine is situated fails to show upon demand a mineral lease, excavation registration or letter of authorization, the Mine Assessor may demand payment of royalty for the quantity of output at the value that the Mine Assessor deems reasonable and it is prima facie evidence that the operator of the mine or owner of the property or premises where the mine is situated has mined output in the quantity and value so determined. *1990, c. 18, s. 115; 1994, c. 36, s. 32; 1999 (2nd Sess.), c. 12, s. 54.*

Royalties payable to Crown and subject to interest and penalty

116 All royalties are payable to Her Majesty in right of the Province and bear interest and penalty from the time when due until paid at the rate and terms fixed by the Governor in Council or this Act. *1990, c. 18, s. 116.*

First charge to Crown

117 Where any royalty, rent, tax, debt or sum of money is due and payable to the Crown by the lessee, the Crown has a first and prior charge on any mineral, mineral stockpile, slimes or tailings and, in addition to any legal remedy available to the Minister in respect of such royalty, rent, tax, debt or sum of money, the Minister may take possession of any mineral, mineral stockpile, slimes or tailings. *1990, c. 18, s. 117.*

Restriction on acquisition

118 (1) Notwithstanding any enactment, no trustee, trustee in bankruptcy, receiver, assignee, liquidator or lienholder shall acquire by any means whatsoever any mineral, mineral stockpile, slimes or tailings or any interest therein where any royalty, rent, tax, debt or sum of money is due and payable to the Crown by the lessee in respect of the lease or otherwise.

(2) Any deemed or actual transfer by the lessee, by any means whatsoever, of any mineral, mineral stockpile, slimes or tailings or any interest therein is void

until such royalty, rent, tax, debt or sum of money is paid to the Crown and the Minister consents to such transfer in writing. *1990, c. 18, s. 118; 1994, c. 36, s. 33.*

Priority of charge of Crown

119 The charge of the Crown for royalties has priority over every other charge against the area, claim or tract covered by the mineral right or permit under which the royalties are payable, and against all fixtures, machinery, goods and chattels used in working and operating the mine situated thereon, and continues against all such fixtures, machinery, goods and chattels, notwithstanding the forfeiture of the mineral right or permit pursuant to this Act. *1990, c. 18, s. 119.*

Use of remaining security

120 Where any debt, sum of money, royalty, rent or tax is due and payable to the Crown by the lessee, the Minister may use and apply the balance of any money or security held, including that designated for the purposes of reclamation, if such reclamation has been completed to the Minister's satisfaction, to such debt, sum of money, royalty, rent or tax due and payable to the Crown. *1990, c. 18, s. 120.*

Amount of royalty

121 (1) The operator is liable for and shall pay an annual royalty of

(a) two per cent of the net revenue; or

(b) fifteen per cent of all net income,

whichever is the greater.

(2) Notwithstanding subsection (1), where gross income for the fiscal year is less than an amount as may be prescribed, upon written notice from the Mine Assessor, the royalty payable by the operator shall be two per cent of net revenue.

(3) In lieu of a royalty imposed pursuant to subsection (1) or (2), upon notice in writing to the operator of a mine by the Minister, the operator shall pay the royalty determined from time to time by the Governor in Council. *1990, c. 18, s. 121.*

Calculation of gross income

122 Gross income shall be calculated during a fiscal year using

(a) when output is sold, the consistent use in any fiscal year of either

(i) the market price of the output at the time of sale, or

(ii) the market price of the output at the time of shipment;

(b) when output is transferred from or consumed at a mining operation, the market price of the output at the time of the transfer or consumption. *1990, c. 18, s. 122.*

Calculation of net revenue

123 Net revenue for a fiscal year is the gross income derived from output less

(a) marketing costs;

(b) shipping costs;

(c) smelting costs;

(d) refining costs;

(e) packaging costs; and

(f) associated and related costs if paid or borne by an operator. *1990, c. 18, s. 123.*

Calculation of net income

124 Net income shall be calculated by taking the amount of net revenue and deducting therefrom the reasonable operating expenses of a mining operation if paid for or borne by the operator, and such reasonable operating expenses may include, without restricting the generality of the foregoing,

(a) allowance for depreciation;

(b) allowance for processing;

(c) actual costs of restoration, reclamation or rehabilitation of the mine incurred during the year and for this purpose, costs of reclamation completed after a mining operation has ceased may be considered as prior years operating expenses and applied in reverse order to prior fiscal years royalty returns to reduce royalties payable to not less than two per cent of net revenue for each fiscal year applied;

(d) primary crushing and processing costs;

(e) actual and proper working expenses of the mine both underground and above ground, including salaries and wages of all necessary employees employed at the mine and the proper salaries and office expenses for necessary office work done at the mine;

(f) head office costs that relate directly to a mining operation;

(g) cost of insuring the equipment, buildings and the stock in storage;

(h) municipal taxes paid by the operator or payments made to essential municipal or public services in lieu of municipal taxes;

(i) prescribed expenditures on assessment work conducted in the Province incurred during the fiscal year if the expenditure is paid or incurred by the operator;

(j) cost of workers' compensation and other contributions to the health and welfare of employees working at the mine;

(k) cost of utilities;

(l) cost of food or provisions for employees;

(m) cost of fuel and explosives and other supplies used in a mining operation;

(n) cost of safeguarding and protecting the mine;

(o) cost of repair and maintenance with respect to movable and immovable property used at the mine;

(p) cost of shafts, excavation, drifts, trenches, borings or other means of development in the area under lease, including the mine; and

(q) donations made in the Province for educational or charitable purposes which have been approved by the Mine Assessor. *1990, c. 18, s. 124; 1999 (2nd Sess.), c. 12, s. 55.*

Prohibited reductions

125 No reduction of gross income shall be made in respect of

(a) operating expenses and allowances attributable to output held in inventory;

(b) cost of plant, machinery, equipment or buildings;

(c) capital invested, interest or dividends upon being paid;

(d) reduction in the value of any asset, including a mineral right, by reason of exhaustion of the minerals;

(e) payments made with respect to the acquisition of surface rights or acquisition of a mineral title;

(f) cost of incorporation, organization or reorganization;

(g) expenses related to manufacturing and industrial enterprises;

(h) royalties payable pursuant to this Act;

(i) taxes on profit or capital;

(j) reserves and provisions except where specifically permitted in this Act;

(k) the portion of expenses or assets recovered by the operator;

(l) deductions allowed in computing a previous year's profit;

(m) lease payments;

(n) direct costs incurred by the operator in the provision of secondary crushing, grinding, concentrating, smelting, refining, packaging or otherwise processing any output other than that derived from a mining operation in the Province controlled by the operator; or

(o) any sum expended, except to the extent that it is expended by the operator for the purpose of realizing or producing a profit from mining. *1990, c. 18, s. 125.*

Information

126 Every lessee in the Province, without any notice or demand and within three months of the expiration of its fiscal year, shall deliver to the Mine Assessor information the Mine Assessor deems necessary to aid in the verification of royalty liability. *1990, c. 18, s. 126; 1999 (2nd Sess.), c. 12, s. 56.*

Examination of information

127 The Mine Assessor shall cause all returns received by the Mine Assessor to be examined as soon as practical after receipt. *1990, c. 18, s. 127.*

Filing of return

128 Every trustee, trustee in bankruptcy, assignee, liquidator and receiver and every agent or other person administering, winding up or controlling in any

manner whatever the property, business, estate or income of an operator who has not filed the return for a fiscal year shall, without notice, file such a return. *1990, c. 18, s. 128.*

Filing of return

129 Where production has terminated prior to the end of a fiscal year, a return shall be filed with the Mine Assessor within three months of the cessation of production. *1990, c. 18, s. 129.*

Time extension

130 Where an operator has attempted to provide a return within the time provided and has requested an extension of time, the Mine Assessor may grant such a single extension not to exceed three months. *1990, c. 18, s. 130.*

Notice of assessment

131 After completion of the examination of an operator's return, the Mine Assessor shall assess the amount of the royalty and give a notice of the assessment of royalties, interest and penalties, if any, to the operator and it shall be dated as of the day on which it is sent. *1990, c. 18, s. 131.*

Additional royalty

132 Any additional amount of royalty assessed, and penalty or interest charged, if any, is payable on the date of the assessment or charge. *1990, c. 18, s. 132.*

Liability for royalty

133 (1) Notwithstanding any prior assessments or if no assessment has been made, an operator continues to be liable for any royalty due and payable.

(2) The Mine Assessor, for reasonable cause, may reassess an operator's annual return and the operator is liable for, and shall pay any additional amount of, royalty due. *1990, c. 18, s. 133.*

Formalities of notice of assessment

134 Every notice of assessment pursuant to this Act shall be in writing and shall be sufficiently given if it is delivered or mailed to the operator, and the notice of assessment is, for all purposes of this Act, deemed to be given to the operator five days after the day on which it is sent. *1990, c. 18, s. 134.*

Application of over-payment

135 Where the examination of an operator's return discloses that an overpayment has been made by the operator, the Minister, on the certificate of the Mine Assessor as to the facts, may apply the overpayment to such debt, sum of money, rent or tax due the Crown, and any remaining balance of the overpayment may be returned to the operator. *1990, c. 18, s. 135.*

Due date of royalties under s. 121(1)(a)

136 (1) Subject to Section 138, payment of royalties imposed by clause (a) of subsection (1) of Section 121 shall be made not later than thirty days after the end of each applicable quarter of the operator's fiscal year in respect of which the royalty is payable, in an amount equal to two per cent of net revenue for the quarter of which the royalty is payable.

(2) The payment of the balance due pursuant to subsection (1) is payable upon filing of the annual return or within three months after the fiscal year, whichever is earlier.

(3) Subject to Section 138, payments of royalties imposed pursuant to subsection (2) of Section 121 shall be made not later than thirty days after the end of each applicable four quarters of the fiscal year in respect of which the royalty is payable. *1990, c. 18, s. 136.*

Due date of royalties under s. 121(3)

137 All royalties imposed by subsection (3) of Section 121 are due and payable quarterly on the twentieth day in each of the months of January, April, July and October in each year. *1990, c. 18, s. 137.*

Variation of payment date

138 Where an operator, upon application, has provided written detail estimating that the royalties payable for a fiscal year are to be less than one thousand dollars, the Mine Assessor may allow payment to be made thirty days after the end of the operator's fiscal year. *1990, c. 18, s. 138.*

Liability for and application of royalties

139 (1) Every operator subject to royalty shall pay to the Minister royalty, interest and penalty, if any, in respect of every fiscal year.

(2) A royalty payment made by an operator shall be first applied to any outstanding balance of interest and penalty charged to the operator. *1990, c. 18, s. 139.*

Interest on balance of annual royalties owing

140 Where the amount paid by an operator for a fiscal year is less than the amount assessed as royalties and penalty, if any, for that year, the operator shall pay interest at the Crown's long term borrowing rate in effect at the time the annual return was due on the balance payable to the Crown until payment in full had been made. *1990, c. 18, s. 140.*

Interest on balance for quarter

141 Where the amount paid by an operator for royalties and penalty, if any, for a quarter is less than the amount required to be paid, the operator shall pay interest at the Crown's long term borrowing rate in effect at the time the quarterly payment is due on the balance payable to the Crown to the day of payment or the day the annual return is due, whichever is earlier. *1990, c. 18, s. 141.*

Penalties

142 (1) Every operator who

(a) makes or participates in the making of a false statement in any return filed or made pursuant to this Act or the regulations;

(b) evades payment of a royalty imposed pursuant to this Act or the regulations;

(c) destroys, alters, mutilates or otherwise disposes of any record required to be kept pursuant to this Act or the regulations; or

(d) fails to keep records or accounts required to be kept pursuant to this Act or the regulations,

is liable to a penalty of fifty per cent of the amount of the royalty evaded or sought to be evaded.

(2) Every operator required to pay royalties pursuant to this Act who fails to pay royalties within the time provided is liable to a penalty of one per cent of the outstanding amount due or twenty-five dollars per month, whichever is greater.

(3) Every operator who fails to deliver to the Minister an annual return within the time provided is liable to a penalty of five per cent of the royalty due. 1990, c. 18, s. 142.

Records of account of operator

143 (1) Every operator shall keep at or near the mine all records of account, including financial, production and general business records, pertaining to the mining operation.

(2) Notwithstanding subsection (1), upon application the Mine Assessor may authorize an operator to keep records of account in an area other than the mine. *1990, c. 18, s. 143; 1999 (2nd Sess.), c. 12, s. 57.*

Additional records of account

144 (1) Every operator liable to pay a royalty shall also keep proper records of accounts showing

(a) each of the deductions and allowances used in the determination of net revenue and net income;

(b) the return from the smelter, refinery or mill;

(c) the return of the amount derived from the sale of mineral output; and

(d) any information required by the Mine Assessor.

(2) If a doubt arises as to where any record of account is required to be kept, how it is to be kept or what records of account shall be kept, the Minister shall, by written order, determine the matter.

(3) Where the operator has been granted permission to maintain records of account and reports elsewhere than in the Province, the operator is required to recompense the Province for expenditures including travel of persons authorized by the Minister to examine the records of account at the location where they are maintained.

(4) Except as may otherwise be approved by the Mine Assessor, whoever is required pursuant to this Act to keep records of account shall retain them for seven years following termination of the lease to which the records apply. *1990, c. 18, s. 144; 1994, c. 36, s. 34.*

Entry, search and seizure

145 With the approval of a judge or justice of the peace which may be granted on demand ex parte following on information made under oath, the Minister may, for all purposes respecting the application of this Act and the regulations, authorize any officer of the Department or any other person whom the Minister designates and any peace officer whom such officer or person calls to his aid, to enter into or upon any premises used in connection with a mining operation and seek therein for documents, records, registers, papers or other things that may be used as evidence of an offence against this Act or a regulation, to seize and remove such documents, records, registers, papers or other things and keep them until they have been produced in judicial proceedings. *1990, c. 18, s. 145.*

Restriction on time of search

146 The search contemplated by Section 145 shall not be made before seven o'clock in the forenoon or after eight o'clock in the afternoon or on a holiday except under express written authorization of the judge who approved it. *1990, c. 18, s. 146; 1999 (2nd Sess.), c. 12, s. 58.*

Operator's right to examine things seized

147 The Minister shall allow, upon request, the operator in whose hands it was at the time of the seizure, the examination of any document, record, register, paper or other thing seized. *1990, c. 18, s. 147.*

Demand for information and documents

148 The Minister may, by a formal demand delivered by registered mail or personal service, require from any operator that the operator file, by registered mail or personal service within a reasonable delay fixed by the Minister,

(a) information or additional information including a return, report or supplementary return or report required pursuant to this Act; or

(b) records, letters, accounts, invoices, financial statements or other documents. *1990, c. 18, s. 148.*

Time for compliance with demand under s. 148

149 The operator to whom the demand is referred pursuant to Section 148 must, within the time provided, comply with that demand whether or not the operator has previously filed such information or documents. *1990, c. 18, s. 149.*

Information privileged

150 (1) Notwithstanding the Freedom of Information and Protection of Privacy Act but subject to this Section, information or documentation provided for the purpose of this Act or any regulation made pursuant to this Act, whether or not such information or documentation is required to be provided pursuant to this Act or any regulation made thereunder, is privileged and shall not knowingly be disclosed without the consent in writing of the person who provided it or as otherwise provided in this Act except for the purposes of the administration or enforcement of this Act for the purposes of legal proceedings relating to such administration or enforcement.

(2) No person shall be required to produce or give evidence relating to any information or documentation that is privileged pursuant to subsection (1) in connection with any legal proceedings, other than proceedings relating to the

administration or enforcement of this Act. *1990, c. 18, s. 150; 1999 (2nd Sess.), c. 12, s. 59.*

Agreements

151 (1) The Minister may, for the purpose of aiding in an investigation for purposes under this or any other Act, enter into an agreement with the Government of Canada or government of any other province under which officers of such government will be allowed access to information obtained, or any written statement furnished pursuant to this Act and officers of the Government of the Province will be allowed access to information obtained or any written statement furnished, under any act of such government.

(2) Such information shall not be disclosed to the government of any province or the Government of Canada other than those to which there is an agreement to exchange such information.

(3) The provinces and Canada under such agreement shall keep the information and documents obtained in the same manner as if such information or documents were obtained directly from the operator pursuant to each party's relevant mining royalty legislation. *1990, c. 18, s. 151.*

Powers of Mine Assessor

152 The Mine Assessor, or any other officer designated by the Minister, within normal business hours may

(a) audit or examine the records of account which, in the opinion of the Mine Assessor or officer, assist the Mine Assessor or officer in verifying the amount of royalty payable pursuant to this Act;

(b) examine any process or methods, an examination of which may, in the opinion of the Mine Assessor or officer, assist in verifying the amount of royalty payable pursuant to this Act;

(c) require the owner or manager of the property or business or any other person on the premises to give all reasonable assistance to the Mine Assessor or officer in respect of the audit or examination, either orally or, should the said authorized person so require, in writing, on oath or by solemn affirmation, and for that purpose, require the owner or manager to attend the premises; and

(d) where during the course of an audit or examination, the Mine Assessor has reasonable and probable grounds to believe that there has been a violation of this Act or the regulations,

(i) with the consent of the operator, remove any records, accounts, vouchers, letters, telegrams and other documents,

(ii) otherwise, subject to Section 145, with a search warrant enter upon the premises where the records are kept and remove any records, accounts, vouchers, letters, telegrams and other documents and retain them until they are produced in any judicial proceeding. *1990, c. 18, s. 152.*

Appeal of assessment

153 (1) Where a notice of assessment shows that

(a) a royalty has been assessed in an amount greater than that paid to the Minister;

(b) a penalty has been assessed; or

(c) interest has been charged,

the operator so notified may, within sixty days from the date of the notice of assessment, serve the Minister with the notice of appeal and Sections 169, 172 and 173 apply mutatis mutandis.

(2) The notice shall state

(a) the name and address of the appellant;

(b) that the appellant thereby appeals against an assessment for royalty or penalty or interest made against him in respect of the period stated in the notice;

(c) the grounds for the appeal or the particulars of the objection to the assessment. *1990, c. 18, s. 153.*

Offence and penalty for contravention

154 (1) Any person who fails to comply with or otherwise contravenes any of the provisions of this Act or any order made thereunder or who interferes with any officer who is carrying out any duties pursuant to this Act or any order made thereunder is guilty of an offence and is, where no penalty is specifically provided in this Act, liable on summary conviction to a fine not exceeding two thousand dollars, and in default of payment to imprisonment for a term not exceeding six months.

(2) The conviction of any person pursuant to this Act for failure to comply with any requirement or obligation referred to in subsection (1) does not operate as a

bar to further prosecution for the continued failure of that person to comply. *1990, c. 18, s. 154.*

Entry and inspection by officer

155 Subject to Section 145, an officer may at any reasonable time enter upon an area where mining is or has taken place for the purpose of making an investigation and obtaining information as to the amount and value of the output of the mine and, for this purpose, the officer may descend all pits and shafts and use all such tackle, machinery and appliances belonging to the mine as deemed necessary or expedient, and shall have free access to all buildings, erections and vessels used in connection with the mine, and shall be allowed to take from the property such samples or specimens as the officer deems necessary for the purpose of determining, by assay or otherwise, the mineral content or value of ore, minerals or mineral-bearing substances being taken therefrom, or any product thereof, and the officer shall have full and complete access and may require the production of all records, accounts, correspondence and documents maintained or used for or in connection with the actual operations and business of such mine, and may examine the same and take copies thereof or extracts therefrom, but any information of a private or confidential nature acquired shall not be disclosed to anyone except so far as may be necessary for the purpose of this Act. *1990, c. 18, s. 155; 1999 (2nd Sess.), c. 12, s. 60.*

Entry or working on private land without consent or permit

156 (1) Any person who passes over, enters upon or performs surface work on private land without the consent of the owner or tenant of the land, or without having obtained a surface rights permit pursuant to Sections 40 or 100, is guilty of an offence and liable upon summary conviction to a fine not exceeding ten thousand dollars.

(2) Where a person is convicted of an offence pursuant to this Act and another person has, as a result of the commission of the offence, suffered damage caused by the person convicted, the court may, on the application of the person who suffered the damage, determine the amount of the damage and order restitution by the person convicted.

(3) repealed 1999 (2nd Sess.), c. 12, s. 61.

1990, c. 18, s. 156; 1994, c. 36, s. 35; 1999 (2nd Sess.), c. 12, s. 61.

Mining without lease or registration

157 Any person who mines without the appropriate lease or non-mineral registration is guilty of an offence and is liable upon summary conviction to a fine

not exceeding ten thousand dollars per day for each day that the offence occurs or continues. *1999 (2nd Sess.), c. 12, s. 62.*

Entry and search by officer

158 (1) An officer may enter upon any property or premises where the officer has reasonable and probable grounds to believe that any person is mining without the appropriate lease or non-mineral registration and may search such property and premises.

(2) Where any property or premises referred to in subsection (1) is a dwelling-house, an officer shall not enter that dwelling-house without the consent of the occupant except under the authority of a warrant issued pursuant to subsection (3).

(3) Where on ex parte application a justice of the peace is satisfied by information on oath that entry to a dwelling-house is necessary for any purpose relating to the administration or enforcement of this Act and

(a) that entry to the dwelling-house has been refused; or

(b) entry has not been sought on the ground that there are reasonable and probable grounds to believe that evidence contained in the dwelling-house would be destroyed or otherwise disposed of if a request for entry were made,

the justice of the peace may issue a warrant authorizing the officer named therein to enter that dwelling-house subject to the conditions specified in the warrant.

(4) In executing a warrant issued pursuant to subsection (3), the officer named therein shall not use force unless the officer is accompanied by a peace officer and the use of force has been specifically authorized in the warrant.

(5) Where it is found that mining has been carried on and the person who has carried on the mining fails to show, upon demand, the appropriate lease or non-mineral registration, an officer may order that person to cease mining and

(a) order that person to reclaim any works, pits, shafts or slopes in or from which mining has been carried out; or

(b) direct the reclamation of such works, pits, shafts or slopes and charge the cost of doing so to that person.

(6) Where the Province performs or causes to be performed, at its own cost, reclamation pursuant to clause (b) of subsection (5), the Minister may certify the amount of the cost of such reclamation to be a debt due to the Crown and the

amount thereof forms a lien on the property or premises which may be registered in the registry of deeds for the registration district in which the property or premises are situated.

(7) The lien referred to in subsection (6) is not a charge against a parcel registered pursuant to the Land Registration Act until a certificate evidencing the lien has been recorded in the register of the parcel. *1990, c. 18, s. 158; 1994, c. 36, s. 36; 2001, c. 6, s. 118; 1999 (2nd Sess.), c. 12, s. 63.*

Seizure by peace officer

159 (1) Where a peace officer has reasonable and probable grounds to believe that a person is or has been mining without the appropriate lease or non-mineral registration, any mineral produced and any installation, equipment or vehicle used in connection with the operation may be seized.

(2) Where a peace officer has seized anything pursuant to subsection (1), the peace officer shall

(a) without delay report particulars of the seizure to the Department; and

(b) where the peace officer has knowledge of the person who was in apparent possession of the mineral, installation, equipment or vehicle at the time of seizure, give notice to that person of the seizure either by personal service or by registered mail.

(3) Where a person is convicted of an offence pursuant to this Act or the regulations, the court or judge may, in addition to any other penalty imposed, order that the mineral, installation, equipment or vehicle seized pursuant to subsection (1) be

(a) forfeited to Her Majesty in right of the Province; or

(b) returned to the owner thereof, or make such other order as the court sees fit.

(4) Where a person is acquitted of an offence, the court or judge shall order that the mineral, if any, installation, equipment or vehicle seized be returned to the owner thereof.

(5) Where a charge is not laid within three months of the date of seizure, and the owner of the mineral, if any, installation, equipment or vehicle seized is known, the Minister shall order that the seized goods be returned to the owner. *1990, c. 18, s. 159; 1999 (2nd Sess.), c. 12, s. 64.*

160 repealed 1999 (2nd Sess.), c. 12, s. 65.

Mining after forfeiture of lease or registration

161 Any person who continues to operate a mine after the forfeiture of a lease or non-mineral registration is guilty of an offence and is liable, upon summary conviction, to a fine not exceeding ten thousand dollars per day for each day that the offence occurs or continues. *1990, c. 18, s. 161; 1999 (2nd Sess.), c. 12, s. 66.*

162 and 163 repealed 1999 (2nd Sess.), c. 12, s. 67.

Contravention of Section 25

164 A person who contravenes Section 25 is guilty of an offence and is liable to a penalty not exceeding one hundred dollars for every day during which the offence occurs and continues. *1990, c. 18, s. 164.*

Consequence of offence by corporation

165 Where a corporation has committed an offence pursuant to this Act, an officer, director or agent of the corporation who directed, authorized, assented to, acquiesced in or participated in the commission of the offence is a party to and guilty of the offence and is liable on summary conviction to the punishment provided for the offence, whether or not the corporation has been prosecuted. *1990, c. 18, s. 165.*

166 repealed 1999 (2nd Sess.), c. 12, s. 68.

Duties of Registrar where failure to comply

167 (1) Where the Registrar has reason to believe that this Act or a term or condition of a mineral right or non-mineral registration has not been complied with, the Registrar shall

(a) investigate the matter and shall, where necessary, with or without notice, make an investigation of the premises;

(b) notify the mineral right holder or registrant of the non-compliance; and

(c) provide the mineral right holder or registrant with an opportunity, exercisable within such reasonable period of time as may be determined by the Registrar, to make representations to the Registrar.

(2) Where the Registrar is satisfied that this Act or a term or condition of a mineral right or non-mineral registration has not been complied with, the Registrar may grant the mineral right holder or registrant thirty days to remedy the non-compliance.

(3) Where the Registrar determines that the mineral right holder or registrant has not complied within the time referred to in subsection (2), the Registrar shall

(a) refer the matter, with his recommendations, to the Minister; and

(b) notify the mineral right holder or registrant of the referral described in clause (a).

(4) Failure on the part of a mineral right holder or registrant to comply with this Section may result in forfeiture of the mineral right or non-mineral registration.

(5) The Registrar, at the direction of the Minister, shall mark the mineral right or lease "Forfeited" or non-mineral registration "Cancelled", amend the record accordingly and forthwith send notification to the mineral right holder or registrant of the forfeiture or cancellation and the reasons therefor that are deemed to have been received five days after being so sent.

(6) A mineral right holder or registrant whose mineral right or non-mineral registration has been forfeited or cancelled pursuant to subsection (3) may, within twenty days of receiving notice of the forfeiture or cancellation, appeal the forfeiture or cancellation to the Minister in the manner provided by Section 169.

(7) Upon the forfeiture of a mineral right or cancellation of a non-mineral registration pursuant to subsection (4), the Registrar shall forthwith post in the office a notice of the forfeiture or cancellation and land or claims comprised in such mineral right or non-mineral registration shall thereupon, unless withdrawn from application, be again open to application at a time set by the Registrar, but such application shall be subject to the result of an appeal by a mineral right holder whose claim has been forfeited or registrant whose non-mineral registration has been cancelled. *1990, c. 18, s. 167; 1994, c. 36, s. 38; 1999 (2nd Sess.), c. 12, s. 69.*

Entitlement to document

168 The mineral right holder or registrant is entitled, upon payment of the prescribed fee, to a certified copy of any report of inspection filed with the Registrar in respect of that holder's mineral right or non-mineral registration. *1990, c. 18, s. 168; 1999 (2nd Sess.), c. 12, s. 70.*

Appeal to Minister

169 (1) Any person aggrieved by a decision of an officer may appeal to the Minister in the manner prescribed.

(2) On appeal the Minister shall examine the matter de novo and give the appellant and any other persons the Minister considers may be interested an opportunity to be heard.

(3) On appeal the Minister has all the powers of the officer appealed from and the decision of the Minister is final. *1990, c. 18, s. 169.*

Investigation by Minister or substitute

170 The Minister or a person appointed, employed or designated by the Minister may make an investigation into any matter to which this Act applies and, for the purpose of the investigation, the Minister or the person making it has all the powers, privileges and immunities of a commissioner appointed pursuant to the Public Inquiries Act. *1990, c. 18, s. 170.*

Powers on investigation

171 Upon an investigation, the Minister or person designated by the Minister has any one or all of the following powers:

(a) to accept, either in whole or in part, any application previously refused;

(b) to amend and adjust the mineral rights of the mineral right holders in dispute;

(c) to adjust the rights of various persons in dispute;

(d) to order any mineral right holder to cease any or all operations pending the outcome of the investigation;

(e) to make such further order for the disposal of the case as appears to be just; and

(f) to refer any question or issue to the Supreme Court for hearing and consideration. *1990, c. 18, s. 171.*

Conversion of decision or order of Minister to Court order

172 (1) Any decision or order made by the Minister or officer pursuant to this Act may be made a rule or order of the Supreme Court and may be enforced in a like manner as a rule, order, decree or judgment of such Court.

(2) To make a decision or order referred to in subsection (1) a rule or order of the Supreme Court, the Minister may make a certified copy of the decision or order upon which shall be made the following endorsement signed by the Minister:

Make the within a rule or order of the Supreme Court of Nova Scotia.

Dated this . . . . day of . . . . , 19. . . . .

. . . .

Minister of Natural Resources

and the Minister may forward the certified copy, so endorsed, to the prothonotary of the Supreme Court who shall, on receipt thereof, enter it as a record and it is thereupon a rule or order of the Supreme Court and is enforceable as any rule, order, decree or judgment thereof. *1990, c. 18, s. 172; 1992, c. 14, s. 61.*

Appeals to Court

173 (1) Notwithstanding subsection (6) of Section 100, any person aggrieved by any decision of the Minister or a person appointed by the Minister, except as in this Act otherwise provided, may within thirty days from the date of such decision appeal to a judge of the Supreme Court.

(2) A decision of the judge of the Supreme Court is final.

(3) An appeal lies to the Court of Appeal upon a question of law. *1990, c. 18, s. 173; R.S., c. 240, ss. 9, 10; 1992, c. 16, ss. 38, 39.*

Regulations

174 (1) The Governor in Council, on the recommendation of the Minister, may make regulations

(a) repealed 1999 (2nd Sess.), c. 12, s. 71;

(b) respecting the restoration, reclamation and rehabilitation of land affected by exploration or mining activities;

(c) governing the mining and recovery of any minerals, mineral-bearing substance, gypsum or limestone;

(d) respecting the use of mineral resources;

(e) respecting returns, reports, records and statements to be submitted or maintained by a mineral right holder, registrant or prospector;

(f) defining the kind and quantity of assessment work required for a renewal of an exploration licence or special licence and the manner and form in which evidence of such work shall be submitted;

(g) defining categories of acceptable work and specifying credit which a licensee may receive for work in each category;

(ga) respecting safety and unsightliness of property to which Section 76 applies;

(h) respecting conditions for opening, closing, reopening and abandoning mines and for rendering a mine inaccessible;

(i) respecting requirements relating to reclamation and rehabilitation of mines;

(j) respecting the establishment of boundaries of mineral lands;

(k) governing the survey of a mineral right;

(l) prescribing forms and providing for their use;

(m) prescribing fees and rentals payable pursuant to this Act;

(ma) prescribing the contents of reports made pursuant to this Act and the manner in which such reports shall be made;

(n) prescribing interest rates and establishing, from time to time, a formula by which interest rates may be calculated;

(o) respecting securities and determining their form and terms;

(p) respecting payments in lieu of assessment work and refunds of such payments;

(q) respecting confidentiality of any information filed with the Department;

(r) respecting the method of application, content, form, terms and conditions of mineral rights licences, notices, non-mineral registrations, letters of authorization and leases;

(s) respecting the definition of minerals for the purpose of this Act;

(t) prescribing the administration, rate and terms of royalties;

(u) repealed 1999 (2nd Sess.), c. 12, s. 71;

(v) requiring from the mineral right holder, persons searching, prospecting or mining or the operator of a mine, statistical information respecting work or operations;

(w) respecting the form and content of records and the manner in which they are to be kept and maintained by the Registrar;

(x) respecting the form and content of notices;

(y) prescribing that certain words and phrases shall be deemed to be contained in licences, leases, excavation registrations, non-mineral registrations and letters of authorization and that certain words therein have an extended meaning;

(z) prescribing the manner of service and defining what is sufficient service of any document or notice referred to or required by this Act or the regulations;

(aa) prescribing the content of a summary required pursuant to subsection (1) of Section 87;

(aaa) respecting the assignment of work and responsibilities, rights and duties under this Act to officers and employees of the Department;

(aab) respecting the submission of excess assessment work as credit for a later application to renew a licence and the allowable time period for such submissions;

(aac) respecting the method of submission and recording, content, form, terms and conditions of excavation registrations as well as the circumstances under which an excavation registration may be refused;

(aad) respecting the circumstances under which a letter of authorization may be refused and the prohibiting of certain activities without a lease or letter of authorization;

(aae) respecting exploration drilling;

(aaf) respecting access to municipal water supply watershed lands;

(aag) respecting uranium encounters.

(ab) defining any word or expression used in this Act and the regulations and not defined in this Act;

(ac) for the better carrying out of the provisions of this Act.

(2) The exercise by the Governor in Council of the authority contained in subsection (1) shall be regulations within the meaning of the Regulations Act. *1990, c. 18, s. 174; 1994, c. 36, s. 39; 1999 (2nd Sess.), c. 12, s. 71.*

Confidentiality

175 (1) Notwithstanding the Freedom of Information and Protection of Privacy Act and except as otherwise provided in this Act and the regulations, all feasibility studies, financial data, mine and mill design studies and plans and equipment specifications in respect of a mine, and information submitted pursuant to Section 61 shall remain confidential for the life of the relevant mineral lease or non-mineral registration.

(2) Notwithstanding subsection (1), the Minister may release information referred to in subsection (1)

(a) notwithstanding any enactment, if there is a grave environmental danger involving the mine to which the information pertains; or

(b) for the purpose of providing statistics regarding mineral production, employment, municipal taxes or economic impacts on the Province, if the statistics are general in nature and do not disclose financial or technical data that would result in undue financial gain or loss to the mineral right holder, registrant or another person.

(3) Notwithstanding Section 47, the assessment work report is confidential for two years from the date of submission but if the licence expires before the two-year period expires, the report submitted and held in confidence shall be released.

(4) Notwithstanding subsections (1) and (3),

(a) the mineral right holder or registrant may, upon application to the Registrar in writing showing reasonable cause, apply for an extension of the period of confidentiality granted pursuant to this Section and the Registrar may grant such extension;

(b) the period of confidentiality may be terminated

(i) where the mineral right holder or the registrant, as the case may be, agrees to a release of the information, or

(ii) where a mineral right or non-mineral registration is surrendered, cancelled, forfeited, abandoned or has expired;

(c) the Minister may use confidential information with the consent of the owner of the information. *1990, c. 18, s. 175; 1994, c. 36, s. 40; 1999 (2nd Sess.), c. 12, s. 72.*

Existing exploration licence

176 (1) An exploration licence in good standing at the coming into force of this Act continues to be subject to the terms and conditions of Chapter 286 of the Revised Statutes, 1989, until the next anniversary date of the licence.

(2) At any time on or before the anniversary date referred to in subsection (1), a licensee shall file two hundred dollars of assessment work per claim.

(3) Where the work required pursuant to subsection (2) is filed and the requirements for renewal pursuant to this Act are met on or before the anniversary date referred to in subsection (1), the exploration licence referred to in subsection (1) shall, on such anniversary date, be replaced by an exploration licence issued pursuant to this Act.

(4) The assessment work required for the renewal of the replacement licence issued pursuant to this Act is that prescribed for the year dating from the time when the original licence was first issued. *1990, c. 18, s. 176.*

Existing development licence

177 (1) Any development licence in good standing at the coming into force of this Act continues to be subject to Chapter 286 of the Revised Statutes, 1989, until the next anniversary date of the development licence.

(2) Upon the anniversary date referred to in subsection (1), the development 1icence expires and upon application and payment of fees shall be substituted by an exploration licence issued pursuant to this Act and the amount of assessment work thereafter required is that prescribed for the year dating from the time when the original exploration licence, which was subsequently converted to the development licence, was issued. *1990, c. 18, s. 177.*

Special licence

178 A special licence in good standing at the coming into force of this Act is subject to this Act for the remainder of its term. *1990, c. 18, s. 178.*

Excess assessment work

179 (1) Any excess assessment work that was recorded by the Department to the credit of an exploration licence or development licence which is valid at the

coming into force of this Act may be applied to the assessment work requirements of the mineral rights granted pursuant to this Act.

(2) Notwithstanding subsection (2) of Section 48, work conducted pursuant to a development licence which is valid at the coming into force of this Act, if acceptable to the Registrar and adequately documented, may be applied to the assessment work requirements of the exploration licence issued pursuant to subsection (2) of Section 177. *1990, c. 18, s. 179.*

Existing lease

180 A lease in good standing at the coming into force of this Act is and is deemed to be a lease issued pursuant to this Act for the remainder of its term upon the coming into force of this Act. *1990, c. 18, s. 180.*

181 and 182 repealed 1999 (2nd Sess.), c. 12, s. 73.

Existing declaration

183 A declaration made pursuant to Section 5 of Chapter 286 of the Revised Statutes, 1989, continues in force and has the same force and effect as if made pursuant to Section 5 of this Act. *1990, c. 18, s. 183.*

Advisory committee

183A The Minister shall appoint an advisory committee to initiate a comprehensive review of this Act and the regulations within five years of the coming into force of this Section and the committee shall submit to the Minister, within six months of initiating the review, a report that includes amendments, if any, recommended by the committee. *1999 (2nd Sess.), c. 12, s. 74.*

Repeal

184 Chapter 286 of the Revised Statutes, 1989, the Mineral Resources Act, is repealed. *1990, c. 18, s. 184.*

Proclamation

185 This Act comes into force on and not before such day as the Governor in Council orders and declares by proclamation. *1990, c. 18, s. 185.*

THE MUNICIPALITY OF THE COUNTY OF CUMBERLAND BY-LAW 06-05

SECONDARY PLANNING STRATEGY

FOR THE

JOGGINS PLANNING AREA

The provisions of this Secondary Planning Strategy apply in addition to and take precedence over the provisions of the County of Cumberland's primary Municipal Planning Strategy where there is a conflict.

Effective Date August 17, 2006

Amendment to the Municipality of the County of Cumberland

Municipal Planning Strategy

to adopt the

Secondary Municipal Planning Strategy

for the

Joggins Planning Area

This is to certify that the attached is a true copy of the amendment to the Municipality of the County of Cumberland Municipal Planning Strategy, which was passed at a duly called meeting of the Cumberland Municipal Council held on July 19, 2006.

Given under the hand of the Clerk of the Municipality of the County of Cumberland and under the corporate seal of the said Municipality this 19th day of July 2006.

Rennie J Bugley

Rennie Bugley
Clerk, The Municipality of the County of Cumberland

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MAPS:

1. INTRODUCTION

In 2005, the Municipality of the County of Cumberland Council began preparing a Secondary Municipal Planning Strategy for the Joggins Area (See Map 1: Joggins Planning Area). Council recognized that the area had unique land use opportunities and issues that could not be adequately addressed by the County-wide Municipal Planning Strategy alone.

Council realized that, because of the potential nomination of the Joggins Fossil Cliffs as a World Heritage Site and the proposal to build a multi-million dollar interpretative centre in the community, the County had an opportunity to contribute to the revitalization of the Joggins area and support the designation of the World Heritage Site. Council decided that they wanted to ensure that local people would benefit to the greatest extent possible from the Joggins Fossil Cliffs' investment and, in turn, ensure the development of a sustainable and appropriate tourism industry. Council realized that, for this to happen, proper land use planning and development control would be essential to ensure there would be sufficient land designated to meet the local community's economic development and quality of life needs and that the management of the resources of the Joggins Fossil Cliffs would be supported.

It is Council's intention that the Secondary Municipal Planning Strategy for the Joggins Area will address these opportunities and issues.

1.1 The Joggins Planning Area

The Joggins Planning Area (See Map 1: Joggins Planning Area) is located in Cumberland County on the shores of Chignecto Bay which is part of the Bay of Fundy. It includes the existing community of Joggins and the sites of the historic settlements of Lower Cove and Ragged Reef. Joggins is located on Highway 242, approximately 45 kilometers from the Nova Scotia-New Brunswick border. The highway becomes Main Street in Joggins and ends at the fossil cliffs.

The Joggins Planning Area is described to include both the nominated Joggins Fossil Cliffs World Heritage Site and the lands within existing local municipal boundaries. On the west side of the planning area, the nominated World Heritage Site extends 16 kilometers from Downing Head, in the north, to Ragged Reef, in the south. It also extends 500 meters seaward from the cliff faces and beaches. On the east side, the municipal boundaries are the General Service Areas established by the Province of Nova Scotia and adopted by Cumberland County Council and the boundary of the incorporated Village of River Hebert. The potential World Heritage Site and municipal boundaries overlap where they meet at the cliffs and beaches.

1.2 History

As with most of Nova Scotia, the first settlers of the Joggins area were the Mi'kmaq. European settlement began around 1700 when coal was first mined by the French and English military. The commercial use of coal from the area began around the mid-1800s. The coal industry and the community of Joggins grew and prospered until the early 1900s.

Other early successful economic activities in the area were grindstone quarrying, at Lower Cove and Ragged Reef, and lumbering.

The historic built character of the Joggins area is typical of rural Nova Scotia with well-spaced residential, commercial and institutional buildings of traditional design, cladding and strong vertical lines. The current population is approximately 500. There are approximately 200 dwelling units in the area.

1.3 The Joggins Fossil Cliffs

The fossil cliffs of Joggins are a world-renowned palaeontological site. They have been designated a Special Place under the Province of Nova Scotia's Special Places Protection Act (Chapter 438, of the Revised Statutes, 1989). The cliffs are located in an area where the tides are some of the world's highest (over 15 meters). This tidal action causes steady erosion of the 23 meter high cliffs and a regular exposure of new fossil resources.

The cliffs have yielded fossils which have given an unprecedented glimpse of life during the Carboniferous Period (350 to 280 million years ago).

Joggins became famous for fossilized tree trunks found in their original upright positions. In 1851, when Charles Lyell, author of The Principles of Geology, and Sir William Dawson, author of Acadian Geology and *Air Breathers of the Coal Period*, visited the site, they discovered the remains of reptiles and amphibians entombed in some of the fossilized tree trunks embedded in the cliffs. The remains were, in fact, the remains of the world's first known reptiles, and the first evidence that land animals had lived during the "Coal Age."

1.4 Municipal Planning

Land use planning and development control are well-established parts of the management of Canadian municipalities. Enabling legislation in the Province of Nova Scotia is the Municipal Government Act, 1999. The Secondary Municipal Planning Strategy for the Joggins Planning Area has been prepared in accordance with the provisions of this legislation.

The Municipal Government Act, 1999 permits a municipal council to adopt a municipal planning strategy. As such, it is a legally binding planning document. Such a strategy sets out a council's vision or intentions for the future development of the municipality. As such, a municipal planning strategy is a legal document which contains a generalized future land used map for the municipality and statements of policy to deal with development problems, opportunities and effects on the natural, social and economic environment of a planning area. The Act also sets out statements of provincial interest which are guiding provincial planning principles with which all municipal planning documents must be reasonably consistent.
The Municipal Government Act, 1999 also deals with how the policies of municipal planning strategies are to be implemented. Policies for controlling land use and development must be prepared and implemented or carried out through a land use bylaw and which must be adopted by Council at the same time as the adoption of the municipal planning strategy.

The land use bylaw contains the details of how the policy statements contained in the municipal planning strategy will be implemented. It sets out "zones" for different land uses and establishes lists of permitted uses and development regulations for each zone. The Act also empowers municipalities to control further details of development through such means as development agreements and site plan approvals. In addition, the Act permits municipalities to prepare secondary municipal planning strategies to deal with issues that are unique to specific areas within a municipality. The Secondary Municipal Planning Strategy for the Joggins Planning Area is such a planning document.

The Municipality of the County of Cumberland adopted its first primary municipal planning strategy in 1993. Since then, it has been updated to account for changes in Provincial legislation and County land use planning priorities. This primary planning document contains policies which deal generally with maintaining the rural character and aesthetically pleasing environment of the County, ensuring land use compatibility, environmental protection and promoting residential, business and tourism development. It also deals with a few county-wide planning issues, such as salvage yards and minimum lot sizes, but its main function is to provide a framework for secondary municipal planning strategies, such as the one for the Joggins Planning Area, which will provide focused and detailed planning for this specific area of the municipality.

1.5 Preparation of the Secondary Municipal Planning Strategy

The Municipal Planning Strategy for the Joggins Planning Area was adopted by the Council of the Municipality of the County of Cumberland on the advice of the Joggins Area Planning Advisory Committee. This Committee was established to undertake research and community consultation toward preparing goals and policies for the secondary municipal planning strategy. The mandate of the Committee was to prepare policies that would support the stewardship and management of the fossil resources of the Joggins Fossil Cliffs, pursuant to the applicable operational guidelines of UNESCO, and the interests of local community members. The policies were to ensure that the development of the Joggins Fossil Cliffs would have a positive impact on the Joggins area.

1.6 Community Consultation

At an early community open house (November 21, 2005), the Joggins Area Planning Advisory Committee was told by community members that some of their future planning priorities for the Joggins area were:

- protecting the fossil resources and public views and enjoyment of the cliffs;
- the preservation of residents' rights to continue the existing use of their properties;
- creating opportunities for the development of tourist facilities;
- cleaning-up dangerous and unsightly public and private properties;
- providing barrier free access to buildings for persons with disabilities; and,
- applying design standards to the extent required to prevent extremes in development and departures from the traditional rural Nova Scotia character of the community, but not to impose rigid architectural controls.

At a subsequent community meeting (April 24, 2006), the Joggins Area Planning Advisory Committee presented a draft of the Secondary Municipal Planning Strategy and accompanying amendments to the Land Use Bylaw. The committee was told by community members that:

- The environmental protection designation along the cliffs, beaches and coastal roads is too restrictive from the perspective of the current property rights of the people. This designation should be removed from the plan;
- It should be clarified that there will be no restrictions on outdoor firewood storage, clothes lines, the keeping of a small number of farm animals, maintaining buildings where they are now located, through "grandfathering" provisions, or architectural controls on the design of new buildings; and,
- The practicality of dealing with outdoor storage and unsightly premises through fencings and screening was questioned.

At a final community meeting (May 29, 2006), the Joggins Area Planning Advisory Committee presented a further draft of the planning strategy and land use bylaw amendments which illustrated the changes that had been made to accommodate the wishes of the residents, as presented at the April 24, 2006 meeting. There were no further concerns raised by the community members in attendance at the meeting.

1.7 General Application

Generally, Cumberland County Council regards the interests of the residents of the community and the potential designation of the Joggins Fossil Cliffs as a World Heritage Site as a key consideration when dealing with any proposed development or updates of the municipal planning strategy or land use bylaw for the Joggins Planning Area that could impact the Joggins Fossil Cliffs. County Council will expect the same respect for their significance from all other levels of government and public agencies.

Council also recognizes that the Secondary Municipal Planning Strategy is reasonably consistent with the applicable Statements of Provincial Interest. In particular, the implementation of the Secondary Municipal Planning Strategy will make efficient use of existing infrastructure by requiring that more intensive development will be directed to areas where piped sewer services are available.

2. Overriding Goal

> *"The overriding goal of the Secondary Municipal Planning Strategy for the Joggins Planning Area is to support healthy and sustainable community development by ensuring that future growth and development throughout the Joggins Area will support the goals and priorities of local community members and maximize the benefits and minimize any adverse effects of the development of the Joggins Fossil Cliffs on the community, and, by ensuring that future land uses and forms of development in the vicinity of the Joggins Fossil Cliffs will protect and enhance their fossil resources and valuable features and be appropriate and compatible with the nominated UNESCO World Heritage Site and Interpretative Centre.*

3. Policies

3.1 In order to provide opportunities for sustainable community development:

(i) a) Land Use Designations

It shall be the intention of Council to establish, on Map 2: Future Land Use of the Secondary Municipal Planning Strategy for the Joggins Area (the "planning strategy"), a variety of land use designations that will be sufficient in terms of size and location to meet the needs of community residents for business development and housing opportunities and not excessive in order to protect their economic development and housing investments. (See Future Land Use map)

b) Land Use Zones

It shall be the intention of Council to include in amendments to the Land Use Bylaw (the "land use bylaw"), which will be adopted by Council at the same time as the adoption of the planning strategy, a variety of land use zones that will contain lists of permitted and accessory uses and development regulations that are necessary to implement the policies of the planning strategy.

c) Residential Designations

It shall be the intention of Council to establish, on the Future Land Use map of the planning strategy, three residential designations: Community Residential, General Residential and Transitional Residential. The Community Residential designation will cover areas where public sewer services are available and, therefore, provide opportunities for the concentration of a wider range of residential and other uses. The General Residential designation will cover areas where piped sewer services are not available and, therefore, a narrower range of residential and business uses, as well as agricultural uses, will be permitted. The Transitional Residential designation will cover areas where piped sewer services are proposed. Until then, the General Residential designation will apply. Afterwards, the Community Residential designation will apply.

d) Wind Turbines by Development Agreement

It shall be the intention of Council, within the General Residential designation, to permit large-scale wind turbines provided that surrounding properties within 300 meters do not suffer any environmental, aesthetic, noise or safety impact. In negotiating the development agreement Council shall ensure that the proponent provides a report and site plans to assess and demonstrate how any impacts of such matters as avian mortality, noise, shadow flicker, ice throw and electromagnetic interference will be mitigated; how aviation and public safety will be assured; how construction will be undertaken, how trespassing will be prevented and how the site will be decommissioned, remediated and restored; and, how the decommissioning will be secured financially with the municipality. The pertinent conclusions of the report and site plans shall be included in the development agreement.

e) Residential Zone Uses

It shall be the intention of Council to include in the land use bylaw, a list of uses that will be permitted in the Community Residential Zone and General Residential Zone, such as a variety of housing forms, public uses, home occupations, and tourist homes, small-scale agricultural uses and tourist commercial uses along Shulie, Hardscrabble and Lower Cove Roads.

f) Residential Zone Regulations

It shall be the intention of Council to include in the land use bylaw, development standards for the Residential Zones to ensure that the range of permitted uses and development requirements will be appropriate for areas with or without piped sewer services, and for agricultural uses. For home occupations and tourist homes, the land use bylaw will contain special requirements such as those that will ensure that they will be sensitive to the residential appearance of nearby buildings. For agricultural uses, the land use bylaw will regulate the number of animals and the location of animal housing and/or manure storage facilities in order to avoid potential negative environmental impacts or impacts on nearby existing, residential development.

g) Community Commercial Designation

It shall be the intention of Council to establish, on the Future Land Use map of the planning strategy, a Community Commercial designation that will function as a re-established traditional retail and service commercial town centre that will be accessible by foot and will become a social gathering and meeting place and provide a sense of place for the community. This Commercial designation will be located generally along both sides of Main Street, from Hardscrabble Road to Alderson Street, and along the east side of Hurley Road and north side of Shulie Road.

h) Community Commercial Zone Uses

It shall be the intention of Council to include in the land use bylaw, a list of uses that will be permitted in the Community Commercial Zone, such as a wide range of retail and service commercial and tourist accommodation uses, interpretative centre-related businesses, living-working designed buildings, existing residences, home occupations and tourist homes.

i) Community Commercial Zone Special Requirements

It shall be the intention of Council to include in the land use bylaw, special requirements for the Community Commercial Zone to ensure that the town centre will be pedestrian friendly, aesthetically pleasing and that renovations and new development will complement its town centre setting and be compatible with the overall rural Nova Scotia character of the community.

j) Institutional Designation

It shall be the intention of Council to establish, on the Future Land Use map of the planning strategy, an Institutional designation that will encompass the site of the primary Joggins Fossil Cliffs interpretative centre. This Institutional designation will be located at the westerly end of Main Street.

k) Institutional Zone

It shall be the intention of Council to include in the land use bylaw, a list of uses that will be permitted in the Institutional Zone that will complement the interpretative centre.

l) Utility Designation

It shall be the intention of Council to establish, on the Future Land Use map of the planning strategy, a Utility designation that will encompass the site of the site of the existing sewage treatment facility.

m) Utility Zone

It shall be the intention of Council to include in the land use bylaw, a Utility Zone to encompass the site of the existing sewage treatment facility.

3.2 In order to support the stewardship of the resources, features and setting of the Joggins Fossil Cliffs:

a) Cliffs and Shoreline Setback

It shall be the intention of Council to include in the land use bylaw, development restrictions in areas within 20 meters of the cliffs and shoreline to ensure that there will be no development or environmental effects from activities or land uses that will interfere with the natural erosion processes which regularly expose fossil resources at the cliffs or adversely affect the setting or views of the Joggins Fossil Cliffs or the aesthetic qualities of the views and natural vistas along the shorelines.

b) Prohibited Uses and Structures

It shall be the intention of Council to include in the land use bylaw, provisions, in areas within 20 meters of the cliffs and shoreline, that will regulate the grading or alteration in elevation or contour of the land and the excavation and deposition of fill and will prohibit the defacing of the face of the cliffs, the construction of any permanent or temporary structures, including large scale wind turbines, communications towers and billboards or signs and the placing or outdoor storage of any scrap or salvage material or inoperative motor vehicles or their parts. This provision does not prohibit the accessory storage of material, such as firewood or compost, for the use of residents of the property.

3.3 In order to protect the aesthetic quality, traditional style and historic character of the community:

a) Panoramic View Protection

It shall be the intention of Council to establish in the land use bylaw special requirements to protect the important views of the community, cliffs, beaches and bay through such means as controls on site alteration, unsightly outdoor storage, obtrusive developments, and setbacks from cliff and beaches.

b) Cliffs View Protection

It shall be the intention of Council to include in the land use bylaw special requirements to preserve the views of the cliffs from the beach area by prohibiting the construction of any fence, sign or structure that would be visible from the beach area that is not required for public safety or security purposes.

c) Piped Sewer Services

It shall be the intention of Council to include in the land use bylaw, a provision that more intensive development will be directed to areas where piped sewer services are available.

d) Outdoor Storage and Facilities

It shall be the intention of Council to establish in the land use bylaw, provisions to prohibit the outdoor storage of scrap or salvage materials or inoperative motor vehicles or their parts. This provision does not prohibit the accessory storage of material, such as firewood and compost, for the use of residents of the property. The land use bylaw will also contain provisions for the location and placement of wind turbines, outdoor wood furnaces, outdoor lighting and signs.

3.4 In order to enhance the quality of life for the residents of the Joggins area:

a) Protection of Non-Conforming Uses and Structures

It shall be the intention of Council to establish in the land use bylaw, provisions to protect the rights of existing residents to the continuation of the existing use of their land and properties, including the repair, renovation, recommencement, replacement or reconstruction of legal non-conforming structures or uses, as permitted by the Municipal Government Act.

b) Housing Alternatives

It shall be the intention of Council to establish in the land use bylaw, provisions for opportunities for a variety of alternate forms of housing and converted dwellings to meet the needs of all ages, incomes and special requirements.

c) Outdoor Lighting Control

It shall be the intention of Council to establish in the land use bylaw, regulations for outdoor lighting in order to preserve the ability to view the night sky, conserve resources and protect against direct glare and light trespass onto nearby properties and public highways.

d) Public Health and Safety

It shall be the intention of Council to support provisions for public health, safety and welfare, such as regulations for clean-up of dangerous or unsightly premises; the design, illumination and maintenance of all walkways, trails, public open space and parking areas; the protection of private property; and, building accessibility for all persons with disabilities.

e) Traffic Management

It shall be the intention of Council to support the provision of efficient traffic and parking facilities, road signage for safety and the upgrading and/or realignment of hazardous roads in consultation with the province.

f) Community Development

It shall be the intention of Council to support community and downtown revitalization and façade enhancement programs and support initiatives for locally generated employment and tourism-related business investment that will capitalize on the Joggins Fossil Cliffs investments and the proposed World Heritage Site designation and benefit the community in the long term.

g) Community Stabilization

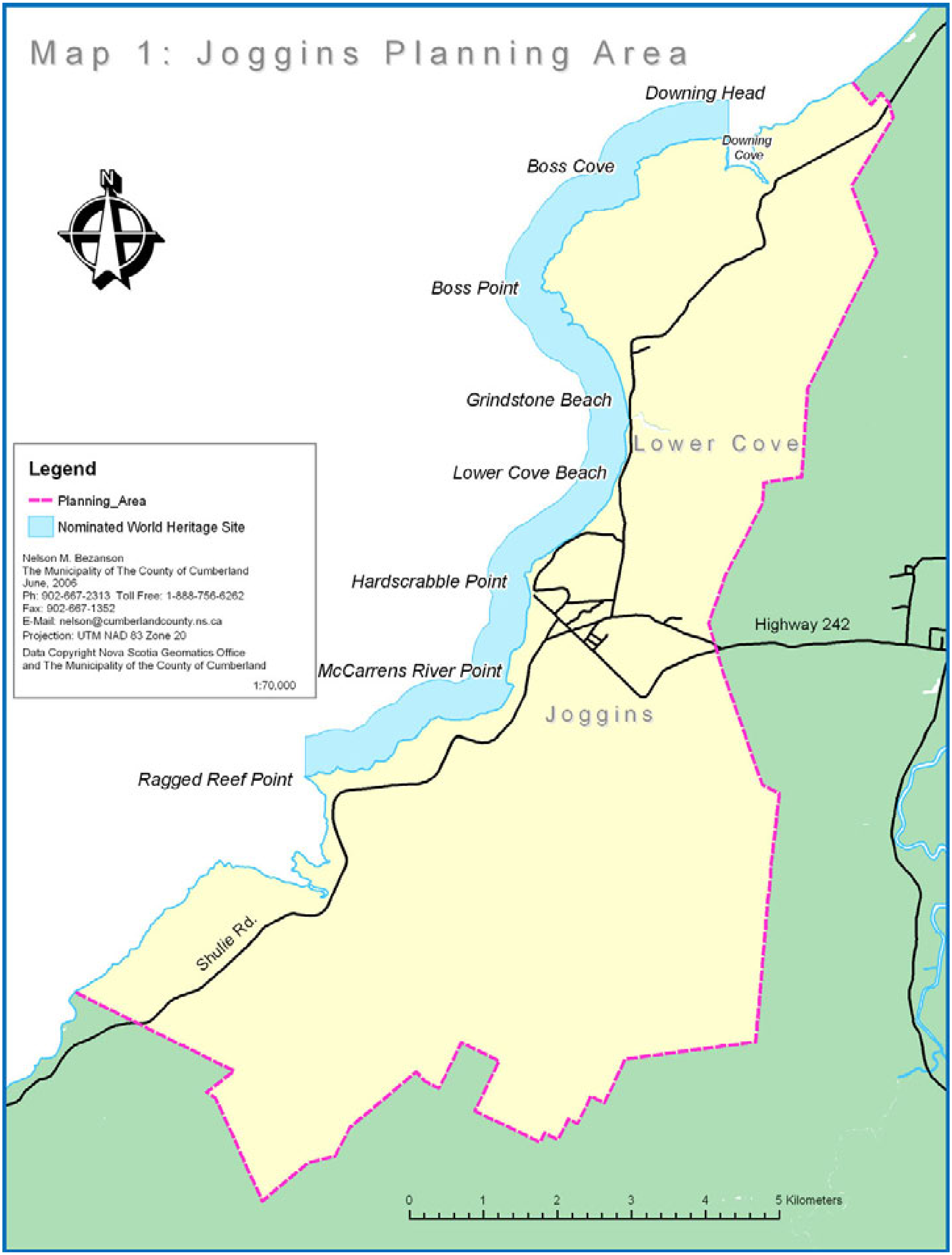
It shall be the intention of Council to support the rural development and community stabilization efforts of provincial and federal levels of government, other public agencies and the private sector to maintain existing and provide new educational and training opportunities and health, safety and social support services for community members.

h) Community Linkages

It shall be the intention of Council to support community-based initiatives and regional linkages for business development, educational, social and cultural investments to capitalize on the tourism potential of the area as a result of the Joggins Fossil Cliffs development.

i) Dark-Sky Preserve

It shall be the intention of Council to support community initiatives to have the Joggins area designated a Dark-Sky Preserve. This is a designation that private citizens can seek, in cooperation with the Royal Astronomical Society of Canada, in order to promote the area for viewing the night sky and support local efforts to improve regulations for exterior lighting. These would protect the ability to view the night sky which, in turn,
would help to attract visitors and preserve the quality of life in the community.


Map 1: Joggins Planning Area
Downing Head
Downing Cove
Boss Cove
Boss Point
Grindstone Beach
Lower Cove
Lower Cove Beach
Hardscrabble Point
Highway 242
McCarrens River Point
Joggins
Ragged Reef Point
Shulie Rd.
Legend
Planning_Area
Nominated World Heritage Site
Nelson M. Bezanson
The Municipality of The County of Cumberland
June, 2006
Ph: 902-667-2313 Toll Free: 1-888-756-6262
Fax: 902-667-1352
E-Mail: nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
Data Copyright Nova Scotia Geomatics Office
and The Municipality of the County of Cumberland
1:70,000
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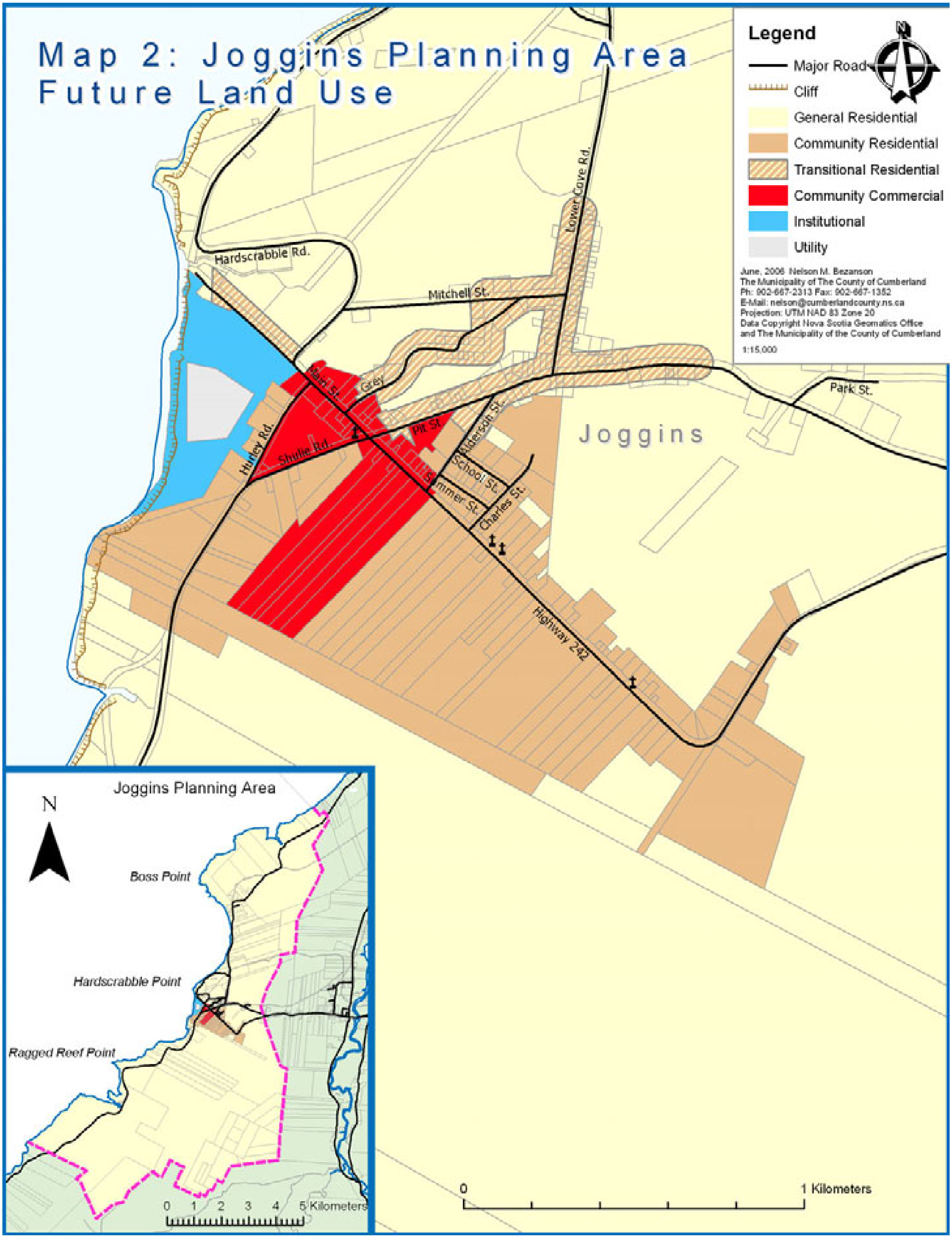


Map 2: Joggins Planning Area
Future Land Use
Legend
Major Road
Cliff
General Residential
Community Residential
Transitional Residential
Community Commercial
Institutional
Utility
June, 2006 Nelson M. Bezanson
The Municipality of The County of Cumberland
Ph: 902-667-2313 Fax: 902-667-1352
E-Mail: nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
Data Copyright Nova Scotia Geomatics Office
and The Municipality of the County of Cumberland
1:15,000
Hardscrabble Rd.
Mitchell St.
Lower Cove Rd.
Main St.
Grey
Pit St.
Shulie Rd.
Hurley Rd.
Alderson St.
School St.
Summer St.
Charles St.
Highway 242
Park St.
Joggins
0
1 Kilometers
Joggins Planning Area
N
Boss Point
Hardscrabble Point
Ragged Reef Point
0 1 2 3 4 5 Kilometers

THE MUNICIPALITY OF THE COUNTY OF CUMBERLAND BY-LAW 06-06

LAND USE BYLAW

FOR THE

JOGGINS PLANNING AREA

The provisions of this Land Use Bylaw apply in addition to and take precedence over the provisions of the County of Cumberland's primary Land Use Bylaw where there is a conflict.

Effective Date August 17, 2006

Amendment to the Municipality of the County of Cumberland

Land Use Bylaw

to adopt the

Amendments to the Land Use Bylaw

for the

Joggins Planning Area

This is to certify that the attached is a true copy of the amendments to the Municipality of the County of Cumberland Land Use Bylaw, which were passed at a duly called meeting of the Cumberland Municipal Council held on July 19, 2006.

Given under the hand of the Clerk of the Municipality of the County of Cumberland and under the corporate seal of the said Municipality this 19th day of July 2006.

Rennie J Bugley

Rennie Bugley
Clerk, The Municipality of the County of Cumberland

TABLE OF CONTENTS

MAPS:

PERMITTED USES

General Residential Zone	Community Residential Zone
General Residential Zone single detached dwellings double dwellings converted dwellings home occupations tourist homes tourist commercial uses: -tourist cabins* -travel trailer/motor home/RV parks* -campgrounds* -restaurants* -motels* -visitor convenience facilities* day care operations parks and open space schools, churches and church hall group homes and homes for special care residential livestock operations agricultural operations accessory uses and buildings *To be located only along Shulie, Hardscrabble & Lower Cove Roads.	**Community Residential Zone** single detached dwellings double dwellings converted dwellings multiple dwellings home occupations tourist homes day care operations parks and open space schools, churches and church halls group homes and homes for special care accessory uses and buildings
Community Commercial Zone retail uses automobile service stations business and professional offices institutional uses public and private schools religious institutions and accessory uses banks and financial institutions restaurants hotels and motels funeral homes personal service shops animal hospitals and veterinarian medical clinics and offices taxi and bus stations private clubs and fraternal organizations craft shops and studios drycleaners and laundromats printing establishments service industries and recycling depots photography studios mixed commercial-residential uses accessory uses and buildings	**Institutional Zone** interpretative centre and related facilities parks and open spaces schools, churches and church halls public buildings government offices and facilities libraries and museums emergency services accessory uses and buildings

ZONE REQUIREMENTS

Zone	Min. Lot Area (sq. m.)	Min. Lot Frontage (m.)	Min. Front & Flanking Yard (m.)	Min. Rear Yard (m.)	Min. Side Yards (m.)	Max. Building Height (m.)
General Residential	**1858**	**30.5**	**6**	**6**	**2**	**11**
General Residential - Tourist Commercial Uses	**1858**	**30.5**	**20**	**20**	**20**	**11**
Community Residential – Single Unit	**557**	**18.3**	**6**	**6**	**2**	**11**
Community Residential – Double Unit	**557**	**18.3**	**6**	**6**	**2**	**11**
Community Residential – Multiple Unit	**100/unit 1000 min.**	**30.5**	**8**	**10**	**2**	**11**
Community Commercial	**557**	**15.3**	**0**	**0/6 adj. to non-com'l**	**2**	**11**
Institutional	**557**	**15.3**	**0**	**0**	**2**	**11**

SPECIAL REQUIREMENTS

Home Occupations - General & Community Residential Zones

Home occupations are business activities carried on wholly within the boundaries of a property upon which is located the residence of the operator of the home occupation. Without limiting the generality of the foregoing shall include: dress making and tailoring, catering, hairdressing and barbershops, custom and craft workshops, instruction and private tutoring, sculpturing, storage of inventory intended for off-site retail sales, business and professional offices such as doctors, lawyers and insurance agents.

Home occupations specifically do not include auto body or mechanical motor vehicle repair, retail stores, canteens, taxi stations or contractors' storage yards.

Home Occupations shall:

- i be permitted within single detached and double dwellings, or accessory structures to such dwellings, operated by the resident of the property;
- ii not occupy more than 25% of the total floor area of the dwelling or 50 square meters, whichever is less, or in the case of accessory structures not more than 25% of the total area of the dwelling and accessory structure combined;
- iii have no visible indication from the exterior of the dwelling unit that a home occupation is being carried out, except for one non-illuminated sign subject to Section 4 of this by-law;
- iv not employ more than 2 assistants not residing in the dwelling;
- v provide 2 off street parking spaces in addition to the normal parking requirements for the zone;
- vi not retail any merchandise not manufactured on the property;
- vii not generate any off site electrical interference, dust, noise smoke or other obnoxious emission; and
- viii not store merchandise, supplies or equipment of any kind in the front yard or otherwise within view of any street.

Tourist Homes – General & Community Residential Zones

Tourist Homes are dwellings where the proprietor supplies rooms to be rented to overnight guests and where a general kitchen and dinning facilities are provided to provide meals to those overnight guests. Tourist Homes shall include Bed and Breakfasts and Guest Homes.

Tourist Homes shall:

- i be limited to single detached and double dwellings;
- ii be limited to no more than 10 sleeping units;
- iii not permit cooking equipment in rooms used or intended to be used for overnight accommodation;
- iv only provide meals or cooking facilities to those renting overnight accommodation;
- v have no visible indication from the exterior of the dwelling unit that tourist accommodation is being provided, except for one non-illuminated sign not exceeding 0.5 square meters in area; and
- vii provide 2 off street parking spaces for every 3 rooms available for rent, or portion thereof, in addition to the normal parking requirements for the zone.

Residential Livestock Operations – General Residential Zone

Residential Livestock Operations to a maximum of 10 animals shall be permitted provided that any animal housing or manure storage facilities are set back a minimum of 50 meters from any residential building, a minimum of 100 meters from the nearest water course and/or off site well and a minimum of 600 meters from an area zoned Community Residential. Existing operations which do not currently satisfy the above setback requirements may expand provided that the expansion does not further reduce the existing setback.

Existing operations which do not currently satisfy the above setback requirements may expand provided that the expansion does not further reduce the existing setback.

Commercial Livestock Operations are not permitted. Commercial Livestock Operations are commercial operations in which animals or fowl are confined to feedlots or buildings for feeding, breeding, egg production, or milking for eventual sale.

Prohibited Uses – Cliffs and Beaches Setback – General Residential Zone

Except for small scale safety and security fences or structures, the following uses and structures are prohibited in a 20 meter landward setback area from the cliffs and beaches: soil removal; grading, excavation or deposition of fill; material storage or processing; permanent or temporary structures, including freestanding utility scale wind turbines, communications towers, fences, cantilevers and billboards or signs; outdoor storage of any scrap or salvage material or inoperative motor vehicles or their parts. This provision does not prohibit the accessory storage of material, such as firewood and compost, for the use of residents of the property.

Signs – All Zones

General

Where this Part is inconsistent with the regulations respecting advertising signs on or near public highways made or administered by the Province of Nova Scotia, the more restrictive regulations shall apply, except where the Provincial regulations permit tourist related signage. In the case of tourist related signage, the Provincial regulations shall apply.

Prohibited Signs

No sign shall be erected, operated, used or maintained which:

i) due to its position, shape, colour, format, or illumination obstructs the view of, or may be confused with, an official traffic sign, signal or device, as determined by the Development Officer;
ii) displays lights or words resembling those usually associated with danger or those used by police, fire, ambulance or other emergency vehicles;
iii) projects over or rests upon any part of the public right-of-way;
iv) is painted on or attached to a utility pole, tree, stone, cliff or other natural object;
v) is advertising a business or is related to a use that is not located on the same site as the sign unless the sign is providing directions to the business on another site;
vi) is a portable sign or roof sign;
vii) is a flashing or animated sign.

Abandoned, Dangerous and Unlawful Signs

Any sign which no longer advertises a bona fide business or service or is in a state of disrepair, abandoned, dangerous or unlawful shall be repaired or removed by the owner or be removed by the Municipality and the expenses involved in such action will be charged to the owner of the sign.

Signs in Residential Zones

i) The maximum number of signs that may be erected, constructed, placed or displayed on a parcel of land within Residential Zones shall be one two-sided sign.
The maximum size of such a sign shall be 1.5 sq. m. per side.
For tourist commercial uses in the General Residential Zone, the requirements for signs in the Commercial and Institutional Zone shall apply.

Signs in Commercial and Institutional Zones

i) The maximum number of signs that may be erected, constructed, placed or displayed on a parcel of land or building within Commercial and Institutional Zones shall be one, two-sided sign per street frontage.
The maximum size of a facial or projecting wall sign or ground sign shall be 3.0 sq. m.
The maximum projection of a projecting wall sign shall be 2 m. and minimum height of a projecting wall sign shall be 3 m. The minimum lot line setback of a ground sign shall be 3 m.

Signs Construction and Illumination

All signs shall be constructed of traditional materials, such as wood, metal or stone, and shall only be illuminated by fully shielded light fixtures mounted on top of the sign and positioned to shine directly on the sign. Window signs may contain paint and neon. Back-lit signs shall be prohibited.

Outdoor Storage – All Zones

Outdoor storage of scrap or salvage materials, including inoperative motor vehicles and their parts, shall be prohibited. This provision does not prohibit the accessory storage of material, such as firewood and compost, for the use of residents of the property. This section is not intended to limit the application of the provisions of Part 15 of the Municipal Government Act. Any property that is dangerous or unsightly, within the meaning of the Municipal Government Act, is subject to Orders or other action, notwithstanding this section.

Outdoor Furnaces – General Residential Zone

Outdoor furnaces or structures containing outdoor furnaces shall be permitted only in the General Residential Zone, be located in rear yards, have a minimum lot line setback of 61 meters and have a chimney or exhaust at least 1 meter above the peak of the roof of any habitable building within 6 meters on the same site or within 100 meters of any habitable building on a neighbouring site.

Outdoor Lighting – All Zones

Flashing lights and lights that could be confused with or interfere with traffic lights or otherwise be hazardous to traffic shall be prohibited.

All parking areas and walkways shall be illuminated and all lighting fixtures used for this purpose shall be fully shielded, designed and mounted to ensure that their direct light is completely restricted to areas below the fixture; is directed downwards towards the surface of the parking area and walkways; and, is directed away from adjacent uses, lots, buildings and public highways.

This provision does not exclude the seasonal use of temporary festive or decretive lighting.

Design – Community Commercial Zone

Applications to construct new buildings or structures or renovate or add to existing buildings or structures in the Community Commercial Zone shall be accompanied by scale drawings to demonstrate how the project will complement the town centre setting and be compatible with the overall rural Nova Scotia character of the community. This provision does not include architectural controls or controls over colour or building materials.

Temporary Uses – All Zones

Development/Building Permits may be issued in any zone-for uses and structures incidental to construction and for assessment facilities for renewable energy generation resources for a temporary period not to exceed 12 months. All sites shall be decommissioned with all structures, accesses and storage being removed and the land being remediated and restored.

Building Height Requirement Exemptions – All Zones

The maximum building height requirements shall not apply to church spires, water tanks, elevator enclosures, silos, flag poles, television or radio antennae, commercial communication towers, ventilators, skylights, barns, chimneys, clock towers, tree houses, wind turbines or solar collection devices.

Accessory Uses and Buildings – All Zones

Accessory uses and buildings are permitted in all zones of this bylaw.

"Accessory use" means a use subordinate and naturally incidental to a main use of land or building located on the same lot, such as the storage of firewood, compost material and the hanging of clothes by the residents of the property or the temporary storage of waste and recyclable material by the operator of a business.

"Accessory building" means a subordinate building or structure on the same lot as the main building, devoted exclusively to an accessory use, such as garden sheds, workshops and storage buildings.

Accessory buildings shall not:
(i) be located in the front yard or flanking yard on a corner lot;
(ii) be more than 4 meters in height;
(iii) be built closer than 2 meters of other structures; and,
(iv) exceed 10 percent of the lot area.

Wind Turbines

Wind turbines are of two types: small-scale wind turbines and large-scale wind turbines.

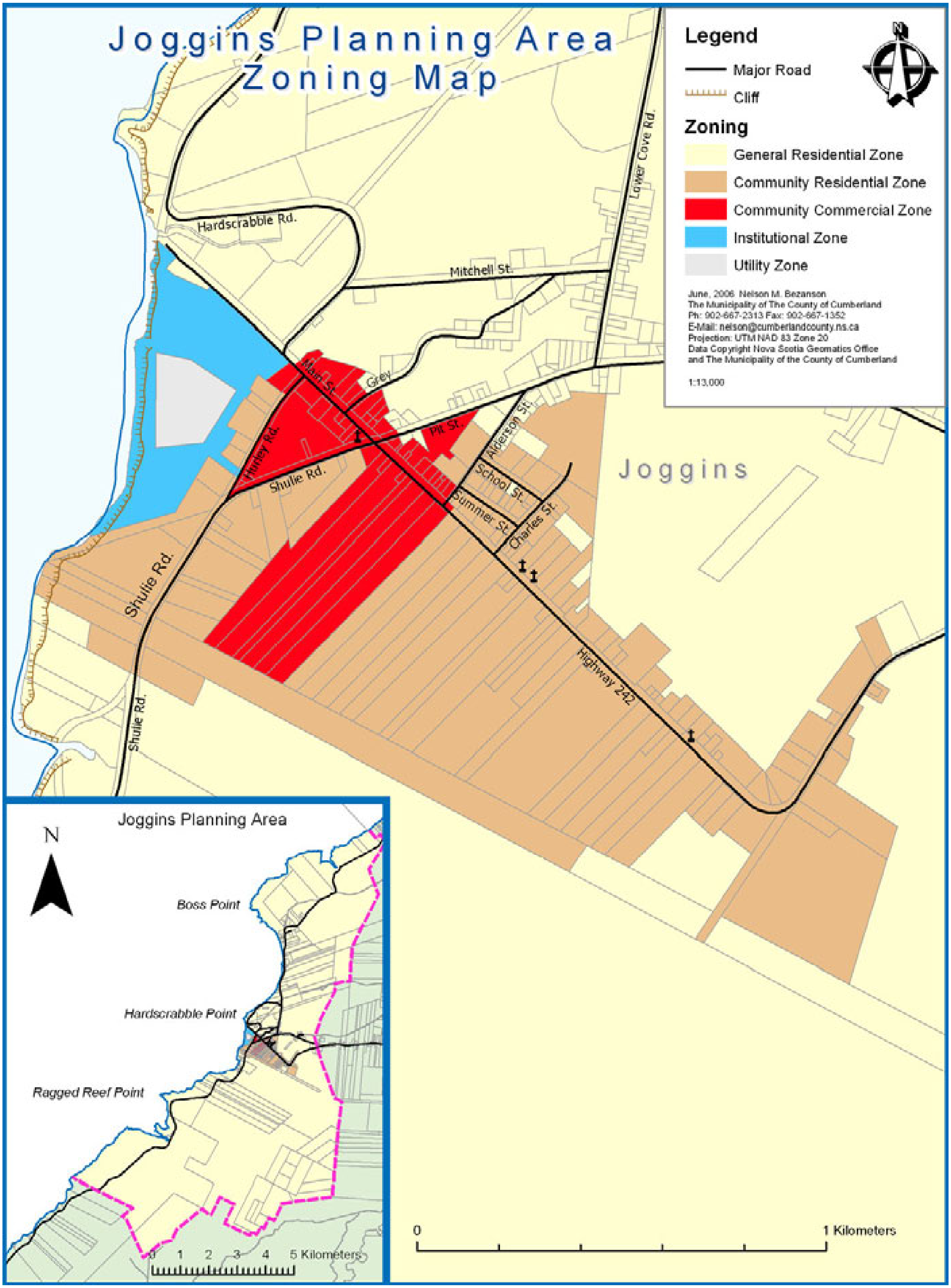
"Small-scale wind turbines" are accessory uses. They may be tied into the grid. However, they generate power primarily for on-site consumption. At a minimum, 50 percent of generated power is consumed on-site. They have a maximum rated output capacity of no more than 100 kilowatts. They are limited to one per site. The turbine, including its tower, rotor blades and nacelle, has a maximum total height of no more than 35 meters, and a minimum rotor ground clearance of no less that 4.5 meters.

“Large-scale, commercial or utility-scale wind turbines” are stand-alone facilities. They provide power to the grid for sale and are often grouped in clusters or “wind farms.” They may be permitted by Development Agreement in accordance with the provisions of Section 3.1 (d) of the Joggins Area Secondary Municipal Planning Strategy.

Small-scale wind turbines and large-scale wind turbines shall be set back from lot lines 125 percent of their total height. They will be decommissioned and removed after 1 year of inactivity. They will contain no signs or advertisements. They will be protected from unauthorized access through the use of fences and locked gates.

Non-Conforming Uses and Structures – All Zones

A use of land or a structure that legally existed prior to the effective date of this bylaw, and is no longer permitted in the zone, in which the use or structure is located, is a non-conforming use. Such legal non-conforming uses and structures may be continued, repaired, and renovated, recommenced, replaced or reconstructed, as permitted by the Municipal Government Act.



Joggins Planning Area
Zoning Map
Legend
Major Road
Cliff
Zoning
General Residential Zone
Community Residential Zone
Community Commercial Zone
Institutional Zone
Utility Zone
June, 2006 Nelson M. Bezanson
The Municipality of The County of Cumberland
Ph: 902-667-2313 Fax: 902-667-1352
E-Mail: nelson@cumberlandcounty.ns.ca
Projection: UTM NAD 83 Zone 20
Data Copyright Nova Scotia Geomatics Office
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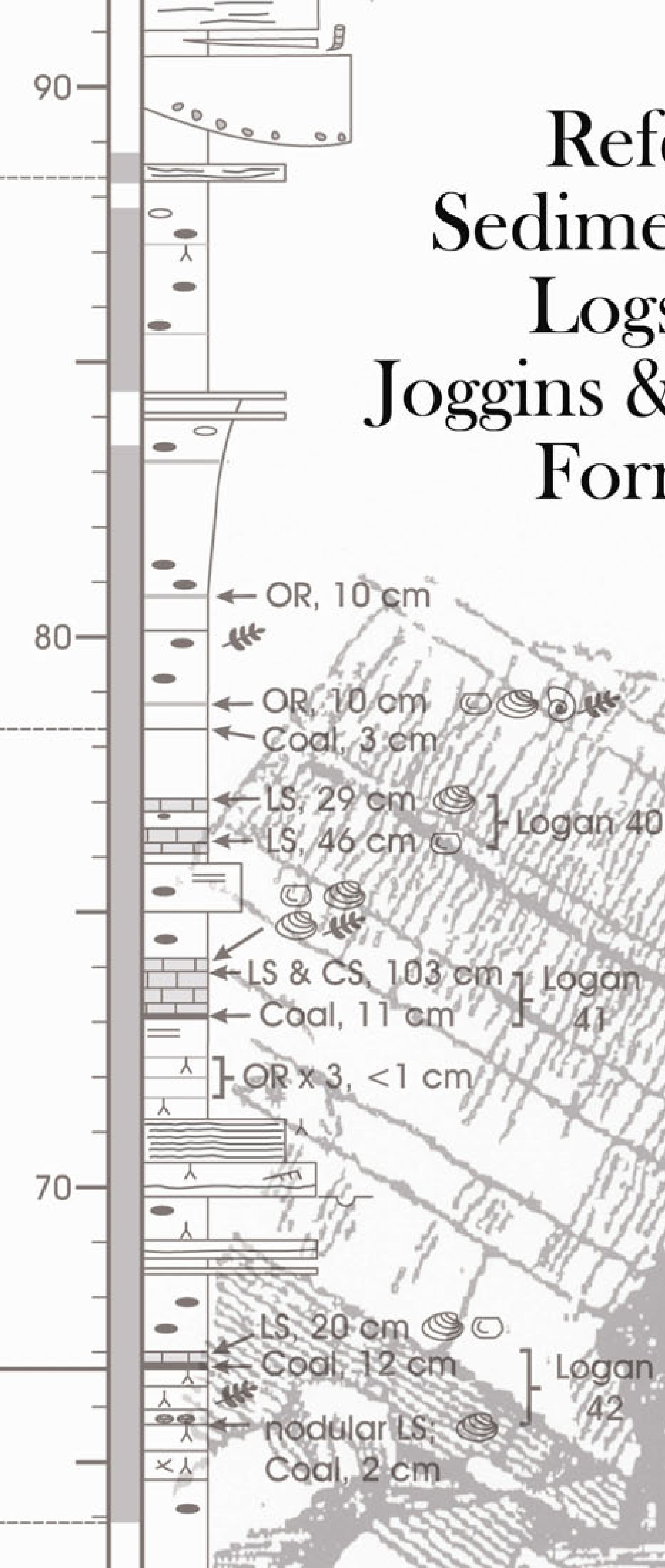
Harley Rd.
Shulie Rd.
Aderson St.
School St.
Summer St.
Charles St.
Highway 242
Shulie Rd.
Shulie Rd.
Joggins
0
1 Kilometers
Joggins Planning Area
N
Boss Point
Hardscrabble Point
Ragged Reef Point
0 1 2 3 4 5 Kilometers

Reference Sedimentological Logs of the Joggins & Little River Formations



Reference Sedimentological Logs of the Joggins and Little River Formations

comprising the "Classic Section" of the Nominated Property

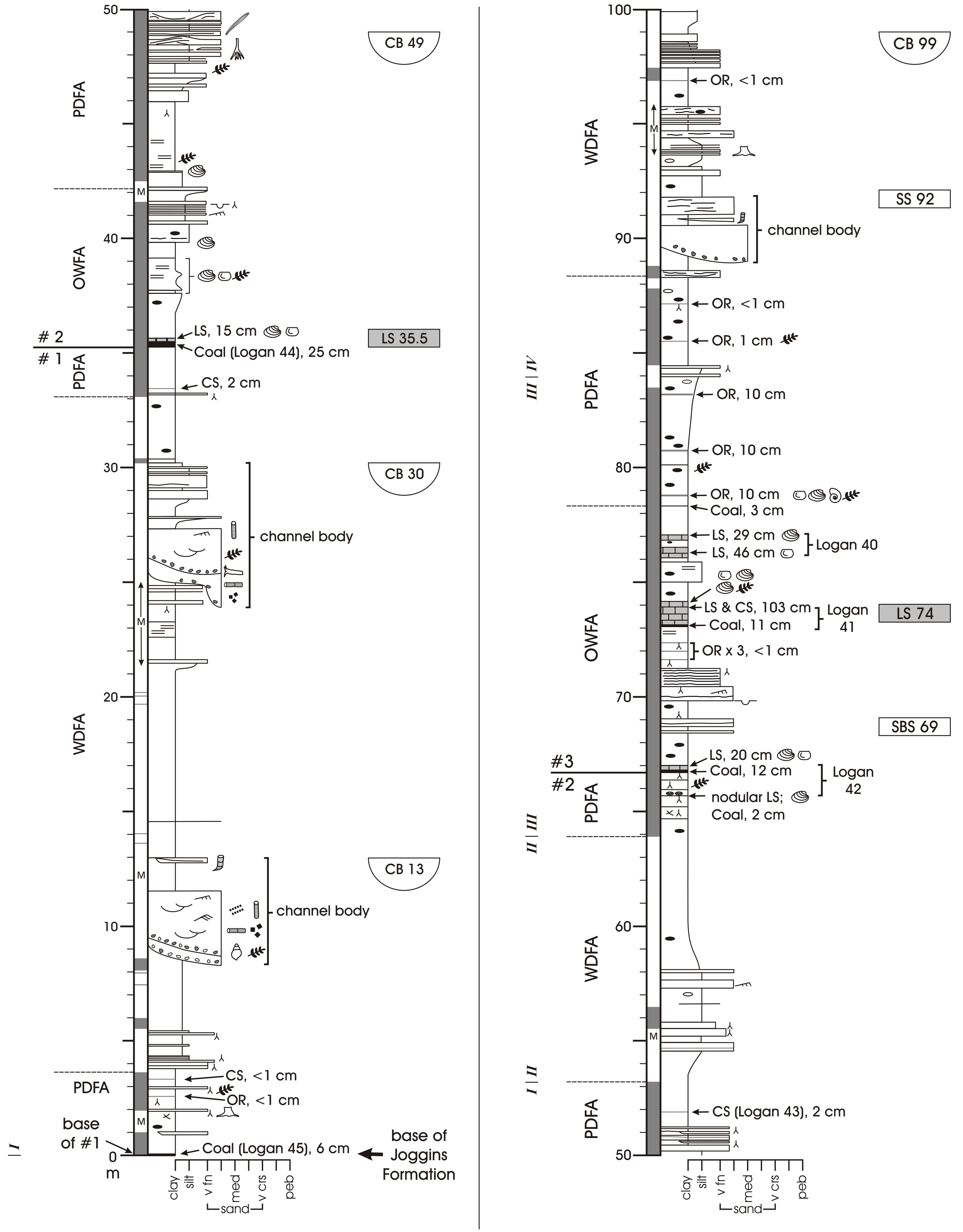
The monumental task of the measuring the outstanding exposure of Pennsylvanian strata exposed in the Joggins Fossil Cliffs was first undertaken in 1843 by Sir William Logan in his first field project as Director of the newly founded Geological Survey of Canada. Logan's written log has stood as the reference description of the coastal exposure for more than 150 years.

In 2005, after a decade of collaborative field work at the site, a modern suite of graphic logs of the Joggins Formation (the so-called "Classic Section") and the underlying, older Little River Formation, was published by a collaborative working group of British and Canadian geoscientists. These graphic logs, painstakingly recorded at centimetre-scale and published at the detailed scale of 1:25, serve as the new reference section for future studies at the site, and permit placement of fossil discoveries in their precise sedimentary context. This will enhance accession information in the curation of the fossil record of biodiversity, and will provide the means for detailed research into the ecology of the tropical "Coal Age" biome in this period of earth history.

These reference logs were first published in 2005 by the Atlantic Geoscience Society in a special issue of *Atlantic Geology*:

Davies, S.J., Gibling, M.R., Rygel, M.C., Calder, J.H. and Skilliter, D.M. 2005. The Pennsylvanian Joggins Formation of Nova Scotia: sedimentological log and stratigraphic framework of the historic fossil cliffs. *Atlantic Geology*, nos. 2-3, volume 41, 115-142.

Calder, J.H., Rygel, M.C., Ryan, R.J., Falcon-Lang, H.J. and Hebert, B.L. 2005. Stratigraphy and sedimentology of early Pennsylvanian red beds at Lower Cove, Nova Scotia, Canada: the Little River Formation with redefinition of the Joggins Formation. *Atlantic Geology*, nos. 2-3, volume 41, 143-167.



CB 49
PDFA
OWFA
2
1
LS, 15 cm
Coal (Logan 44), 25 cm
LS 35.5
CS, 2 cm
CB 30
channel body
WDFA
CB 13
channel body
PDFA
CS, <1 cm
OR, <1 cm
base of #1
Coal (Logan 45), 6 cm
base of Joggins Formation
0 m
10
20
30
40
50
M
I
clay silt v fn med v crs peb
sand
CB 99
OR, <1 cm
WDFA
SS 92
channel body
OR, <1 cm
OR, 1 cm
PDFA
OR, 10 cm
OR, 10 cm
OR, 10 cm
Coal, 3 cm
LS, 29 cm
LS, 46 cm
Logan 40
OWFA
LS & CS, 103 cm
Coal, 11 cm
Logan 41
LS 74
OR x 3, <1 cm
SBS 69
#3
#2
LS, 20 cm
Coal, 12 cm
nodular LS;
Coal, 2 cm
Logan 42
PDFA
WDFA
CS (Logan 43), 2 cm
PDFA
III | IV
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50
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80
90
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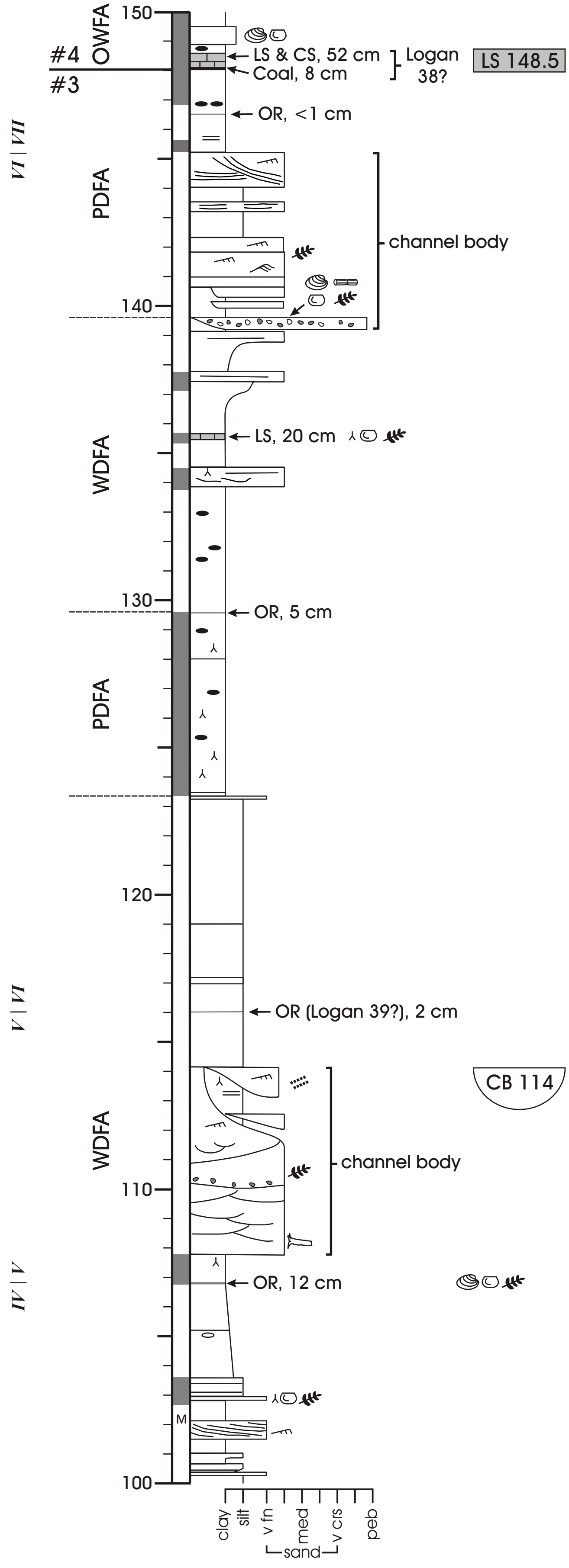
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#4
#3
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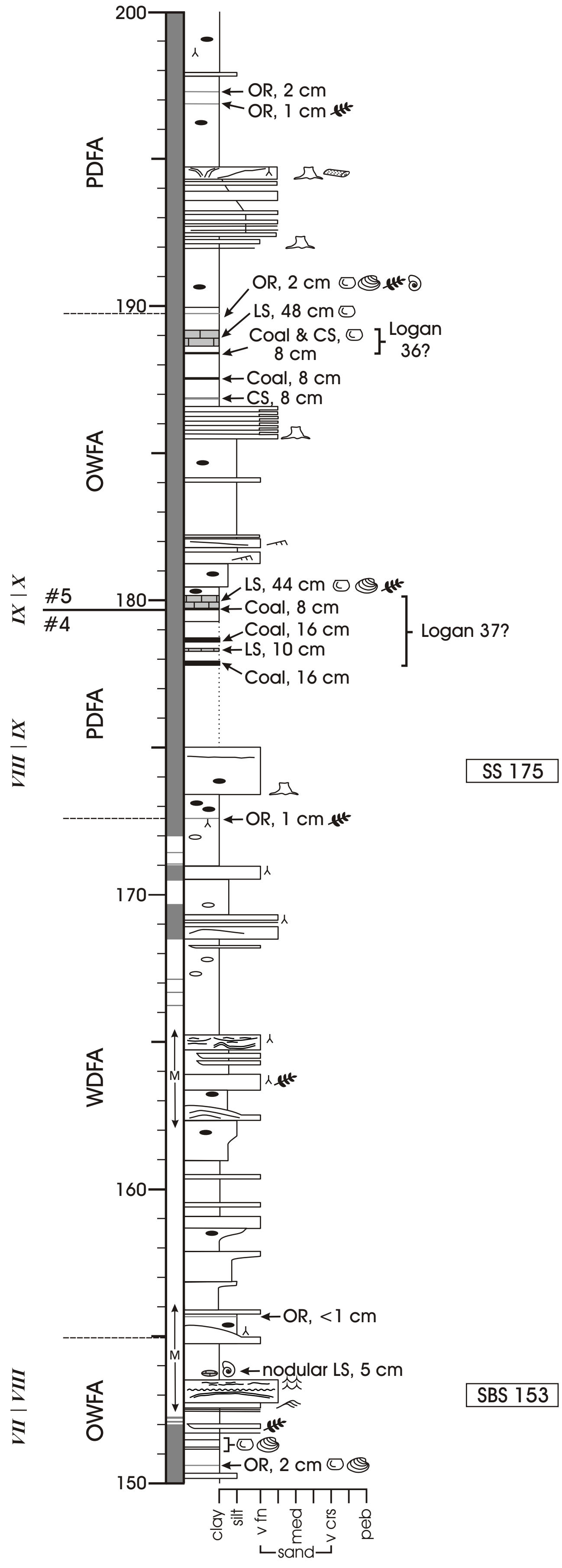
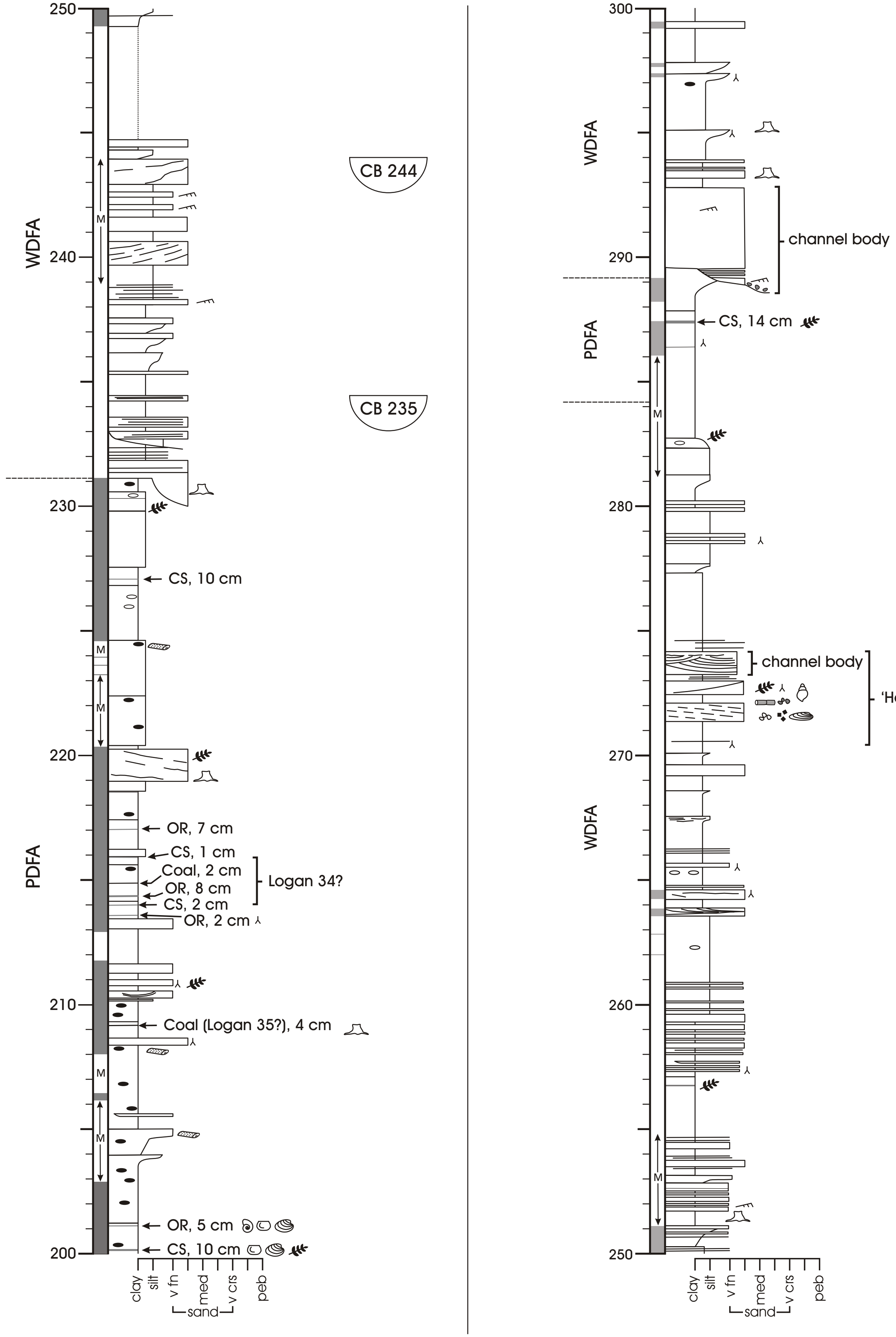
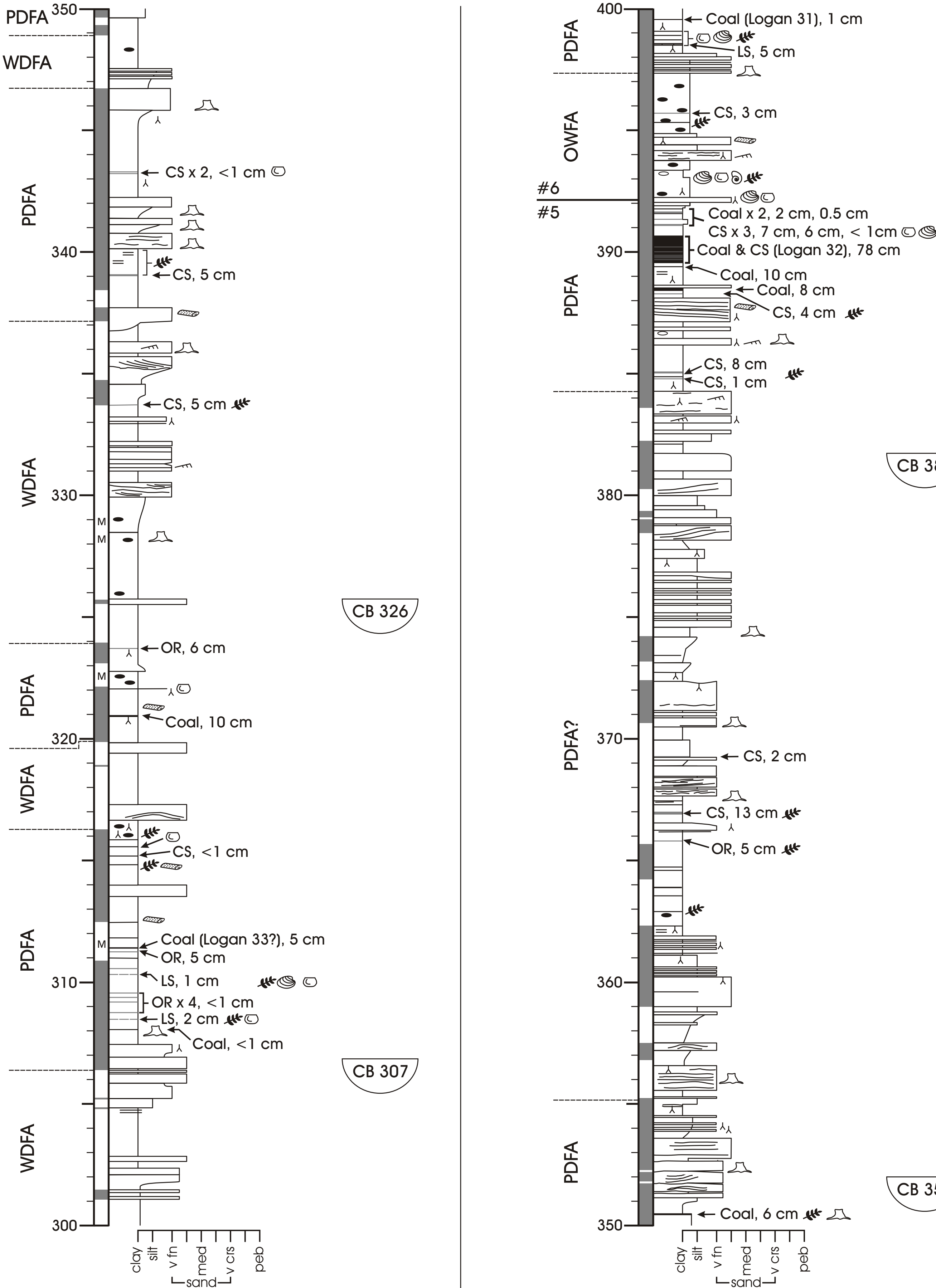
Coal, 8 cm
Logan 38?
LS 148.5
OR, <1 cm
VI | VII
PDFA
channel body
WDFA
LS, 20 cm
OR, 5 cm
PDFA
OR (Logan 39?), 2 cm
V | VI
CB 114
WDFA
channel body
IV | V
OR, 12 cm
M
150
140
130
120
110
100
clay
silt
v fn
med
v crs
peb
sand

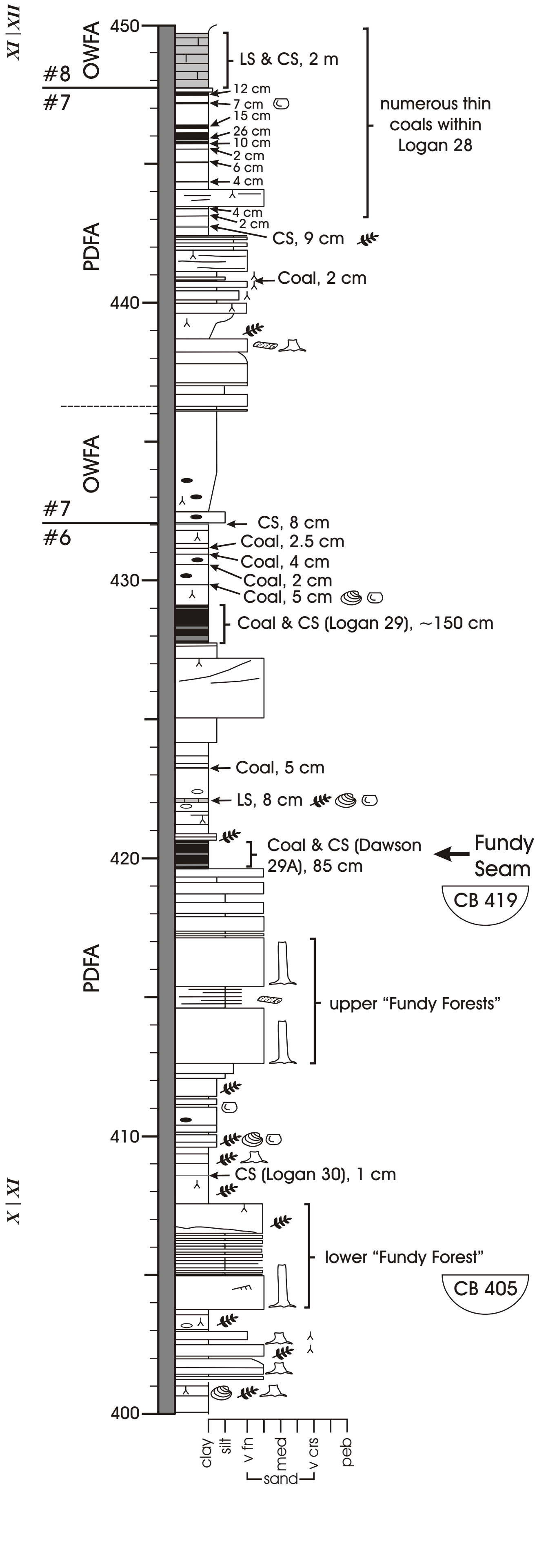

200
OR, 2 cm
OR, 1 cm
PDFA
OR, 2 cm
LS, 48 cm
Coal & CS, 8 cm
Logan 36?
Coal, 8 cm
CS, 8 cm
OWFA
IX | X
#5
#4
LS, 44 cm
Coal, 8 cm
Coal, 16 cm
LS, 10 cm
Coal, 16 cm
Logan 37?
VIII | IX
PDFA
SS 175
OR, 1 cm
WDFA
M
OR, <1 cm
nodular LS, 5 cm
SBS 153
VII | VIII
OWFA
OR, 2 cm
190
180
170
160
150
clay
silt
v fn
med
v crs
peb
sand



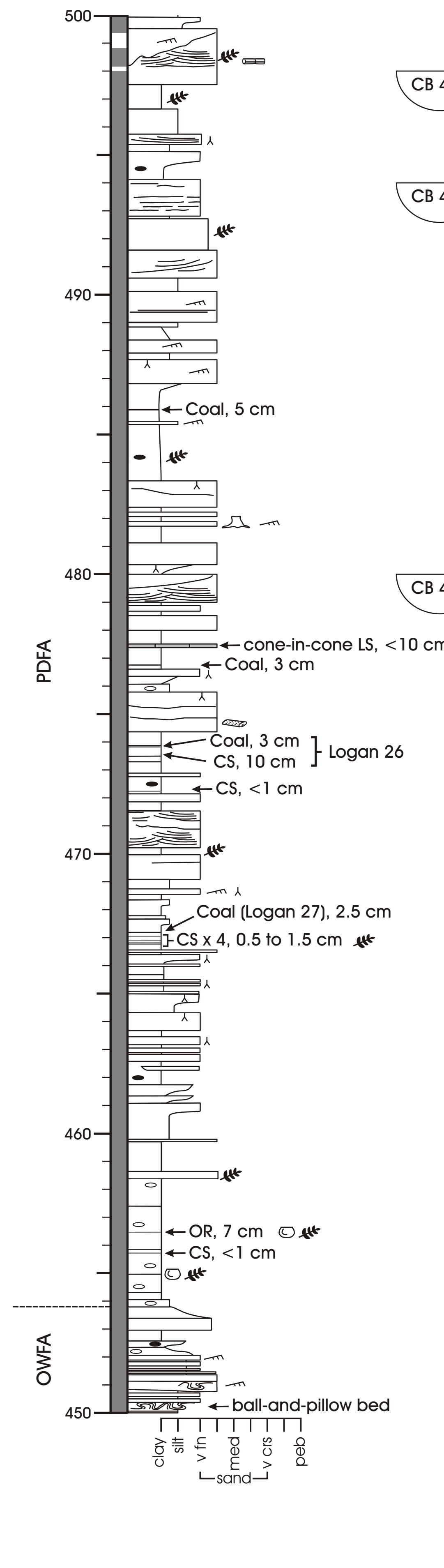
250
240
230
220
210
200
WDFA
PDFA
M
CB 244
CB 235
CS, 10 cm
OR, 7 cm
CS, 1 cm
Coal, 2 cm
OR, 8 cm
CS, 2 cm
OR, 2 cm
Logan 34?
Coal (Logan 35?), 4 cm
OR, 5 cm
CS, 10 cm
clay
silt
v fn
med
v crs
peb
sand
300
290
280
270
260
250
WDFA
PDFA
CB 295
channel body
CS, 14 cm
CB 283
channel body
'Hebert beds'
CB 271



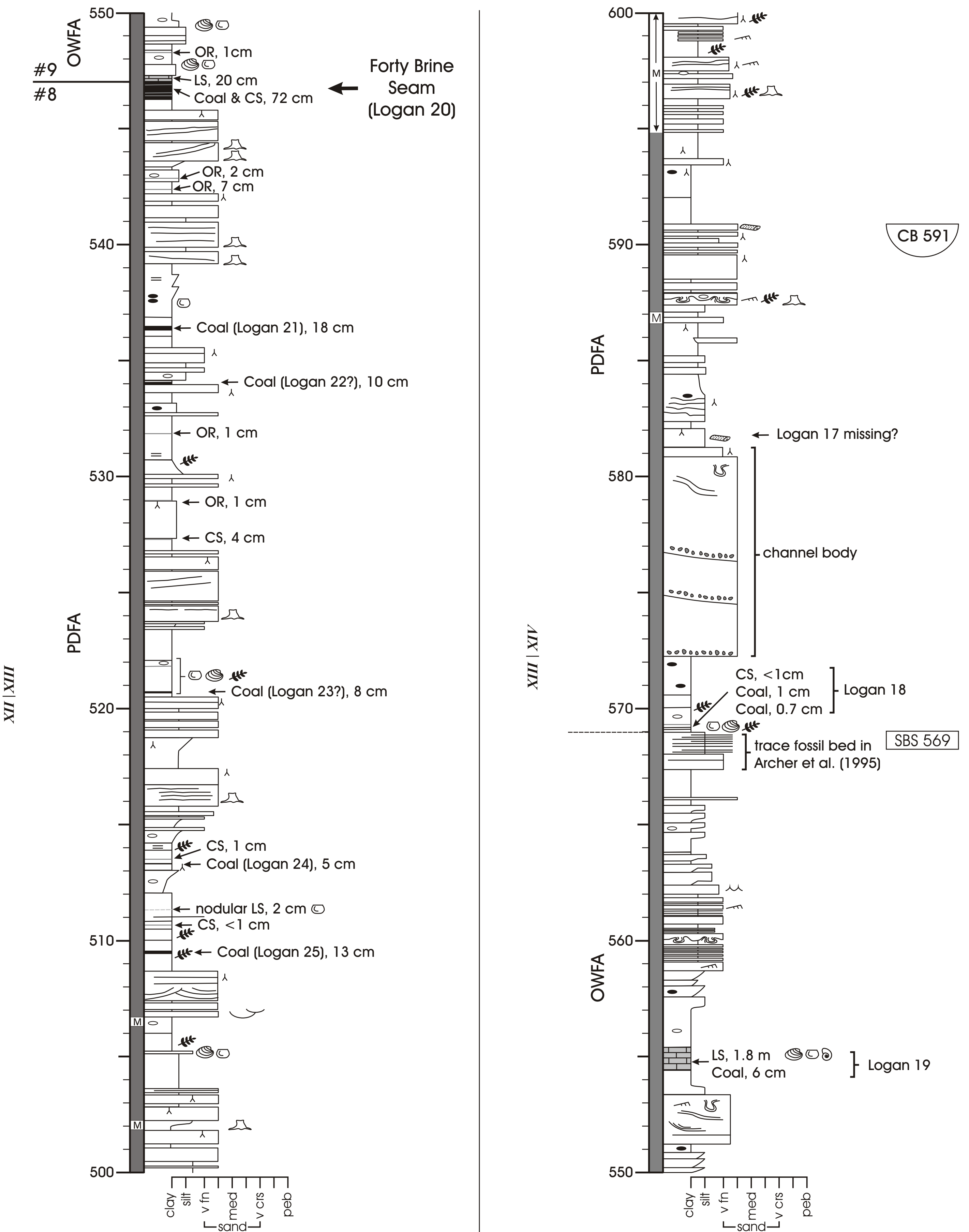
PDFA
WDFA
PDFA
CS x 2, <1 cm
CS, 5 cm
CS, 5 cm
WDFA
CB 326
OR, 6 cm
PDFA
Coal, 10 cm
WDFA
CS, <1 cm
PDFA
Coal (Logan 33?), 5 cm
OR, 5 cm
LS, 1 cm
OR x 4, <1 cm
LS, 2 cm
Coal, <1 cm
CB 307
WDFA
clay silt v fn med v crs peb
sand
Coal (Logan 31), 1 cm
PDFA
LS, 5 cm
CS, 3 cm
OWFA
#6
#5
Coal x 2, 2 cm, 0.5 cm
CS x 3, 7 cm, 6 cm, < 1cm
Coal & CS (Logan 32), 78 cm
Coal, 10 cm
PDFA
Coal, 8 cm
CS, 4 cm
CS, 8 cm
CS, 1 cm
CB 382
PDFA?
CS, 2 cm
CS, 13 cm
OR, 5 cm
PDFA
CB 352
Coal, 6 cm
clay silt v fn med v crs peb
sand



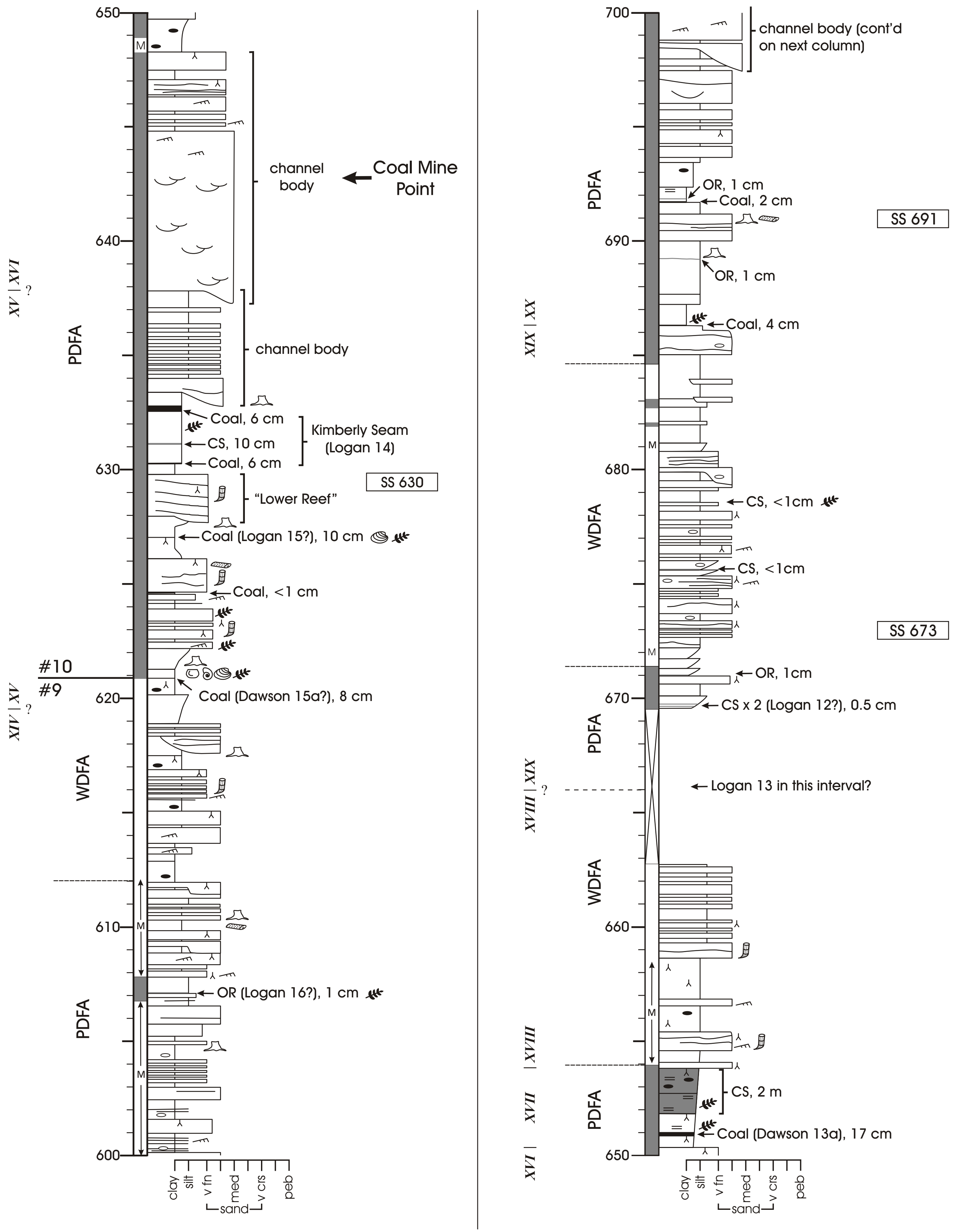
XI | XII
X | XI
450
440
430
420
410
400
OWFA
PDFA
OWFA
PDFA
#8
#7
#7
#6
LS & CS, 2 m
12 cm
7 cm
15 cm
26 cm
10 cm
2 cm
6 cm
4 cm
4 cm
2 cm
numerous thin coals within Logan 28
CS, 9 cm
Coal, 2 cm
CS, 8 cm
Coal, 2.5 cm
Coal, 4 cm
Coal, 2 cm
Coal, 5 cm
Coal & CS (Logan 29), ~150 cm
Coal, 5 cm
LS, 8 cm
Coal & CS (Dawson 29A), 85 cm
Fundy Seam
CB 419
upper "Fundy Forests"
CS (Logan 30), 1 cm
lower "Fundy Forest"
CB 405
clay
silt
v fn
med
v crs
peb
sand



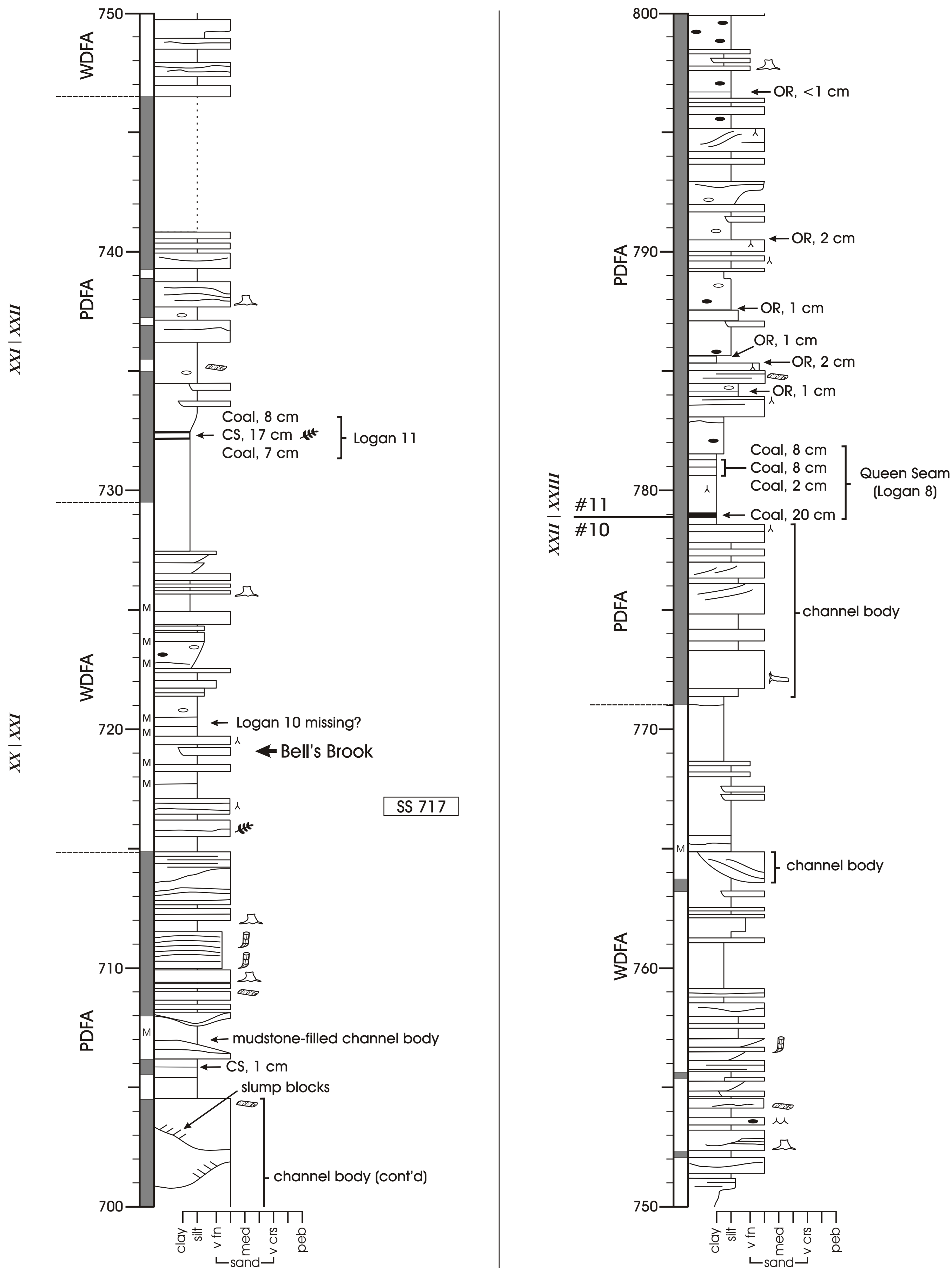
500
490
480
470
460
450
PDFA
OWFA
CB 498
CB 494
Coal, 5 cm
CB 480
cone-in-cone LS, <10 cm
Coal, 3 cm
Coal, 3 cm
CS, 10 cm
Logan 26
CS, <1 cm
Coal (Logan 27), 2.5 cm
CS x 4, 0.5 to 1.5 cm
OR, 7 cm
CS, <1 cm
ball-and-pillow bed
clay
silt
v fn
med
v crs
peb
sand



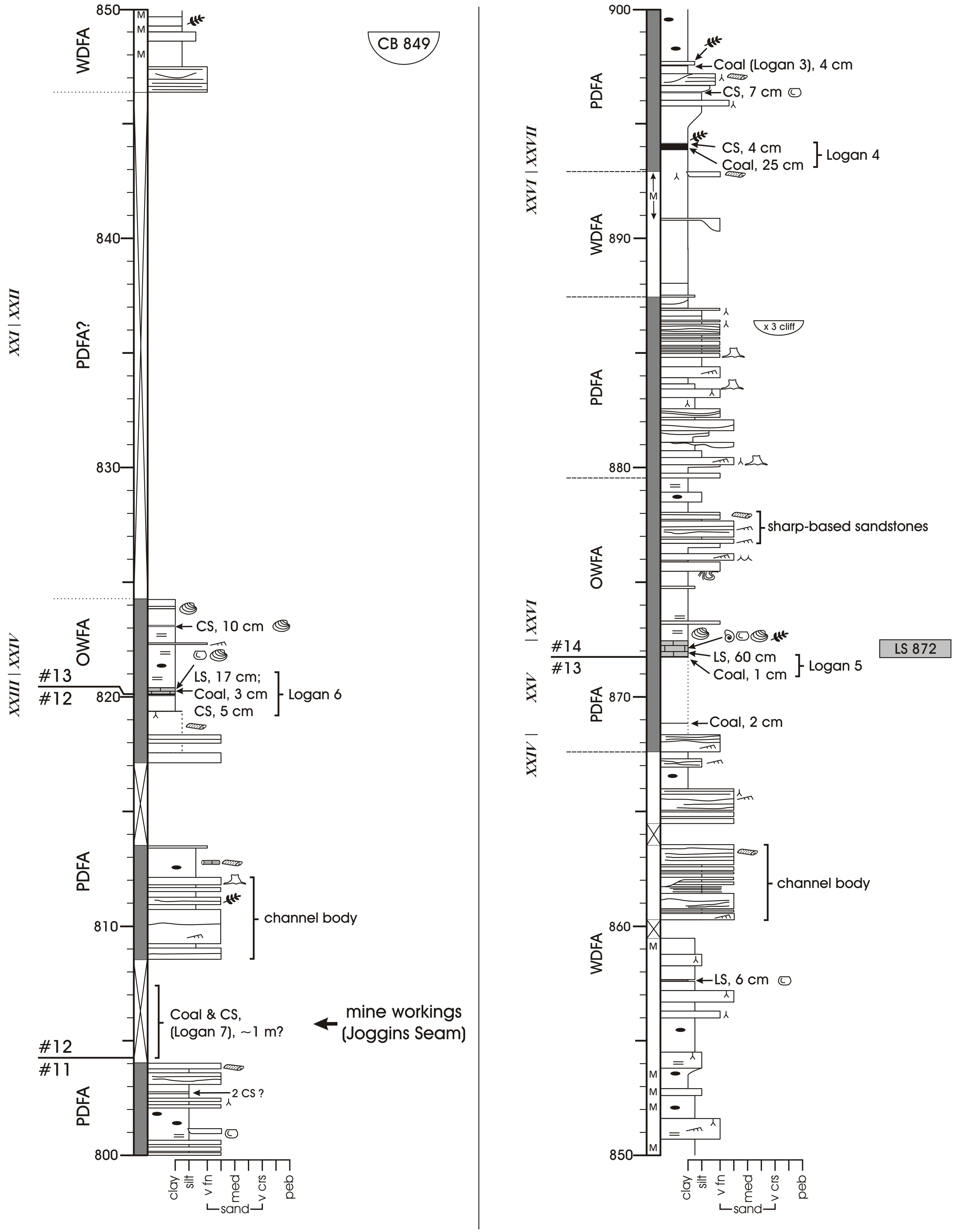
550
OWFA
OR, 1cm
#9
#8
LS, 20 cm
Coal & CS, 72 cm
Forty Brine Seam (Logan 20)
OR, 2 cm
OR, 7 cm
540
Coal (Logan 21), 18 cm
Coal (Logan 22?), 10 cm
OR, 1 cm
530
OR, 1 cm
CS, 4 cm
PDFA
Coal (Logan 23?), 8 cm
520
XII | XIII
CS, 1 cm
Coal (Logan 24), 5 cm
nodular LS, 2 cm
CS, <1 cm
Coal (Logan 25), 13 cm
510
M
500
clay
silt
v fn
med
v crs
peb
sand
600
M
CB 591
590
PDFA
Logan 17 missing?
580
channel body
XIII | XIV
CS, <1cm
Coal, 1 cm
Coal, 0.7 cm
Logan 18
570
trace fossil bed in Archer et al. (1995)
SBS 569
560
OWFA
LS, 1.8 m
Coal, 6 cm
Logan 19
550



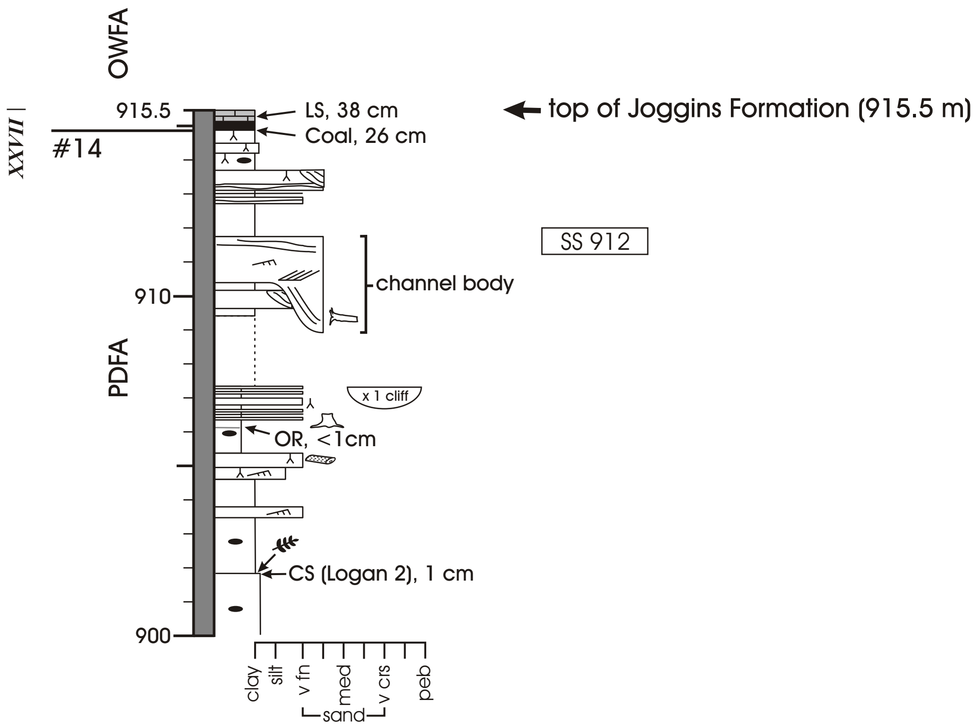
650
640
630
620
610
600
channel body
Coal Mine Point
channel body
Coal, 6 cm
CS, 10 cm
Coal, 6 cm
Kimberly Seam (Logan 14)
SS 630
"Lower Reef"
Coal (Logan 15?), 10 cm
Coal, <1 cm
#10
#9
Coal (Dawson 15a?), 8 cm
OR (Logan 16?), 1 cm
XV | XVI ?
XIV | XV ?
PDFA
WDFA
PDFA
M
clay
silt
v fn
med
v crs
peb
sand
700
690
680
670
660
650
channel body (cont'd on next column)
OR, 1 cm
Coal, 2 cm
SS 691
OR, 1 cm
Coal, 4 cm
CS, <1cm
CS, <1cm
SS 673
OR, 1cm
CS x 2 (Logan 12?), 0.5 cm
Logan 13 in this interval?
CS, 2 m
Coal (Dawson 13a), 17 cm
XIX | XX
XVIII | XIX ?
| XVIII
XVII
XVI |
PDFA
WDFA
PDFA
WDFA
PDFA



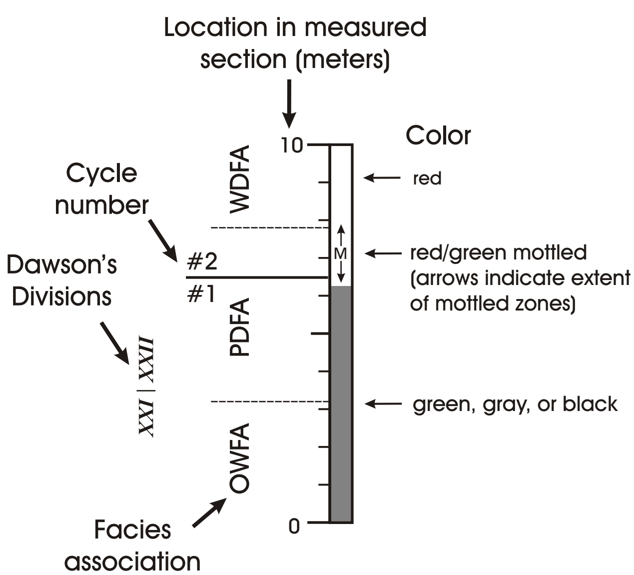
750
740
730
720
710
700
WDFA
PDFA
WDFA
PDFA
XXI | XXII
XX | XXI
Coal, 8 cm
CS, 17 cm
Coal, 7 cm
Logan 11
Logan 10 missing?
Bell's Brook
SS 717
mudstone-filled channel body
CS, 1 cm
slump blocks
channel body (cont'd)
clay
silt
v fn
med
v crs
peb
sand
800
790
780
770
760
750
PDFA
PDFA
WDFA
XXII | XXIII
#11
#10
OR, <1 cm
OR, 2 cm
OR, 1 cm
OR, 1 cm
OR, 2 cm
OR, 1 cm
Coal, 8 cm
Coal, 8 cm
Coal, 2 cm
Coal, 20 cm
Queen Seam
(Logan 8)
channel body
channel body
clay
silt
v fn
med
v crs
peb
sand



CB 849
WDFA
PDFA?
XXI | XXII
OWFA
XXIII | XXIV
#13
#12
CS, 10 cm
LS, 17 cm;
Coal, 3 cm
CS, 5 cm
Logan 6
PDFA
channel body
Coal & CS,
(Logan 7), ~1 m?
mine workings
(Joggins Seam)
#12
#11
2 CS ?
800
810
820
830
840
850
clay
silt
v fn
med
v crs
peb
sand
900
890
880
870
860
850
Coal (Logan 3), 4 cm
CS, 7 cm
CS, 4 cm
Coal, 25 cm
Logan 4
XXVI | XXVII
M
x 3 cliff
sharp-based sandstones
LS 872
#14
#13
LS, 60 cm
Coal, 1 cm
Logan 5
XXVI
XXV
XXIV
Coal, 2 cm
LS, 6 cm



Explanation of Sedimentological Log



Tidal Flat Outcrops

CB # = channel body

SBS # = sharp-based sandstone

SS # = sheet sandstone

LS # = limestone

# indicates meterage at top of the bed (to the nearest meter)

Facies Associations

OWFA = open-water facies association

PDFA = poorly drained facies association

WDFA = well drained facies association

Organic Horizons

← LS = limestone

← Coal (Logan # if applicable)

← CS = carbonaceous shale

← OR = organic-rich horizon

Symbols used in Sedimentological Log

Sedimentary Features

- concretion or nodule (calcareous)
- concretion or nodule (non-calcareous)
- calcareous rip-up clast
- mud-chip rip-up clast
- climbing ripple cross-lamination
- wave ripple
- ripple cross-lamination
- trough cross-bedding
- planar cross-bedding
- horizontal lamination
- groove cast or tool mark
- pedogenic slickenside
- convolute bedding

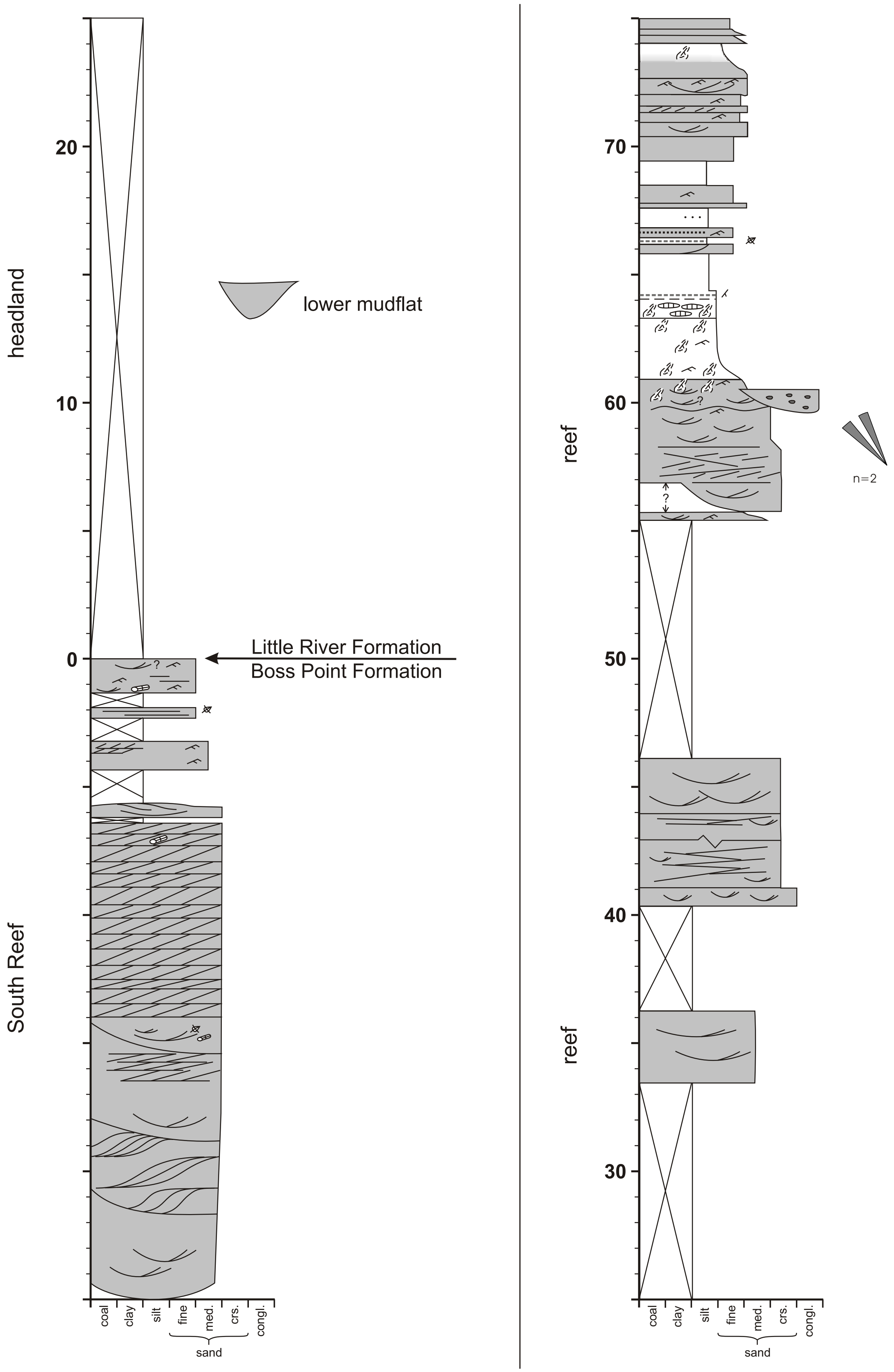
Flora

- calamite (*in situ*)
- calamite (transported)
- lycopsid trunk (*in situ*)
- lycopsid trunk (transported)
- *Stigmaria* Sp.
- cordaite gymnosperm (*in situ*)
- *Artisia transversa* (cordaite pith cast)
- *Cordaites principalis* (cordaite leaf)
- finely macerated plant material
- root compression
- charcoal

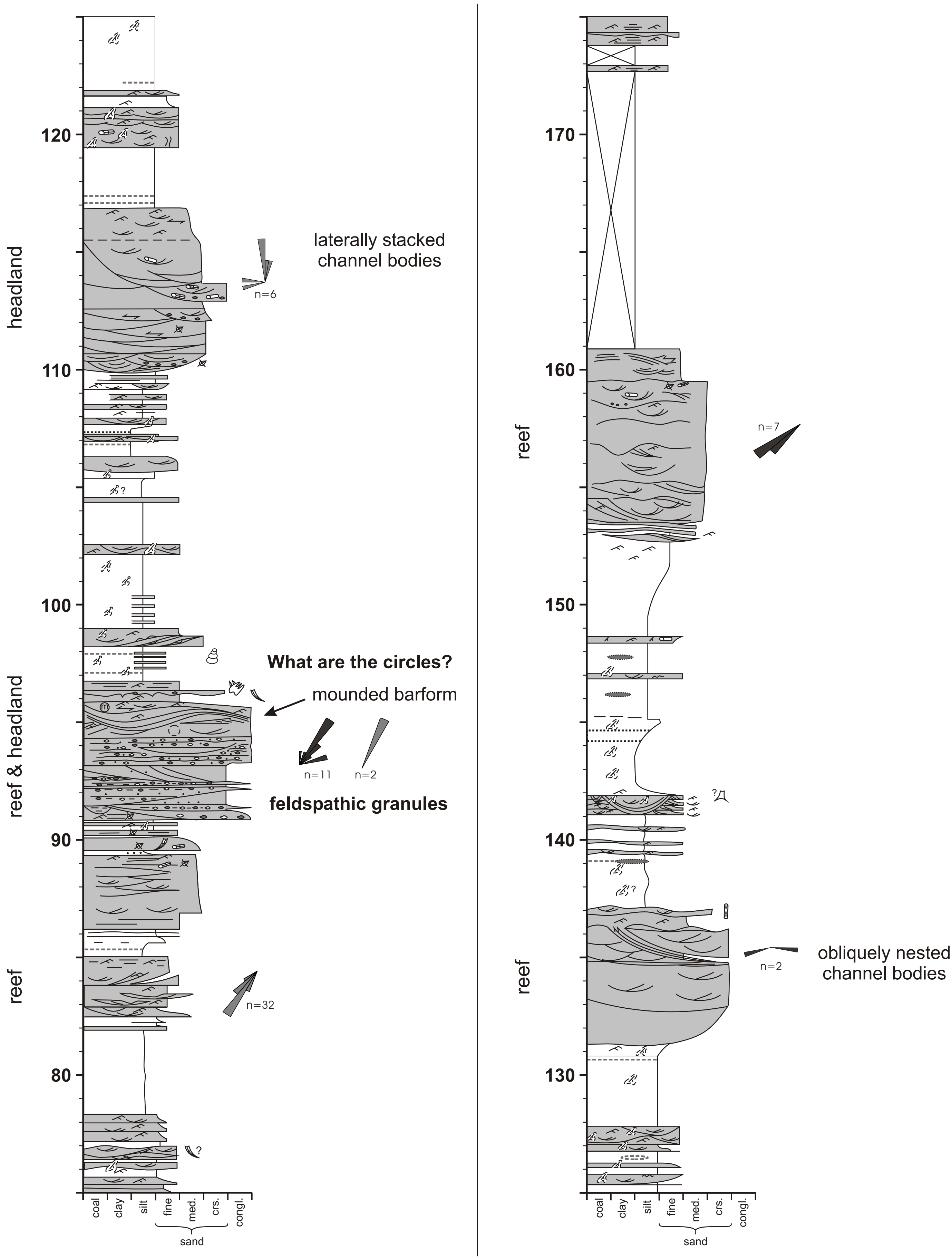
Fauna

- *Diplichnites* (*Arthropleura* trackway)
- bivalve
- ostracode
- *Spirorbis*
- *Dendropupa vetusta*
- tetrapod bone
- tetrapod trackway
- fish bone or scale

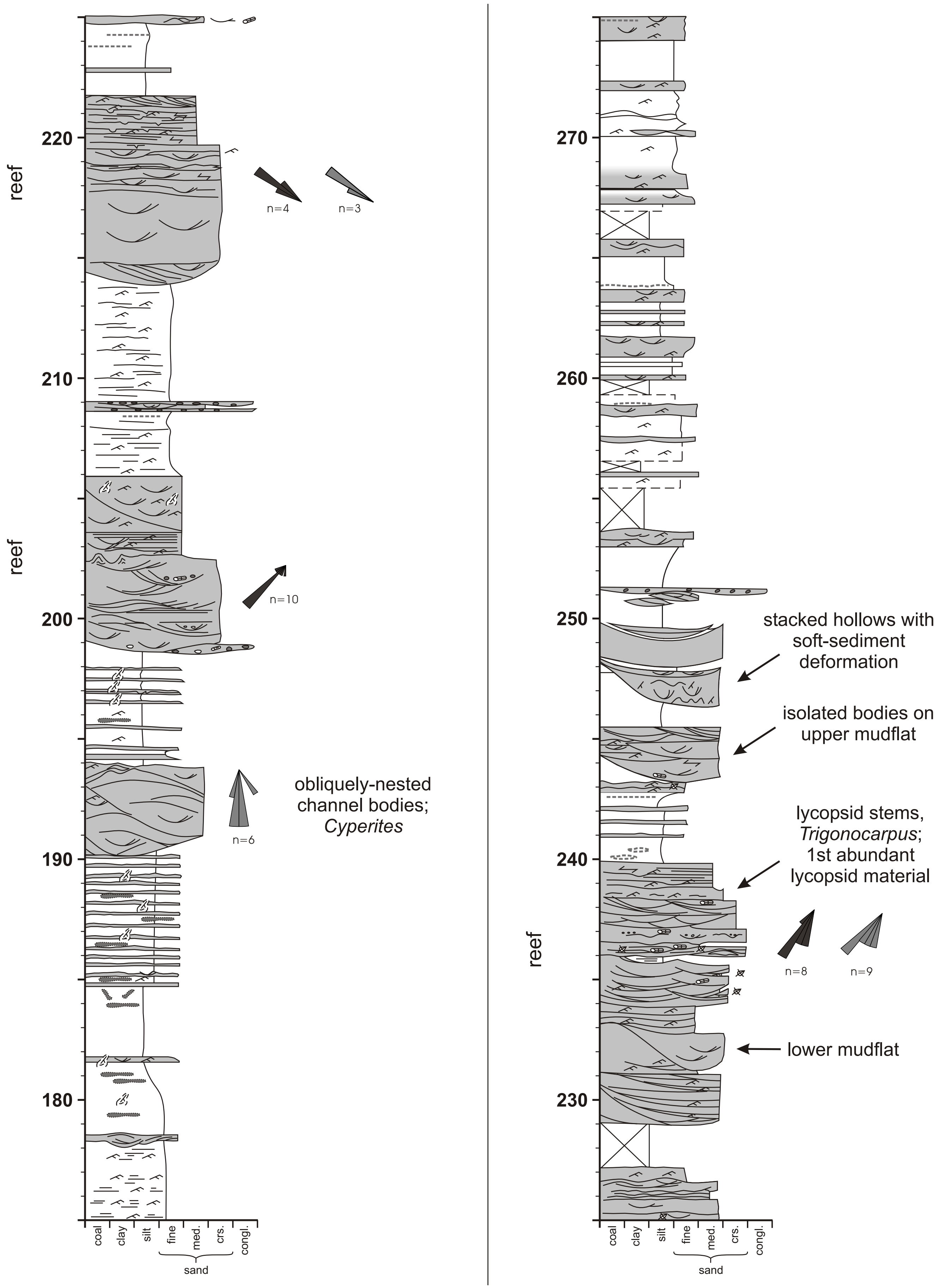
Appendix 1



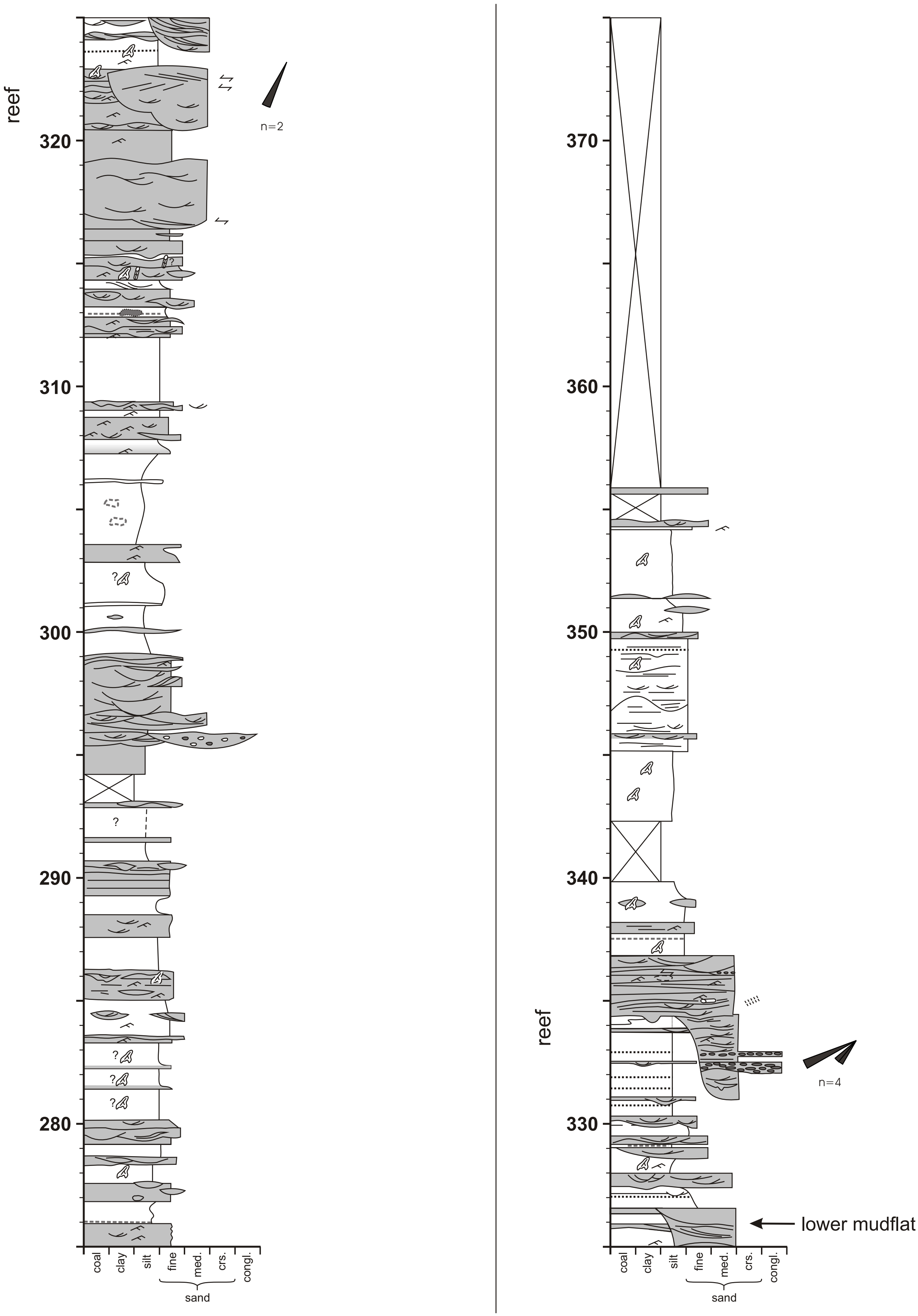
20
10
0
headland
South Reef
lower mudflat
Little River Formation
Boss Point Formation
coal
clay
silt
fine
med.
crs.
congl.
sand
70
60
50
40
30
reef
reef
n=2
coal
clay
silt
fine
med.
crs.
congl.
sand



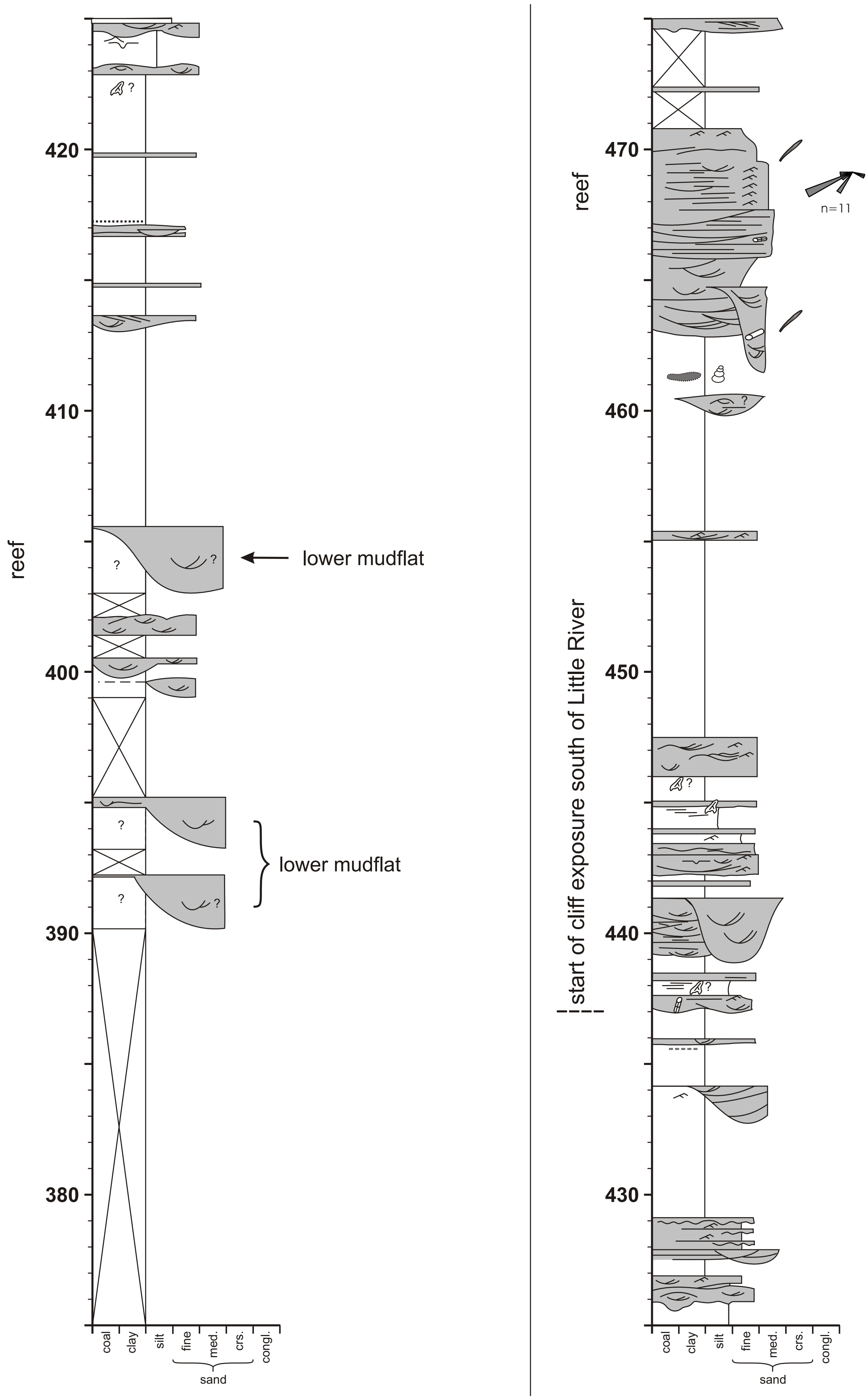
headland
reef & headland
reef
laterally stacked
channel bodies
n=6
What are the circles?
mounded barform
n=11
n=2
feldspathic granules
n=32
reef
n=7
reef
obliquely nested
channel bodies
n=2
120
110
100
90
80
170
160
150
140
130
coal
clay
silt
fine
med.
crs.
congl.
sand



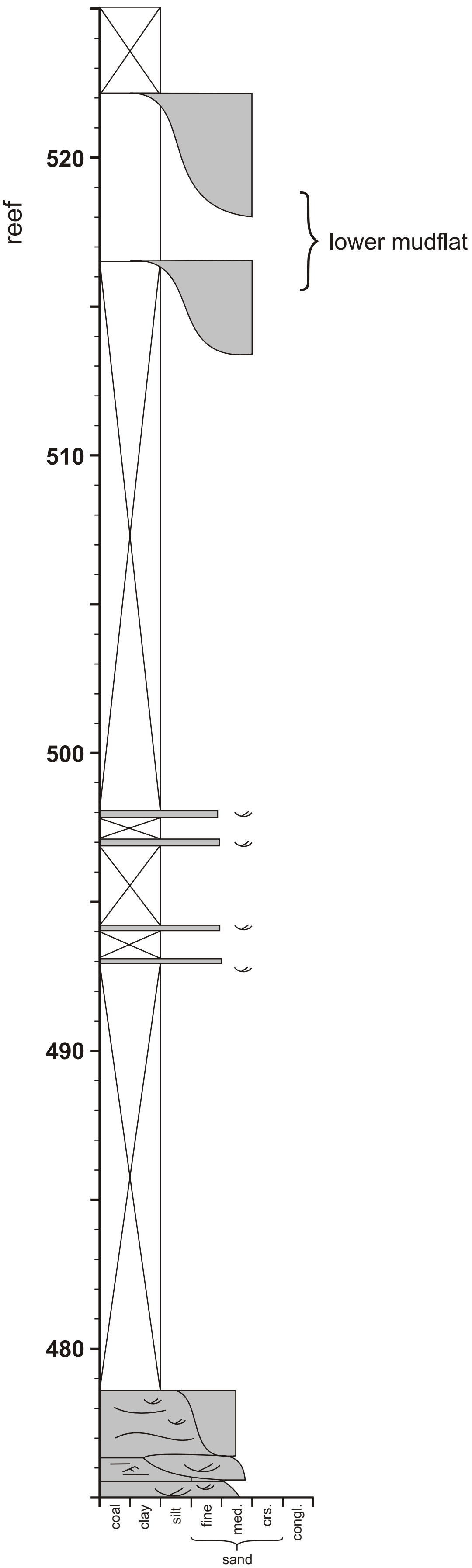
220
210
200
190
180
reef
reef
n=4
n=3
n=10
n=6
obliquely-nested channel bodies; *Cyperites*
coal
clay
silt
fine
med.
crs.
congl.
sand
270
260
250
240
230
reef
stacked hollows with soft-sediment deformation
isolated bodies on upper mudflat
lycopsid stems, *Trigonocarpus*; 1st abundant lycopsid material
n=8
n=9
lower mudflat
coal
clay
silt
fine
med.
crs.
congl.
sand



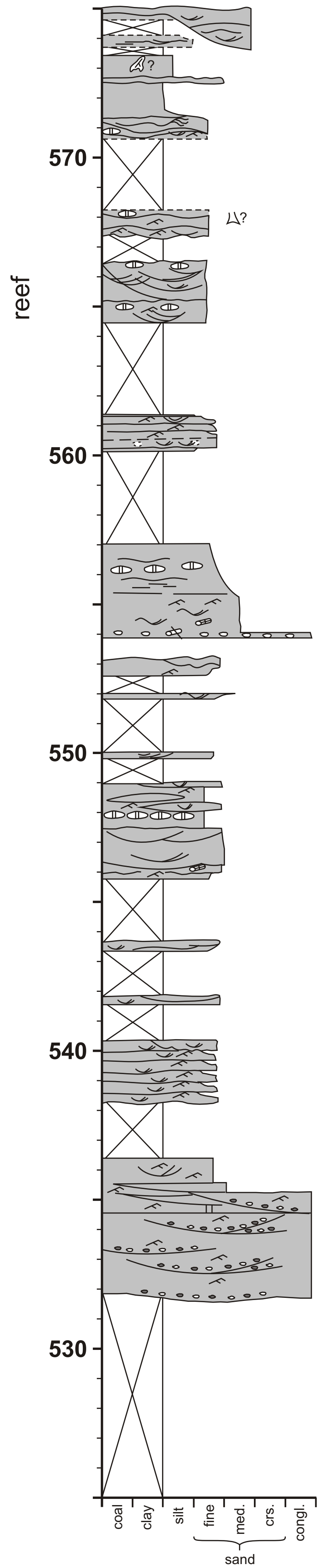
reef
320
310
300
290
280
n=2
coal
clay
silt
fine
med.
crs.
congl.
sand
370
360
350
340
330
reef
n=4
lower mudflat
coal
clay
silt
fine
med.
crs.
congl.
sand



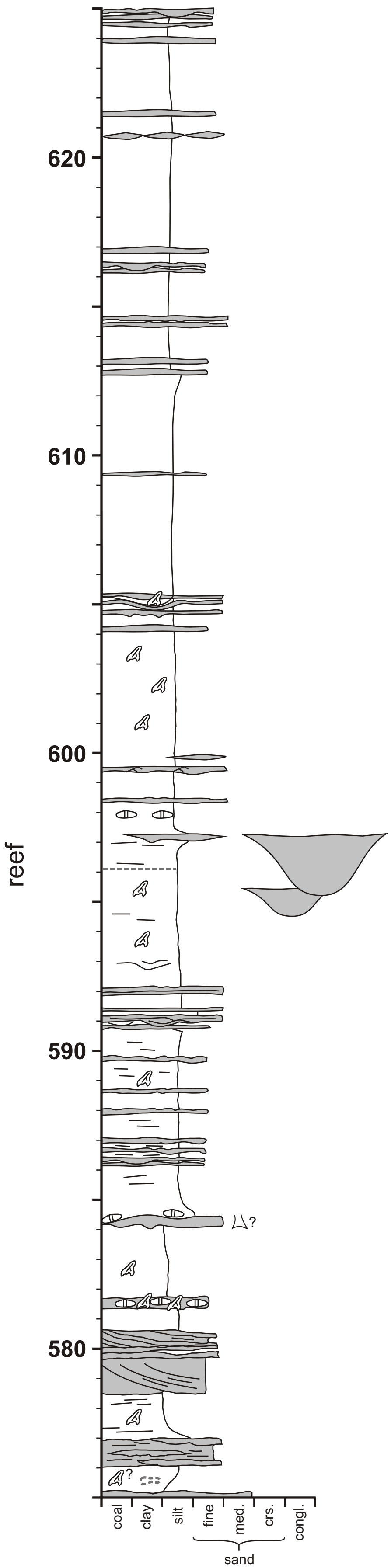
420
410
400
390
380
reef
lower mudflat
lower mudflat
coal
clay
silt
fine
med.
crs.
congl.
sand
470
460
450
440
430
reef
n=11
start of cliff exposure south of Little River
coal
clay
silt
fine
med.
crs.
congl.
sand



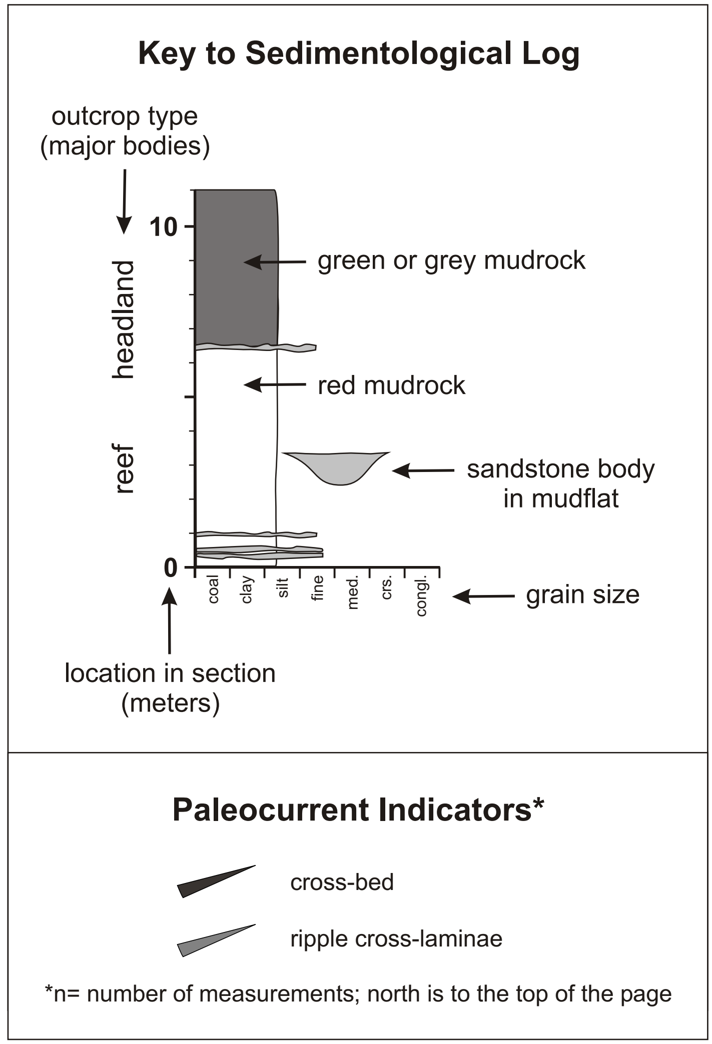
reef
520
510
500
490
480
lower mudflat
coal
clay
silt
fine
med.
crs.
congl.
sand



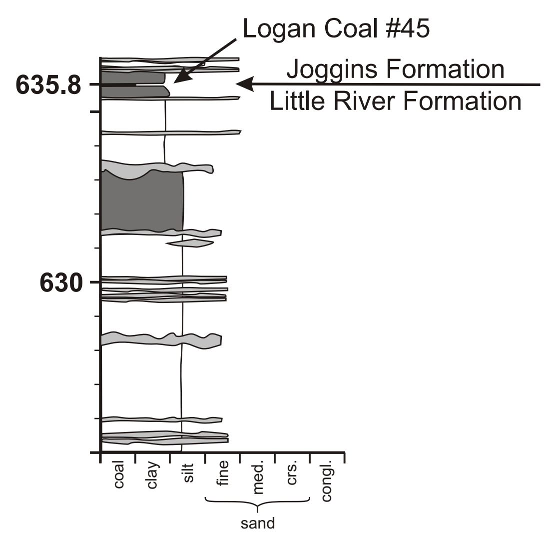
reef
570
560
550
540
530
coal
clay
silt
fine
med.
crs.
congl.
sand



reef
620
610
600
590
580
coal
clay
silt
fine
med.
crs.
congl.
sand



Key to Sedimentological Log
outcrop type (major bodies)
10
0
headland
reef
green or grey mudrock
red mudrock
sandstone body in mudflat
coal
clay
silt
fine
med.
crs.
congl.
grain size
location in section (meters)
Paleocurrent Indicators*
cross-bed
ripple cross-laminae
*n= number of measurements; north is to the top of the page



Logan Coal #45
Joggins Formation
Little River Formation
635.8
630
coal
clay
silt
fine
med.
crs.
congl.
sand

Symbols used in Sedimentological Log

Sedimentary Features

- ripple cross-lamination
- primary current lineation
- trough cross-bedding
- organic-rich horizon
- organic-rich lens
- calcareous nodule or concretion (*in situ*)
- planar cross-bedding
- mud-chip rip-up clasts
- calcareous rip-up clasts
- green or grey horizon
- green or grey lens

Flora & Fauna

- finely macerated plant material
- lycopsid trunk (*in situ*)
- calamite (*in situ*)
- calamite (transported)
- *Cordaites principalis* (cordaite leaf)
- *Artisia transversa* (cordaite pith cast)
- medullosan stem
- drab-haloed root trace
- tetrapod trackway
- *Dendropupa vetusta*
- *Diplichnites* (*Arthropleura* trackway)

A SELECTION OF KEY PAPERS OF THE MODERN ERA IN INTERNATIONAL PEER-REVIEWED JOURNALS

BINDER 1 OF 2

HISTORY OF GEOLOGY AND SCIENCE

PAPER 1 Calder, J.H., 2006. 'Coal Age Galapagos': Joggins and the Lions of Nineteenth Century Geology. *Atlantic Geology*, **42**, 37-51.

PAPER 2 Falcon-Lang, H.J. 2006. A history of research at the Joggins Fossil Cliffs, Nova Scotia, Canada, the world's finest Pennsylvanian section. Proceedings of the Geologists' Association, 117, 377-392.

PALEOECOLOGY

PAPER 3 Calder, J.H., Gibling, M.R., Scott, A.C., Davies, S.J. and Hebert, B.L., 2006. A fossil lycopsid forest succession in the classic Joggins section of Nova Scotia: paleoecology of a disturbance-prone Pennsylvanian wetland. *In* S. Greb and W.A. DiMichele (editors), *Wetlands Through Time*. Geological Society of America Special Paper 399, 169-195.

PAPER 4 Falcon-Lang, H.J., Rygel, M.C., Calder, J.H. and Gibling, M.R., 2004. An early Pennsylvanian waterhole deposit and its fossil biota in a dryland alluvial plain setting, Joggins, Nova Scotia. *Journal of the Geological Society of London*, **161**, 209-222.

PAPER 5 Falcon-Lang, H.J. 1999. Fire ecology of a Late Carboniferous floodplain, Joggins, Nova Scotia, Canada. *Journal of the Geological Society of London*, 156, 137 – 148.

PALEONTOLOGY AND EVOLUTIONARY THEORY

PAPER 6 Benton, M.J. and Donoghue, P.C.J. 2007. Paleontological evidence to date the Tree of Life. Molecular Biology and Evolution, **24**, 26-53.

PAPER 7 Carroll, R.L., 1970b. The earliest known reptiles. *Yale Scientific Magazine*, 16-23.

PAPER 8 Carroll, R.L., 2001. The origin and early radiation of terrestrial vertebrates. *Journal of Paleontology,* **75**, 1201-1213.

PAPER 9 Reisz, R.R., 1997. The origin and early evolutionary history of amniotes. *Trends in Ecology and Evolution*, **12**, 218-222.

PAPER 10 Reisz, R.R. and Müller, J., 2004. Molecular timescales and the fossil record: a paleontological perspective. *Trends in Genetics*, **20**, 237-241.

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BINDER 2 OF 2

THE FOSSIL RECORD AT JOGGINS

PAPER 11 Falcon-Lang, H.J., Benton, M.J., Braddy, S.J. and Davies, S.J., 2006. The Pennsylvanian tropical biome reconstructed from the Joggins Formation of Nova Scotia, Canada. *Journal of the Geological Society of London*, **163**, 561-576.

SEDIMENTOLOGY AND STRATIGRAPHY

PAPER 12 Calder, J.H., Rygel, M.C., Ryan, R.J., Gibling, M.R., Falcon-Lang, H.J. and Hebert, B.L., 2005. Stratigraphy and sedimentology of early Pennsylvanian red beds at Lower Cove, Nova Scotia, Canada: the Little River Formation with redefinition of the Joggins Formation. *Atlantic Geology*, **41**, 143-167.

PAPER 13 Davies, S.J. and Gibling, M.R., 2003. Architecture of coastal and alluvial deposits in an extensional basin: the Carboniferous Joggins Formation of eastern Canada. *Sedimentology*, **50**, 415-439.

PAPER 14 Davies, S.J., Gibling, M.R., Rygel, M.C., Calder, J.H. and Skilliter, D.M., 2005. The Pennsylvanian Joggins Formation of Nova Scotia: sedimentological log and stratigraphic framework of the historic fossil cliffs. *Atlantic Geology*, **41**, 115-142.

PAPER 15 Rygel, M.C. and Gibling, M.R. 2006. Natural geomorphic variability recorded in a high-accommodation setting: fluvial architecture of the Pennsylvanian Joggins Formation of Atlantic Canada. Journal of Sedimentary Research, **76**, 1230-1251.

BASIN EVOLUTION

PAPER 16 Waldron, J.W.F. and Rygel, M.C., 2005. Role of evaporite withdrawal in the preservation of a unique coal-bearing succession: Pennsylvanian Joggins Formation, Nova Scotia. *Geology*, **33**, 337-340.

GLOBAL CHANGE

PAPER 17 Falcon-Lang, H.J., 2003. Response of Late Carboniferous tropical vegetation to transgressive-regressive rhythms at Joggins, Nova Scotia. *Journal of the Geological Society of London*, **160**, 643-647.

WORLD HERITAGE

PAPER 18 Falcon-Lang, H.J. and Calder, J.H., 2004. UNESCO World Heritage and the Joggins cliffs of Nova Scotia. *Geology Today*, **20**, Part 4, 140-144.

"Coal Age Galapagos": Joggins and the Lions of Nineteenth Century Geology

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ABSTRACT

The celebrated coastal section at Joggins, Nova Scotia, has played a seminal role in the development of the Earth Sciences, figuring in the careers of such lions of Nineteenth Century science as Lyell, Dawson, Darwin, Logan, Marsh, Gesner, Agassiz, Wyman and Owen, among others. The story that unfolds is not only one of scientific discovery, but one of enlightening interactions between the players that brings to life these personalities, their debates and, for some, their personal agendas. The "marvellous chapter of the big volume" of Earth's history recorded in the sea cliffs at Joggins served as a "Coal Age Galapagos" for Lyell, Darwin, Dawson and others, furthering their case for geological and evolutionary principles that continue to inform scientific and popular views today. Coincidental with Lyell's appearance on the scene, Logan undertook at Joggins one of the first field projects of the Geological Survey of Canada. Against the backdrop of advancing scientific thought and positions, a penny opera of professional one-upmanship was played out. Gesner sought reprimand of Lyell from Murchison, President of the Geological Society for misleading Nova Scotia's geologists; Owen, who earlier coined the word "dinosaur", beat Lyell and Dawson in naming their own discovery; while a young O.C. Marsh, presaging his intensely competitive dinosaur battles with Edward Cope, arrived at Joggins from Yale hot on Lyell and Dawson's trail, only to be duped by a worldly traveller ready to oblige his desire for fame. Above all others, the work of Dawson in describing the fossil record and its ecological context established a lasting legacy of relevance for the Joggins cliffs.

RÉSUMÉ

Le célèbre secteur côtier de Joggins, en Nouvelle-Écosse, a joué un rôle majeur dans l'essor des sciences de la terre : il figure parmi les carrières de plusieurs personnages scientifiques du 19e siècle, tels que Lyell, Dawson, Darwin, Logan, Marsh, Gesner, Agassiz, Wyman et Owen, entre autres. L'histoire des lieux ne se limite pas à une découverte scientifique; elle relate des interactions instructives entre les protagonistes mettant au jour ces personnalités, leurs débats et, dans certains cas, leurs priorités personnelles. Le « merveilleux chapitre du grand volume » de l'histoire de la terre, enregistré dans les falaises de Joggins, a constitué un « genre de Galapagos de l'âge du charbon » pour Lyell, Darwin, Dawson et d'autres : il a soutenu les principes géologiques et les principes de l'évolution qu'ils avançaient et sur lesquels continuent de s'appuyer aujourd'hui les opinions scientifiques et populaires. En même temps que Lyell apparaissait sur la scène, Logan entreprenait à Joggins l'un des premiers projets de la Commission géologique du Canada sur le terrain. Avec le désir de faire progresser la pensée et les positions scientifiques en toile de fond, un opéra aux nombreux rebondissements s'est alors joué entre chercheurs professionnels. Gesner a demandé à Murchison, président de la Société géologique, que Lyell soit réprimandé pour avoir induit en erreur les géologues de la Nouvelle-Écosse. Owen, qui avait antérieurement avancé le terme de « dinosaure », a battu Lyell et Dawson en baptisant leur propre découverte. Cependant, un jeune O. C. Marsh, pressentant ses luttes profondes intensément compétitives avec Edward Cope, arrivait à Joggins en provenance de Yale, tout enthousiaste de s'engager dans le sillage de Lyell et de Dawson, mais seulement pour être dupé par un voyageur d'expérience prêt à se plier à son désir de célébrité. Émergeant au-dessus de tous les autres, les travaux réalisés par Dawson pour décrire les fossiles présents et leur contexte écologique ont implanté un héritage durable et pertinent par rapport aux falaises de Joggins.

[*Traduit par la redaction*]

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INTRODUCTION

The Joggins coastal section has long been heralded as the most outstanding section of Carboniferous strata in the world (Lyell 1871), a distinction now recognized with its placement on Canada's Tentative List of future World Heritage Site nominees (Parks Canada 2004). It is the coincidence of Earth history recorded at this special place and the instruction that it has provided in the development of some of the seminal scientific principles of earth and biological sciences that raises Joggins to the rank of "most outstanding example in the world" of the Coal Age. This paper, compiled in the course of preparing the case for World Heritage inscription, brings together for the first time an evocation of this rugged place and the labours and interactions of some of the leading scientific thinkers of the Nineteenth Century.

BEGINNINGS

Long before the beginnings of the science of geology, the Mi'kmaq people of Atlantic Canada named this place. The earliest record of their place name appears on the 1735 map of George Mitchell and Edward Amhurst (Public Records Office, Kew Maps, MPG 972, Fig. 1) as "Grand Nyjagon" (J. Dawson 1988). The place name has been interpreted since as Chegoggin – "place of the fishing weirs" (Hamilton 1978) or Chegoggins – "the great encampment" (Brown 1922 and Mi'kmaq elders via Gerald Gloade, personal communication, 2005). Like many other native place names, it became construed as "The Joggins", and later, in the time of the earliest geological visitors, to "The South Joggins" ("The North Joggins" being across Chignecto Bay at Cape Maringouin, New Brunswick (Barlow *et al.* 1886), the twin names likely coming from the quarrymen working both shores for grindstones). Coal was mined from the cliffs of Joggins by the French, long before any written reference to its geology in English. Archaeological investigations at Port Royal, some hundred kilometres farther down the Bay of Fundy, suggest that the first forges of the New World in North America were fuelled by the coal beds of Joggins in the earliest years of the Seventeenth Century (Brigitta Wallis, personal communication, 1996; Rebecca Duggan, personal communication 2004). Over a century later, the fires of the French garrison at Fort Beausejour at the head of the Bay continued to be stoked by coal worked from the Joggins cliffs.

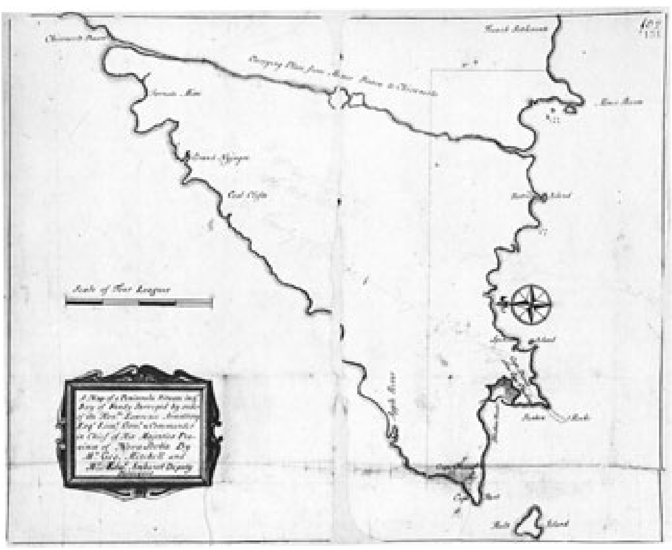


Fig. 1 The earliest known map to record a place name for Joggins, given as the Mi'kmaq name "Grand Nyjagon", by George Mitchell and Edward Amhurst, 1735. "Coal cliffs" are marked immediately to the southwest. Note that north is to the left of the map, as indicated by the compass rose. (Public Records Office, Kew Maps, MPG 972)

Accounts of the geology of the celebrated coastal section at Joggins first appear in the published literature in 1828–1829, by Americans C.T. Jackson and F. Alger, and by Richard Brown and Richard Smith, managers for the General Mining Association in the Sydney and Pictou coalfields (Brown and Smith in Haliburton's "Nova Scotia", 1829). Brown and Smith's astute account is the first stratigraphic reconstruction of the section and the first to document the standing fossil trees and their implications for subsidence of the Earth's surface, whereas Jackson and Alger (1828) was strictly a geographic travelogue. In 1836, Abraham Gesner (Fig. 2), later inventor of a process to distil kerosene from coal oil, described Joggins in his typically effusive style as "... the place where the delicate herbage of a former world is now transmuted in stone." Ever the advocate, Gesner's exhortations of the Provincial government brought pressure to bear on the General Mining Association of London, who opened their first operation at Joggins in 1847 (Goudge 1945).

THE ARRIVAL OF LYELL

July 1842 saw the first visit to Joggins by Sir Charles Lyell, a side excursion from his first trip to the United States and the Province of Canada in 1841–1842. Lyell (Fig. 3), then 45 years old and near the pinnacle of his career, had just nine years earlier published the first edition of his seminal work "*Principles of Geology*" (1830–33), which more than any other work had defined geology as a science. Moreover it provided the temporal backdrop for the theories of a young Charles Darwin, who was presented a copy of the first volume (1830) as a parting gift by his father as he embarked on the historic voyage of *The Beagle* in 1831. Lyell was drawn to the fossil forests of Joggins not out of singular interest in the trees, but for their implications for his principles of basin subsidence and his theory on the terrestrial origin of coals (see Fig. 4). The context that the section provides the fossils in the cliffs of Joggins continues to be one of its most outstanding attributes (Falcon-Lang and Calder 2004). Preparing for his first trip to America in 1841, Lyell later recalled that

> I was particularly desirous, before I left England, of examining the numerous fossil trees alluded to by Dr. Gesner as

Fig. 2 Abraham Gesner, who described Joggins as "the place where the delicate herbage of a former world is now transmuted to stone", and who first escorted Lyell to Joggins in 1842.

Fig. 3 Sir Charles Lyell, who arguably conferred on Joggins its pedigree by describing it unequivocally as the best example of "Coal Age" strata in the world.

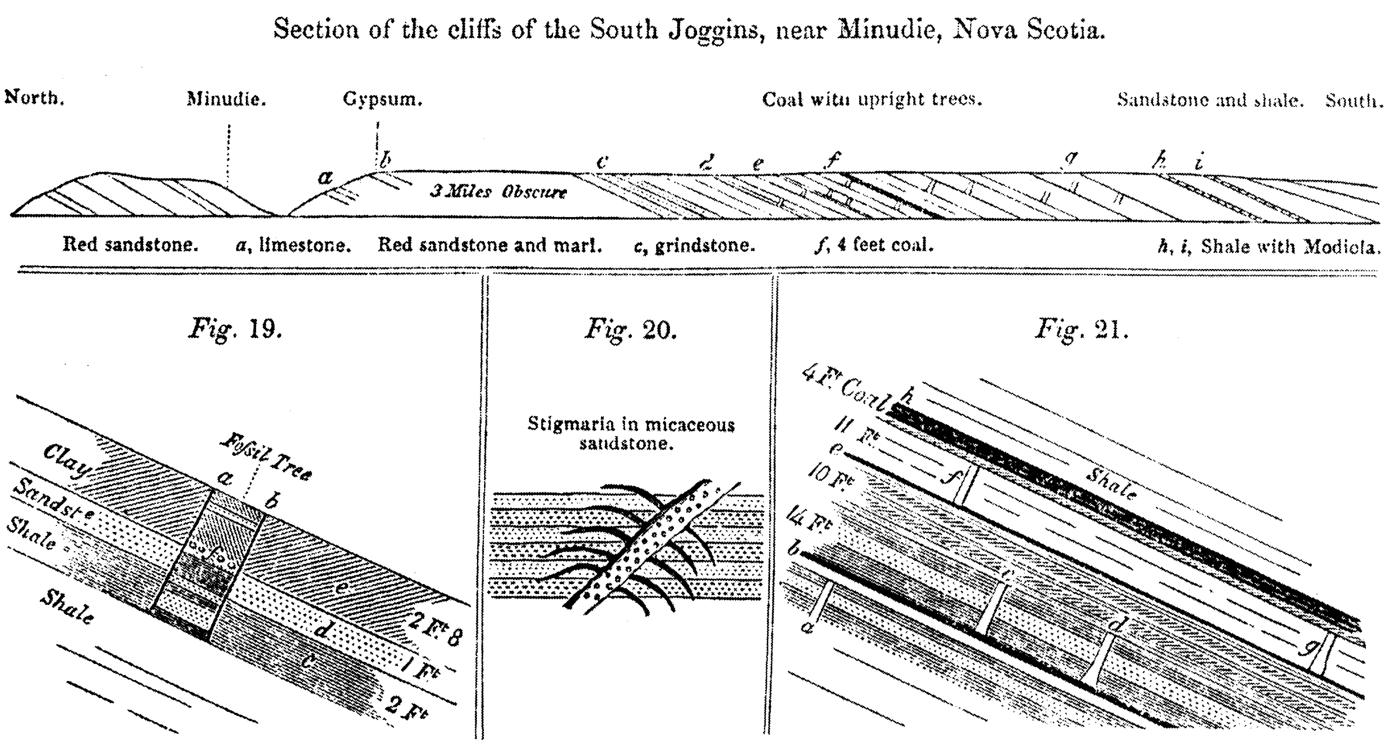


Fig. 4 Lyell's sections from Joggins, from his 1843 paper to the Geological Society of London. Note the correct stratigraphic position of the gypsum south of Minudie, and the emphasis on the upright trees and stigmarian rootstocks.

imbedded in an upright posture at many levels in the cliffs of the South Joggins, near Minudie.

The first allusion to the trees which I have met with, is that published in 1829 by Mr. Richard Brown, in Halyburton's Nova Scotia, and he attributed their fossilization to the inundation of the ground on which the forests stood. I felt convinced that, if I could verify the accounts of which I had read, of the superposition of so many different tiers of trees, each representing forests which grew in succession on the same area, one above the other; and if I could prove at the same time their connexion with seams of coal, it would go farther than any facts yet recorded to confirm the theory that coal in general is derived from vegetables produced on the spots where the carbonaceous matter is now stored up in the earth.

Travels in North America (1845) pp. 177–178

Sir William Dawson, late in his life, recalled Lyell's arrival as a pivotal date in geology for Joggins and for the region: and so it was. 1842 was the year that brought to Joggins not only Lyell, but also William Logan and about the same time, a young student home from Edinburgh, J. William Dawson, to this celebrated place. Following a wild sail across the Minas Basin, Lyell was met at Parrsboro by Gesner, who had a medical practise there; from there they continued the journey north to Joggins (Lyell 1845). Lyell was not to be disappointed. In a letter to his sister of 30 July 1842, he wrote, "My dear Marianne, — We have just returned from an expedition ... whither I went to see a forest of fossil coal-trees — the most wonderful phenomenon perhaps that I have seen...." Soon after, in a letter dated 9 April 1843, Lyell alerted Darwin of his forthcoming paper on the erect trees of Joggins, to be read before the meeting of the Geological Society in London. Darwin would take note.

Lyell once wrote "I never travelled in any country where my scientific pursuits seemed to be better understood, or were more zealously forwarded, than in Nova Scotia ..." (1845, p. 229–230). Chief among these kindred spirits was a young Dawson; Dr. Gesner, on the other hand, was not making it easy for himself to be included in said company. Gesner, preparing to publish his geological map of Nova Scotia with the Geological Society in London, was unhappy that Lyell disagreed with his interpretation of the stratigraphic succession of Carboniferous strata in Nova Scotia (Fig. 4), specifically, the position of the gypsum now assigned to the Windsor Group, which Gesner (1843) erroneously held to be younger than the Coal Measures. In a letter to Roderick Murchison (President of the Geological Society), read before the Society in May 1845, Gesner sought a reprimand of Lyell for having "misled" the geologists of the day with his stratigraphy. Ironically, Gesner's map and accompanying memoir (Gesner 1843) and Lyell's contrary position (Lyell 1843) are recorded for posterity, back-to-back in volume 4 of the *Proceedings of the Geological Society*.

LOGAN AND THE FIRST FIELD PROJECTS OF THE GEOLOGICAL SURVEY OF CANADA

In 1843, the year following Lyell's arrival on the scene at Joggins, Sir William Logan (Fig. 5) undertook the daunting bed-by-bed measurement of the Joggins section, measuring in total 14 570 feet, 11 inches (Logan 1845). His work together with Alexander Murray's transect from Lake Erie to Georgian Bay (Murray 1845) comprised the first field projects of the nascent Geological Survey of Canada, with Logan as its first Director. Logan's feat is all the more remarkable in that he completed his log of the section (Fig. 6) in less than one week (Rygel and Shipley 2005), as he set off for the Gaspé in his search for strategic deposits of coal in the new Province of Canada (Harrington 1883). In his memoir, Sir William Dawson noted the very different personalities of Lyell and Logan: "Logan and Lyell, both able geologists, were men of entirely different stamps. The former was all for observation, measurement, and careful plotting and sketching, and therefore admirably fitted for the work of a detailed survey; the latter observant, yet always full of thought and compassion, and endeavouring to realize on the spot the relations of what he saw" (Dawson 1901, p. 61). Logan's impressive achievement served as the reference section for Joggins for 150 years, only recently being superseded (Davies *et al.* 2005: Calder *et al.* 2005a).

LYELL, DAWSON AND THE TREE STUMP FAUNA

In 1852, on his third trip to America, Lyell made his second excursion to Joggins, this time accompanied in the field by a 32-year-old J.W. Dawson (Fig. 7). Their goal was to investigate "the peculiar circumstances which favoured the preservation of so many fossil trees" (Lyell and Dawson 1853). Dawson and Lyell made their re-acquaintance in Halifax in early September and set out for Joggins, a two day journey by stage coach. In a letter of 12 September, Lyell wrote, "Dawson and I set to work and measured foot by foot many hundred yards of the cliffs, where the forests of erect trees and calamites most abound. ... I never enjoyed the reading of a marvellous chapter of the big volume more" (see Fig. 8). In total, Dawson and Lyell remeasured 2800 ft. of Logan's section, including the entire coal measures of Logan's Division IV.

They would also make one of the most famous of fossil discoveries — tetrapods (amphibians and later by Dawson alone, reptiles) within the erect fossil trees, together with millipedes and the earliest land snails. Dawson later recounted Lyell's excitement at their discovery: "I well remember how, after we had disinterred the bones of *Dendrerpeton* from the interior of a large tree on the Joggins shore, his thoughts ran rapidly over all the strange circumstances of the burial of the animal, its geological age, and its possible relations to reptiles and other animals, and he enlarged enthusiastically on these points, till, suddenly observing the astonishment of a man who accompanied us, he abruptly turned to me and whispered, 'The

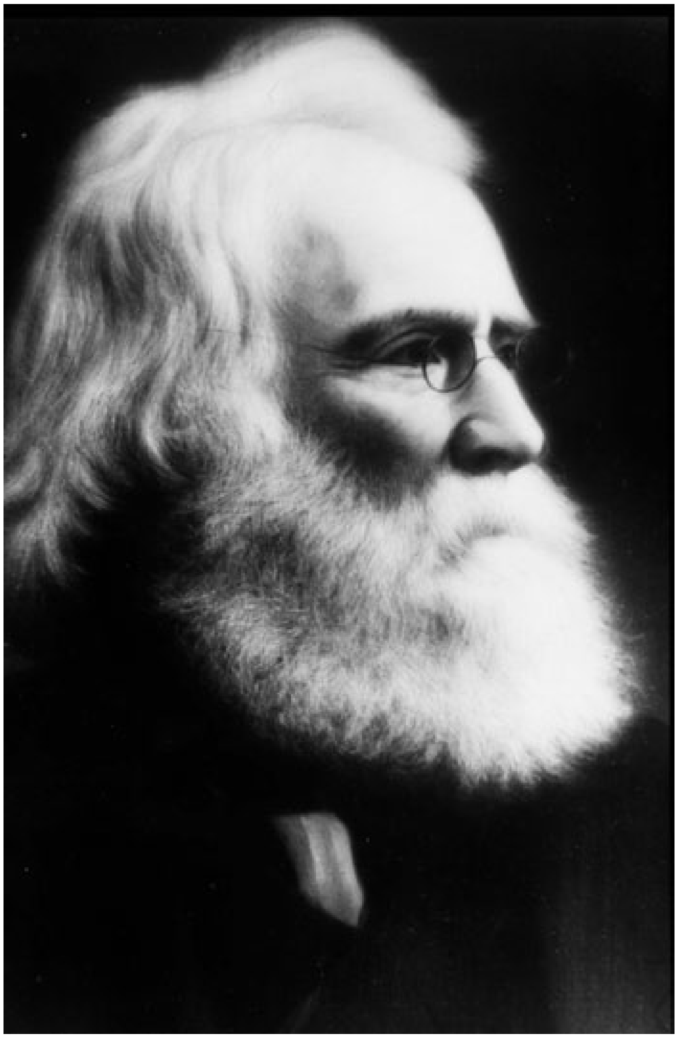


Fig. 5 Sir William Logan, whose bed-by-bed measurement of the Joggins section in 1843 constituted one of the two initial field projects of the fledgling Geological Survey of Canada (GSC Photograph 68772).

Fig. 6 A page from Sir William Logan's 1843 field notebook, with one of his characteristic field sketches.

Fig. 7 (Right) Sir William Dawson, who made a remarkable inventory of the fossil record at Joggins, all the more so for capturing its paleoecological context (Nova Scotia Public Archives).

Fig. 34.—*Section of middle part of Subdivison XV. in which the Dendrerpeton, Land Shells, etc., have been found.*

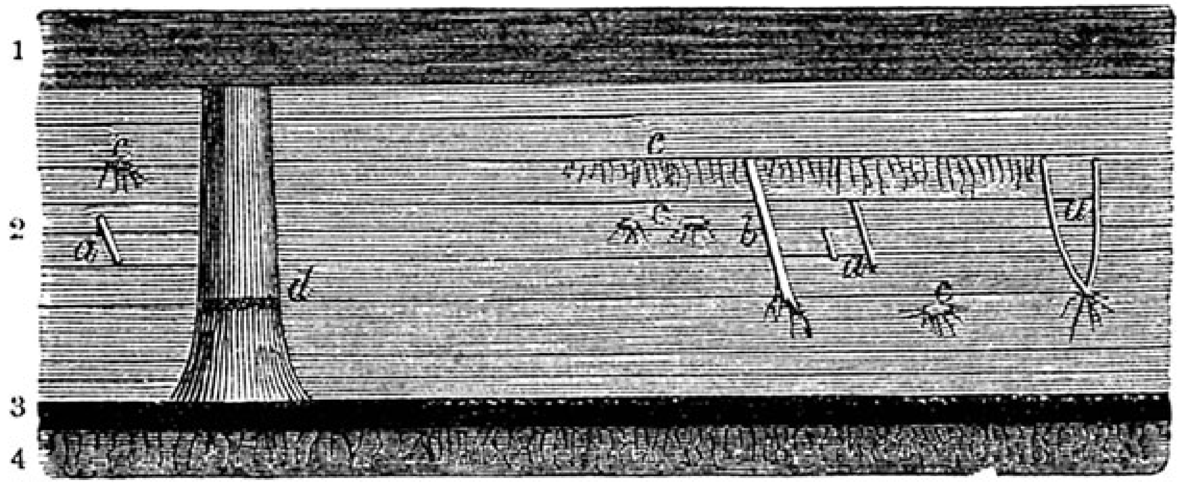


Fig. 8 Wood block etching from Lyell and Dawson's 1853 account of the fossil trees of Joggins. The careful noting of the association of erect calamites succeeding the buried lycopsid trees bears witness to their keen powers of observation.

man will think us mad if I run on in this way'." Lyell took the specimens with him to Boston, where they were examined by Louis Agassiz and Jeffries Wyman of Harvard. Lyell and Dawson waited excitedly for their decision on what they grew to hope were "reptilian" remains, their hopes rising and falling with each revelation. (Note that in the mid-Nineteenth Century, the term "reptile" included amphibians, in much the same sense as the term "tetrapod" is employed today; Carroll 1982). In a letter to Dawson written 6 November 1852 (K.M. Lyell 1881), Lyell related the excitement:

> My dear Sir,—I have very good news to tell you. Agassiz only conjectures that hollow-tree Joggins animal is a coelocanth fish.... Wyman begins to suspect an ichthyic reptile allied to Siren, Proteus anguinus (Nemobranchus?), &c., as he says there is a bone in them more like it. So much for our principal skeleton. But you will be delighted to hear that in the same stone Wyman has worked out part of a vertebral column, seven vertebrae in a series, and three other detached ones of the same dorsal and lumbar region, belonging to a distinct creature, and which he at once pronounced a salamander from the articulating surface of the ball-and-socket joints, &c. Afterwards, when it was shown to Agassiz, he exclaimed, 'This is more reptilian than anything I ever saw in the coal!' I now begin to regret that we left a single fragment of the stone on the beach. For Wyman worked this treasure out of a most unpromising stone, like many which I threw away.
>
> *Latest intelligence.*—Dr. Wyman has just been here with great news. The first bone which we found is clearly not the hyoid bone of a fish, but the iliac bone of a reptile. Do not say anything about it, as every hour he is advancing.... So we have two reptiles according to this, and as only four individuals were previously known in the coal of the whole world, I hope we have added 33 1/3 per cent. at one stroke to the reptilian paleontology of that era.
>
> Believe me, my dear sir, ever truly yours,
> Charles Lyell

Lyell and Dawson's discovery was first announced through the "Lowell lectures" given by Lyell a few weeks later in Boston (Dott 1998). Arriving back in England, Lyell and Dawson's "Reptile of the Coal Age" was quickly named *Dendrerpeton acadianum,* not by the discoverers but to Dawson's chagrin by Sir Richard Owen (Fig. 9), that great usurper of names and credit (see Chapter 6 of Bryson 2003), in a postscript that he added to their discovery paper read before the Geological Society on 19 January 1853 (Owen 1853). Less than a year later, on New Year's Eve 1853, Owen would dine at Crystal Palace in London inside a partially completed *Iguanodon,* the first ever reconstruction of a dinosaur. Owen would claim his seat at the head of the table, having earlier in 1841 laid claim also to the name "Dinosauria". With Lyell and Dawson, however, rest the honours of one of the most celebrated of all fossil discoveries.

O.C. MARSH AND *EOSAURUS ACADIANUS*

The fame of Joggins quickly spread, made all the more accessible with the first printing of Dawson's *Acadian Geology* in 1855. One of the first to be drawn to Joggins from beyond the immediate circle of Lyell's collaborators heralded from the United States. In 1855, O.C. Marsh (Fig. 10) was a wealthy

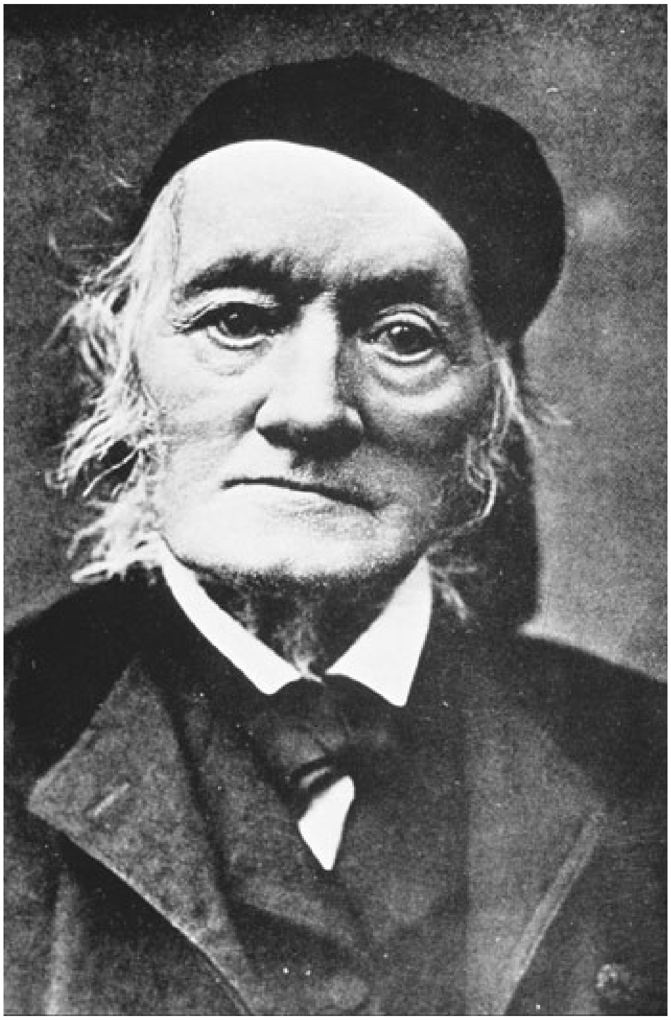


Fig. 9 Sir Richard Owen, first keeper of the British Museum of Natural History, and a scientist with a compulsive nature for claiming ownership of others' discoveries.

Fig. 10 O.C. Marsh of Yale, the famed "dinosaur hunter", who made an uncertain start to his career at Joggins.

young man of 24 just entering Yale when he decided to embark on the voyage north to Joggins. One can speculate that word of Lyell and Dawson's discovery sparked hope in the zealous "dinosaur hunter" of later years of making a name for himself in paleontology. Marsh's purported "discovery" of two large vertebrael centrae (Fig. 11) was proclaimed "*Eosaurus acadianus*", but in an uncharacteristic show of restraint not until 1862, after input from Agassiz (1862). Dawson (1868, p. 382) remarked with his trademark insight and restraint on the uncanny resemblance of *Eosaurus* to the Mesozoic marine reptile *Ichthyosaurus*. Legend has it that Marsh's fossil actually was purchased from a fellow seafarer who convinced O.C. of its origins at Joggins (D. Baird, written communication, 1994). Subsequent vertebrate paleontologists (Romer 1945; Carroll *et al.* 1972; as well as Baird) widely hold the vertebrae to be those of an icthyosaur from Lyme Regis, Dorset, home to the seaside fossil shop of Mary Anning.

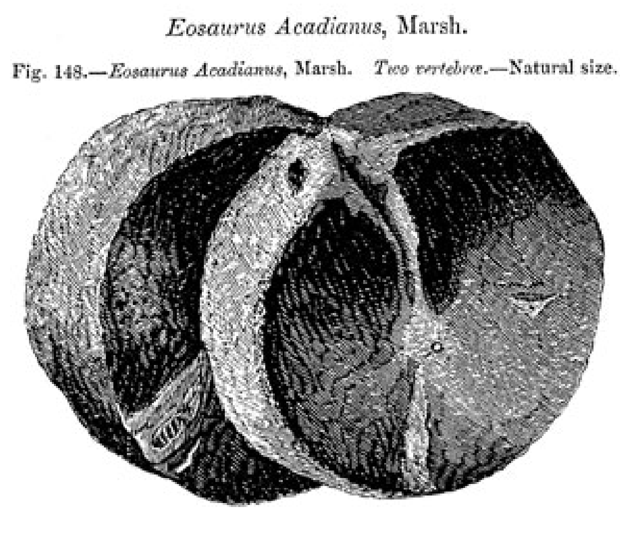


Fig. 11 The two vertebrae that Marsh named *Eosaurus acadianus* (YPM 1648: wood block etching from *Acadian Geology*, 1868).

THE BIG PICTURE: LYELL, DARWIN AND DAWSON ON EVOLUTION

Lyell was delighted with his discovery with Dawson of Coal Age "reptiles" largely because it argued against the progression of fishes in the Paleozoic to reptiles in the Mesozoic (Thackray 1998), part of his long-standing campaign against the proponents of catastrophism (Bryson 2003). Charles Darwin (Fig. 12), in *The Origin of Species* (1859) drew on the completeness of exposure at Joggins and the recurrence of the fossil forests to illustrate that the fossil record is inherently incomplete. What at first may seem a paradox was, in fact, a shrewd, pre-emptive argument against critics of gradual and progressive evolution. Darwin argued that even in the unrivalled exposures at Joggins (Lyell 1871), where fossil forests appear at no less than 68 horizons, the intervening beds theoretically could hide "the fine intermediary gradations which must on my theory have existed between them", with the result that the fossil record generally gives the misleading appearance of "abrupt, though perhaps very slight, changes of form." (Darwin 1859, Ch. IX, *Imperfection of the Geological Record*, p. 296.)

Dawson continued to argue the case for Lyell, his close friend, mentor and benefactor. In 1863 he published *Air-Breathers of the Coal Period*, (subtitled *A descriptive account of the remains of land animals found in the coal formation of Nova Scotia with remarks on their bearing on theories of the formation of coal and of the origin of the species*), which as the complete title reveals, was in part a counterpoint to Darwin's *Origin of Species* (1859). Dawson advocated that the discovery of essentially modern, conservative forms such as the land snail *Dendropupa* (Fig. 13), virtually unchanged over millions of years, argued against Darwinian progressive change – imperfections in the geological record aside. Bishop Samuel Wilberforce (1860, p. 244) in his review and criticism of *Origin of Species* had already taken obvious pleasure in chiding Darwin about "this miserable little *Dendropupa*" (Fig. 14). It is clear that Dawson never accepted Darwin's transmutation of species (Dawson 1893), even though he did recognize the concept of deep time and the slow progress of the appearance of progressively higher forms of life in the fossil record, and so could not be called a creationist in today's sense. Indeed, it is one of the great ironies in the history of science that Dawson fought to convince his contemporaries that life had microbial origins far deeper in time than most were willing to accept: his *Eozoon canadense* (Dawson 1875). Historians (e.g. O'Brien 1971) have done Dawson disservice in dismissing his challenges to Darwin as religious myopia and not considering them further. Like all his work, Dawson was a careful observer and documenter of geologic phenomena. His observation, for example, that conservative forms such as *Dendropupa* persist unchanged for long expanses of time presaged later modification to evolutionary theory expressed in the "tempo and mode" of Simpson (1944) and "punctuated equilibria" of Gould and Eldredge (1977), but which would have to await the passage of a century for wide acceptance (Rolfe 1982; Carroll 1982).

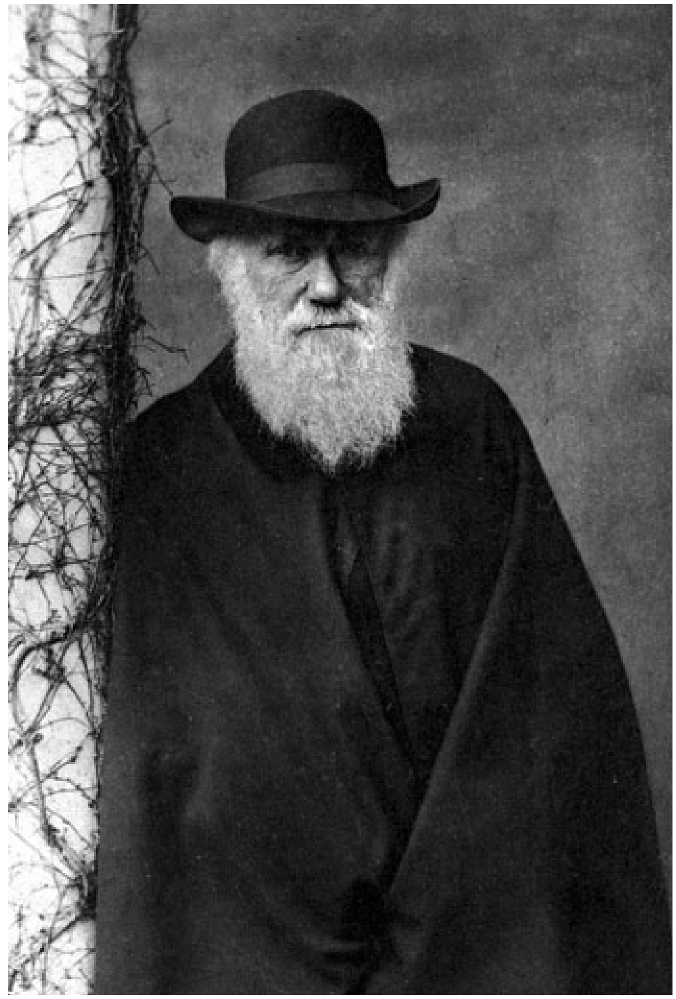


Fig. 12 Charles Darwin, who crafted a pre-emptive argument on the incomplete nature of the fossil record, using Joggins as an example. Darwin also was compelled to address the existence of the land snail *Dendropupa* at Joggins. (Elliot and Fry portrait.)

THE ORIGIN OF COAL

"I shall never rest easy in Down church-yard, without the problem be solved by someone before I die."
Charles Darwin in a letter to J.D. Hooker,
10 May 1848
(DAR 114.2: 112 in Burkhardt and Smith 1988).

Debate on the origin of coal, the fuel of the Industrial Revolution, revolved very much around the Joggins section (see Scott 1998). Lyell cited this as one of his main reasons for first visiting the cliffs in 1842 and it was the subject of one his Lowell lectures delivered in Boston and repeated in New York and Philadelphia during his first trip to America (Dott 1998). Coal beds remained enigmatic to many scientists of the day (Horner 1846), some of whom, including Darwin (correspondence of 19 May 1846; DAR 114.2: 62–62b in

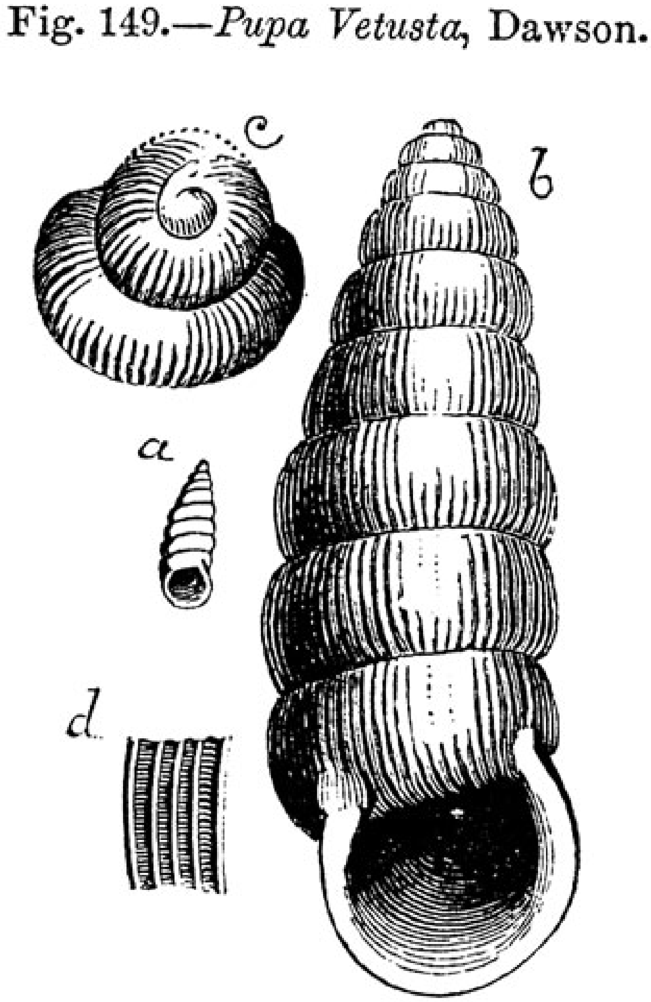


Fig. 13 Wood block etching of the earliest land snail *Dendropupa vetusta*, an illustration that bears witness to Dawson's prowess with the microscope (from *Acadian Geology*, 1855).

Fig. 14 Caricature of "Soapy Sam" Wilberforce, by Carlo Pelligrini in Vanity Fair, 24 July 1869.

Burkhardt and Smith 1987), speculated that their great areal extent necessitated a submarine origin. Darwin's suggestion to Joseph Hooker that the upright trees of Joggins and elsewhere might also have been submarine by association, having grown at depths of 5 to 100 fathoms (DAR 114.2: 89), drew a "savage onslaught" from his trusted confidant, cited in Darwin's rebuttal letter of 6 May 1847 (DAR 114.2: 91 in Burkhardt and Smith 1988). Dawson (1865), like Lyell, correctly advocated a terrestrial plant origin for coal beds. Thomas Huxley, "Darwin's bulldog", however, drew sweeping conclusions – a position consistent with Darwin's – that coal beds were derived from subaquatic concentrations of spores. Huxley (1897) eventually acquiesced to Dawson, citing his command of the subject, but continued to stress the significance of spore cases, as if to keep Darwin's torch alight.

The first convincing argument for the terrestrial origin of coal had come from Logan's observations (1841) that *Stigmaria* were the roots of lycopsid trees in their original position of growth. Logan felt that Lyell had failed to credit his observations, however, which he had provided Lyell by letter from Halifax (see Dott 1996, p. 139). Lyell's defense was that his Lowell lecture on the subject, given after their correspondence, was actually written beforehand. However, Logan was unconvinced and, in a letter to Henry De la Beche of 3 December 1841 (H.T. De la Beche Papers, National Museum of Wales, NMW 84.20G.D876, cited in Dott 1996), wryly observed: "I see he mentions that I had made independent observations on Nova Scotia. How the devil he knew that before I told him I cannot imagine." For Darwin, however, it was not the *in situ* nature of *Stigmaria*, but rather the discovery of terrestrial fauna within the upright trees at Joggins (Dawson 1860) that finally persuaded him of the terrestrial origin of coal, in essence "fossil peat", and of the fossil trees: in a letter of 22 May 1860 to Lyell (American Philosophical Society 213 in Burkhardt *et al.* 1993), he exclaimed "What a fact about the Coal Land Shells!!!". Darwin may rest easy.

DAWSON'S LABOUR OF LOVE

Dawson revisited the site of his initial discovery with Lyell of *Dendrerpeton* over the course of the next few years, and in 1859 reported to the Geological Society yet another discovery, the significance of which has continued to grow with time. *Hylonomus lyelli*, meaning "forest dweller", named in honour of his mentor and friend, Sir Charles, a century and a half later was proclaimed Nova Scotia's Provincial fossil and remains the earliest known amniote in the fossil record (Carroll 1964, 1970; Reisz 1997; Clack 2002). (*Hylonomus* was briefly usurped by *Westlothiana lizzeae*, an older tetrapod known from the Visean of Scotland, but which is now widely considered to represent a more primitive, stem amniote; Reisz 1997; Clack 2002).

In 1877, armed with a grant of £50 from the Royal Society, and with the assistance — and explosives — of the mining company at Joggins, Dawson set out to investigate the tree-entombed tetrapods with vigour (Fig. 15). Dawson (1882) exposed an entire fossil forest horizon comprising 25 lycopsid trees entombed in the "Lesser Reef of Coal Mine Point". Incredibly, 15 — over half — were productive, yielding more than 100 individual tetrapods from this one concentrated Lagerstätten, which remains the most significant single collection of Paleozoic terrestrial tetrapods in the world. The curious circumstances of the entombment of these denizens of the Coal Age forests has continued to enthral scientists and the public. Lyell and Dawson (1853) early on ascribed their occurrence to denning, pitfall, or the possibility that the animals had been washed into the buried hollow trees. Dawson (1891a) ultimately came to favour the pitfall theory, which has been figured in countless texts on the history of life, although recent research (Calder *et al.* 2005b) points to another of Lyell and Dawson's original hypotheses: denning.

Much of our knowledge of the fossil record at Joggins derives from the lifelong work of Dawson, which encompassed a broad range of paleontological disciplines including plants, tetrapods, fishes, terrestrial and aquatic invertebrates, and trace fossils. Dawson sought the collaboration of peers on both sides of the Atlantic, including among others Louis Agassiz and S.H. Scudder of Harvard, and their colleague A.A. Gould, Joseph Leidy of the Academy of Natural Sciences, Philadelphia, J.W. Salter at the Geological Survey of Great Britain and T.P. Jones, fellow of the Geological Society and professor at Sandhurst.

Dawson was a pioneer in the field of terrestrial paleoecology

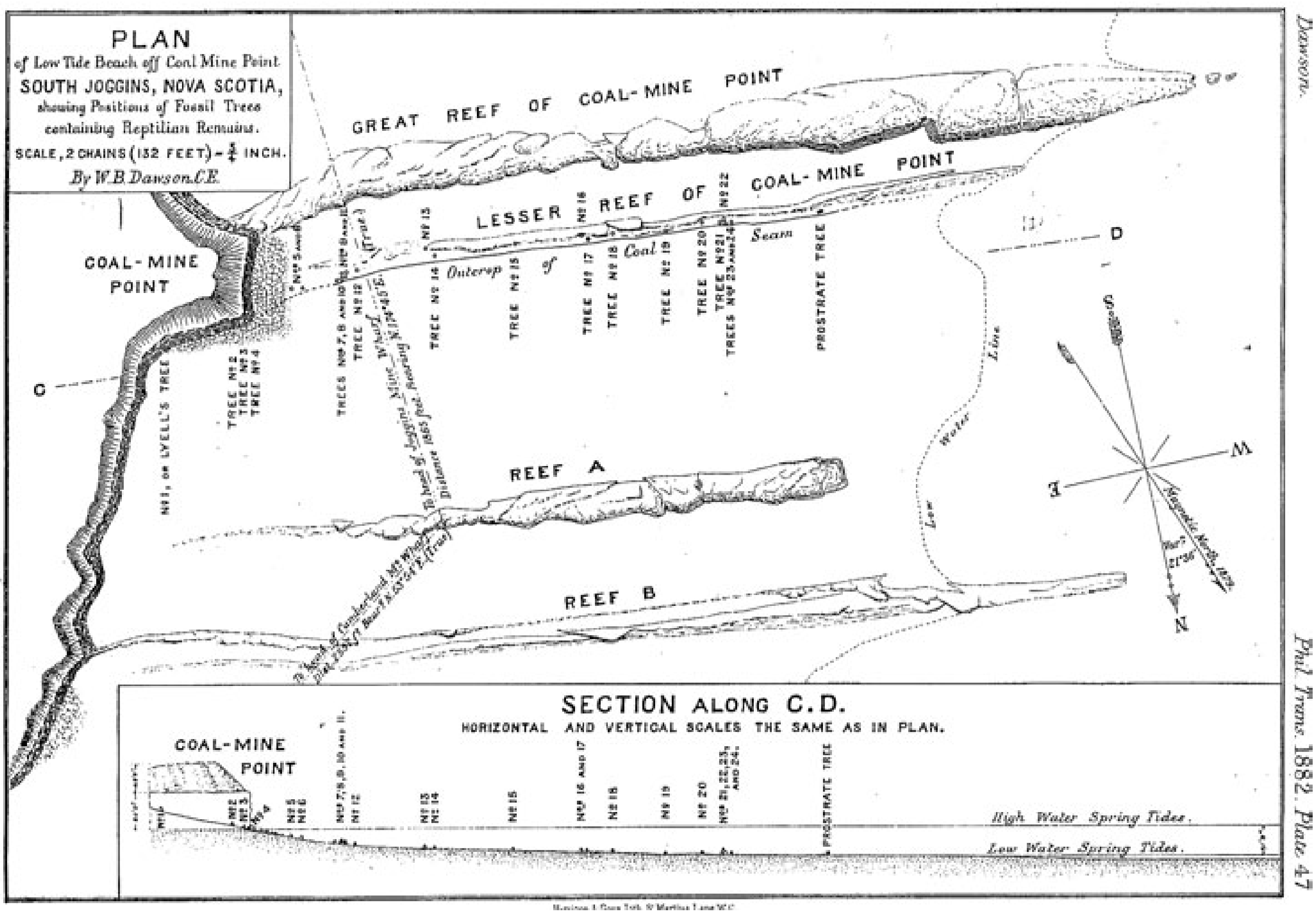


Fig. 15 **Map of Dawson's explorations for tetrapod-bearing trees at Coal Mine Point (from Dawson 1882). The position at the cliff face of the fauna-bearing tree co-discovered with Lyell in 1852 is annotated "No. 1, or Lyell's tree".**

(Falcon-Lang and Calder 2005). In a letter written 13 August 1868 (cited in Sheets-Pyenson 1995), Dawson commiserated with Lyell on the lack of field investigation that typified and hobbled paleontologists of the day, offering that advances would come by careful study of "… plants as they stand in the cliffs at Sydney and the Joggins, instead of on the shelves of the British Museum." The breadth of Dawson's work and his careful observations of the relationships of fossils and their entombing sediments (Falcon-Lang and Calder 2005), coupled with observations by Lyell and others of modern environments, enabled him to draw astute inferences of the ancient Joggins landscape and its paleoecology: "… these beds carry our thoughts back to a period when the district was covered by a strange and now extinct vegetation, and when its physical condition resembled that of the Great Dismal Swamp, the Everglades, or the Delta of the Mississippi" (*Acadian Geology*, Dawson 1868, p.182). His historic diorama of the terrestrial environment and fauna at Joggins for the frontispiece of *Air Breathers of the Coal Period* (1863) is one of the earliest for the Paleozoic (Fig. 16). Dawson's publications stemming from Joggins, spanning 44 years, are summarized eloquently in his opus "*Acadian Geology*" (1855), and updated through the addition of supplements in subsequent editions (1868, 1878 and 1891b).

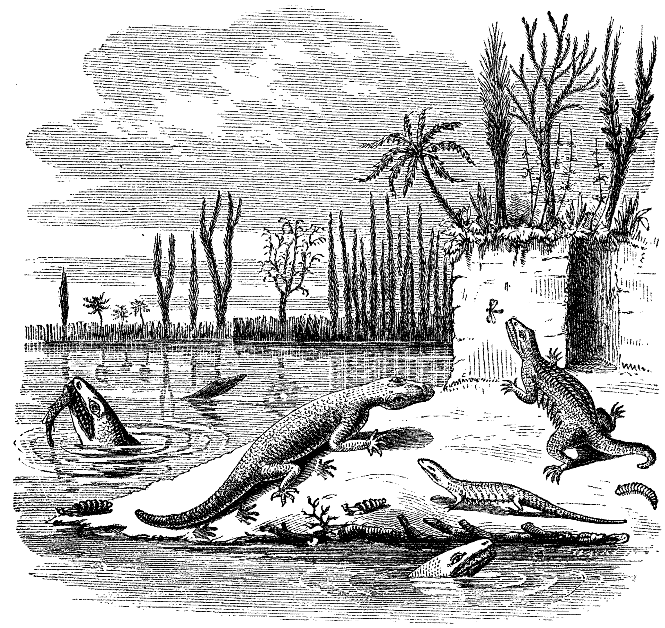
NEW CENTURIES DAWN

Lyell's first impression of the coastal section at Joggins was never diminished. In discussing the coal measures of the Carboniferous in *The Student's Elements of Geology* (1871), Lyell would bequeath to Joggins the following blessing: "But the finest example in the world of a natural exposure in a continuous section ten miles long, occurs in the sea cliffs bordering a branch of the Bay of Fundy in Nova Scotia."

Late in his life, Dawson (1901) recalled his first visit to Joggins in the early 1840s, a memory evocative to many who have followed in his footsteps…:

> The tide being low in the afternoon, I rose early next morning, and taking some luncheon in my basket, walked along the shore to the south-westward for several miles. I was amazed at the grand succession of stratified beds exposed as plainly as in a pictured section, and was interested beyond measure in the beds of coal, with all their accompaniments, exposed in the cliffs and along the beach, the erect trees (*Sigillaria*) represented by sandstone casts, and the numerous fossil plants displayed in the beds. The tide favoured my expedition, and the day was fine, though small banks of fog drifted up the bay from time to time, dissolving as they touched the cliffs, warmed by the sun. I returned in the evening to the quarrymen's shanty, thoroughly fatigued, but loaded with fossils, delighted with the knowledge I had acquired, and with my enthusiasm for geology raised to a higher point than ever before. Such was my first visit to the celebrated coast-section of the Joggins, on which I have spent so many pleasant and profitable days.

REPTILES OF THE COAL PERIOD.



RESTORATIONS OF BAPHETES, DENDRERPETON, HYLONOMUS, AND HYLERPETON.

Fig. 16 "Reptiles of the Coal Period", one of the earliest dioramas of terrestrial life in the "Coal Age" (from Dawson 1863).

In the twilight of Dawson's life, the momentum of his work carried paleontology forward at Joggins. In 1893, T.C. Weston of the Geological Survey of Canada discovered one of the few taxa to escape Dawson's eye, the large and enigmatic bivalve *Archanodon*, originally described as *Asthenodonta* by Whiteaves (1893), who the year before had described fauna from the Burgess Shale. As a new century dawned without Sir William, George Frederic Matthew, founder of the New Brunswick Museum, pursued the trackways of Lyell and Dawson's tetrapods (Fig. 17) in a series of keynote papers (Matthew 1903, 1905) that remain definitive works in tetrapod ichnology. In 1909, the torchbearer of field work in the Carboniferous of Nova Scotia, Hugh Fletcher of the GSC, lost his life to pneumonia contracted while working the section (Zaslow 1975).

Research at Joggins in the Twentieth Century reflected the pragmatism and geopolitical divide of a world conflicted, with attention focusing on characterizing the coal beds that continued to be strategically important. A major focus of research was that of Walter Bell, one of the delegates to the International Geological Congress of 1913 (Fig. 18), who pursued paleobotanical studies at Joggins and elsewhere in the Carboniferous rocks of eastern Canada. Bell's interest in the fossil plants lay chiefly in their utility in correlating the rocks of eastern Canada with, in particular, those of the European coal measures (see Calder 1998).

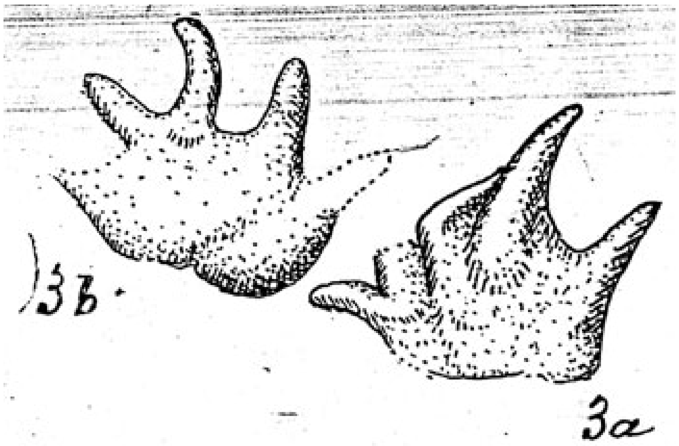


Fig. 17 Tetrapod footprints (*Asperipes flexilis*) figured by G.F. Matthew (1903).

A resurgence in scientific publication at Joggins to rival that of the Nineteenth Century has waited for the passage of a century since the work of the "Lions", and has required the collective wisdom and efforts of an informal working group drawn, as in Lyell and Dawson's day, from both sides of the Atlantic (see Atlantic Geology volume 41, issues 2 & 3, 2005). Just as in the mid-Nineteenth Century, this work was made possible only with the return to careful, bed by bed scrutiny of this daunting section (Davies *et al.* 2005; Calder *et al.* 2005; Calder *et al.* 2006). The graphic logs derived from this work now serve as the reference section for specimens collected from this most outstanding exposure of the "Coal Age".

POSTLUDE

The void left in the wake of Sir William's departure, and of his contemporaries of the Nineteenth Century, is one that is impossible to measure, but more than a century later is almost palpable. How the delegates to the International Geological Congress must have longed for their guidance as they walked

Fig. 18 Delegates to the International Geological Congress dine near the Fundy seam (Logan's coal 29) during their field excursion to Joggins in 1913 (GSC photograph 24289).

these shores in 1913, as we have since. They walk with us still in the mists of time that hug these magnificent cliffs, their voices mingle with the crashing waves. This paper is dedicated to their memory.

ACKNOWLEDGEMENTS

I would like to offer my appreciation to the many people who have helped to shed light on the history of geology at Joggins over the past 25 years, and have allowed the perspective of this synthesis to take shape. These have including Stephen Archibald, Don Baird, Bob Carroll, Howard Falcon-Lang, Tim Fedak, Laing Ferguson, Martin Gibling, Gerald Gloade and elders of the M'ikmaw First Nation, Bob Grantham, the late Peter Hacquebard, Brian Hebert, Ernie Hennick, Heidi MacDonald, J. Lynton Martin, Ley Missidailis, Donald Reid, Andrew Scott, the late Susan Sheets-Pyenson, Deborah Skilliter, Charles Smith, the late John Thackray, Harry Thurston, Brian Todd, Robert Wagner and Brigitta Wallis. To those who inevitably I have not named here, I offer my apology and thanks. I would also like to thank the Martin Rudwick for perusing an early draft, to reviewers Michael Rygel and Christy Vodden for their thoughtful, helpful reviews, and to Rob Fensome for his characteristic care in improving the manuscript as editor. I wish to thank David McMullin for his careful attention in preparing the manuscript for publication.

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Editorial responsibility: Robert A. Fensome

A history of research at the Joggins Fossil Cliffs of Nova Scotia, Canada, the world's finest Pennsylvanian section

Howard J. Falcon-Lang

FALCON-LANG, H. J. 2006. A history of research at the Joggins Fossil Cliffs of Nova Scotia, the world's finest Pennsylvanian section. *Proceedings of the Geologists' Association*, **117**, 377–392. The Joggins section is the finest natural exposure of Pennsylvanian strata anywhere in the world. These towering sea-cliffs fringing the Bay of Fundy in Nova Scotia have attracted geologists for nearly two hundred years. The earliest detailed study of the site, in 1836, was by Abraham Gesner, the man who later pioneered the technique for the distillation of kerosene. In 1842, Charles Lyell described fossil trees in growth position, an observation that proved the autochthonous origin of coal. In 1843, William Logan, Nova Scotia's first provincial geologist, famously logged the entire section in only five days. When Lyell returned to Joggins with William Dawson, in 1852, they made the sensational discovery of amphibian bones within a fossil tree. In 1859, Dawson found additional skeletons, amongst these the earliest known reptile, *Hylonomus lyelli*. A dearth in field research followed Dawson's death in 1899 and subsequent studies mainly focused on pre-existing museum collections. Beginning in the late 1980s, Martin Gibling, John Calder and colleagues embarked on a multi-disciplinary research programme, which has now resulted in a new synthesis of the section.

Key words: history of geology, Charles Lyell, William Dawson, William Logan, Joggins, Nova Scotia, Pennsylvanian, Coal Measures

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1. INTRODUCTION

The Joggins Fossil Cliffs of Nova Scotia is a candidate UNESCO World Heritage Site (Falcon-Lang & Calder, 2004), renowned for its unrivalled record of Pennsylvanian ('Coal Age') tropical environments and ecosystems (Fig. 1; Davies *et al*., 2005). The site contains one of the richest fossil assemblages of this age anywhere in the world, including representatives from both aquatic and terrestrial realms (Calder, 1998). Of particular importance is the fact that fossils are mostly preserved in the palaeoenvironments in which they lived (an *eco-lagerstätte*), allowing ancient communities and food webs to be reconstructed in detail (Falcon-Lang *et al*., 2006).

Joggins was propelled to international fame by Sir Charles Lyell in the mid-nineteenth century (Lyell, 1843). Following his first visit to the site, he wrote to his sister of the occurrence of 'forests of fossil coal-trees, the most wonderful phenomenon perhaps that I have ever seen' (Lyell, 1845, p. 63). During a second visit a decade later, accompanied by Sir William Dawson, he discovered amphibian skeletons which, at the time, were the earliest known (Lyell & Dawson, 1853). To Lyell, the global significance of Joggins was self-evident. It is undoubtedly 'the finest example in the world of a natural [Pennsylvanian] exposure' he wrote towards the end of his life, reflecting on the extensive body of research that had subsequently accumulated (Lyell, 1871, p. 671).

The enduring significance of Joggins is, of course, closely linked to its geographical setting. Hewn by the world's highest tides on the Bay of Fundy, new fossils are constantly emerging from these towering sea-cliffs. Dawson, who devoted a staggering 50 years to Joggins research (Dawson 1901), pointed out that, 'it is only by repeated visits that the geologist can thoroughly appreciate the richness of this remarkable section' (Dawson, 1861, p. 5). The aim of this paper is to lay out the history of research at Joggins from the early nineteenth century to the present day. In doing so, some of those 'repeated visits', which have provided us with such dramatic insight into the life and times of the Pennsylvanian 'Coal Age', will be documented.

2. THE ORIGIN OF COAL

Joggins research began in the early nineteenth century. To put this work in its proper context it is essential to recognize the popular and scientific interest in Pennsylvanian coal-bearing strata at that time. Pennsylvanian palaeobotany, in particular, was a vibrant, cutting-edge research field of central importance to unravelling the origin of coal, the raw material that powered the industrial world (Scott, 1998). New discoveries of fossil plants were published frequently in the philosophical magazines of Europe and North America (Falcon-Lang & Calder, 2005).

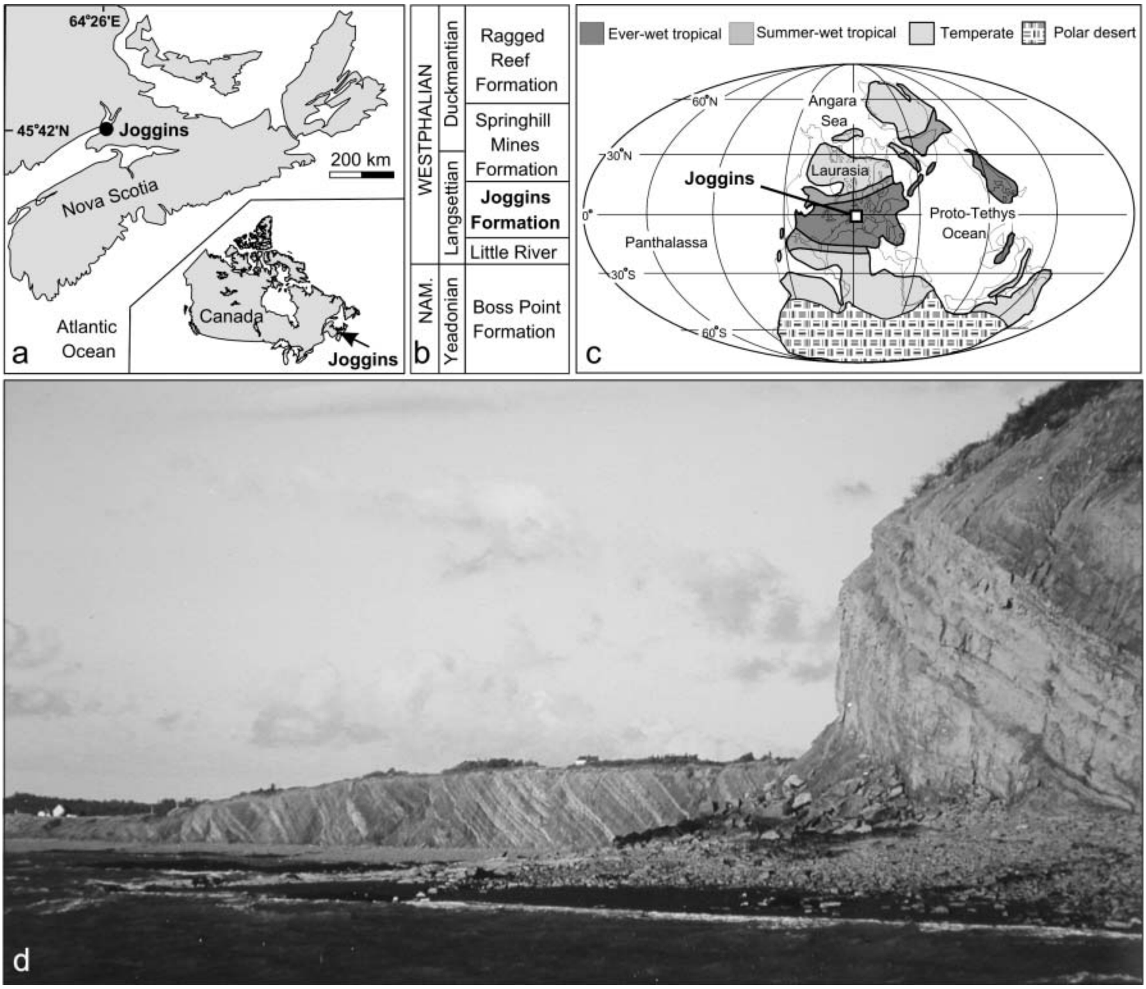


Fig. 1. Geological setting: (**a**) location of Joggins in Nova Scotia, Canada; (**b**) stratigraphy of the Pennsylvanian Joggins section; (**c**) palaeogeographical context of Joggins at the heart of equatorial Euramerica (Falcon-Lang, 2005); (**d**) the Joggins Fossil Cliffs looking northward from Coal Mine Point towards Lower Cove (courtesy of Mike Rygel).

Although long recognized as the product of compressed plant remains, a key outstanding question concerned whether coal formed from drifted material, or *in situ* beneath forest profiles (Stevenson 1911). In his *Principles of Geology*, Lyell (1832) leaned towards the former opinion, pointing to the great masses of driftwood that annually accumulated on the MacKenzie delta. However, the latter view was also amply supported by reports of upright fossil trees rooted in coal-bearing strata in both the British Isles and continental Europe (Thomson, 1820; Conybeare & Phillips, 1822).

It was against this philosophical backdrop that the first geological account of Joggins was prepared by Richard Brown (1805–1882). Brown was a twenty-year-old mining engineer from northwest England. Beginning in 1826, he was employed by the General Mining Association of London, who held the regional monopoly on mineral rights, to survey Nova Scotia's coal resources (Fleischman & Oldroyd, 2001). His work, published in Haliburton's *Nova Scotia*, documented 'the high cliffs of the Joggen shore' and its many horizons of upright fossil trees (Brown & Smith, 1829, p. 429). That same year, Jackson & Alger (1829) also wrote about Joggins, commenting that its pyrite-rich coals represented only a poor quality fuel source.

Shortly afterwards, Joggins attracted a third geological visitor, Abraham Gesner (1797–1864), a medical doctor based in Parrsboro, Nova Scotia. Gesner is perhaps best known as the man who pioneered the technique for the distillation of kerosene (from 'albertite' deposits in New Brunswick) and is thus recognized, in some circles, as the father of the petroleum industry. He reminisced how he had often

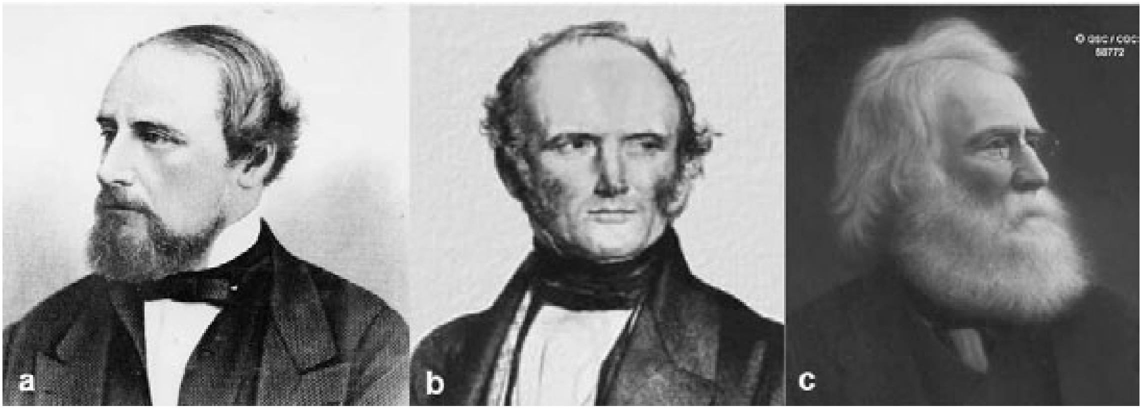


Fig. 2. Geologists from the Golden Age of Joggins research in the mid-nineteenth century: (**a**) Sir William Dawson; (**b**) Sir Charles Lyell; (**c**) Sir William Logan (after Falcon-Lang & Calder, 2004).

> gazed in astonishment upon the precipices of the Joggins shore and beheld the beach on which the broken branches and limbs of ancient trees are scattered in great profusion – the place where the delicate herbage of a former world is now transmuted into stone (Gesner, 1836, p. 157).

However, reading between the lines, it seems that Gesner almost did not return to tell this tale. Having attempted to collect fossils directly from the cliff face, he records how his field party found themselves 'in danger of being killed from the launch of a huge [fossil] tree' (Gesner, 1836, p. 159).

Still wrestling with the origin of coal, these reports were to come to the attention of Lyell in London, and their implications were not lost on his astute mind.

> I felt convinced that, if I could verify the accounts of which I have read, of the superposition of so many different tiers of trees, each representing forests which grew in succession on the same area, one above the other; and if I could prove at the same time their connexion with seams of coal, it would go farther than any facts yet recorded to confirm the theory that coal in general is derived from vegetables produced on the spots where the carbonaceous matter is now stored up in the earth (Lyell 1845, p. 178).

3. LYELL'S FIRST VISIT

Lyell did not have to wait long for an opportunity to visit Joggins. Invited to give the prestigious Lowell Lecture Series in Boston, he spent over a year in eastern North America, beginning in June 1841 (Dott 1998). From the outset he was determined to geologize extensively, and aimed to write a popular travelogue, which eventually appeared as *Travels in North America* (Lyell, 1845). Naturally, he was particularly desirous 'of examining the numerous fossil trees alluded to by Gesner as imbedded in an upright position at many levels in the cliffs of the South Joggins' (Lyell, 1845, p. 177).

In August 1841, an extraordinary coincidence occurred which had major implications for the future of Joggins research: by chance, Lyell was spotted by Sir William Logan (1798–1875) on the streets of New York, and they later met to discuss geology (Fig. 2). Logan was a Canadian by birth but had been educated at Edinburgh University, where he had developed a passionate interest in geology. In the preceding decade he had made extensive stratigraphic studies in Britain and was an active member of the Geological Society (presumably the reason he was able to recognize Lyell). He had recently returned to North America to study geology (Harrington, 1883). Logan, like Lyell, was fascinated by the origin of coal. His discovery of rooted underclays beneath Welsh coal seams in the late 1830s had already gone far to prove that coal was deposited in place (Logan, 1841). Logan went on to examine coal-bearing strata in Pennsylvania later that same year, and documented additional examples of underclays (Lyell, 1841; Logan, 1842); he was also eager to see the Joggins section.

Of the two, Lyell was the first to visit Joggins in the summer of 1842, towards the end of his North America trip (Dott, 1998). Sailing from Boston to Halifax, Nova Scotia, he travelled overland to Wolfville on the Bay of Fundy, and from there, by schooner, to Parrsboro on the far shore (Lyell, 1845). If Lyell's report of his Fundy crossing is accurate, it must have been a 'white knuckle ride', with the deck repeatedly pitching to angles of 45°. At Parrsboro, he was entertained by Gesner, who was now employed as New Brunswick's provincial geologist, and together they explored Joggins for a single day in late July (Lyell, 1845).

Late in that field day, Lyell fell into conversation with a local cottager and casually enquired as to the origin of the peculiar name, Joggins. He records in his

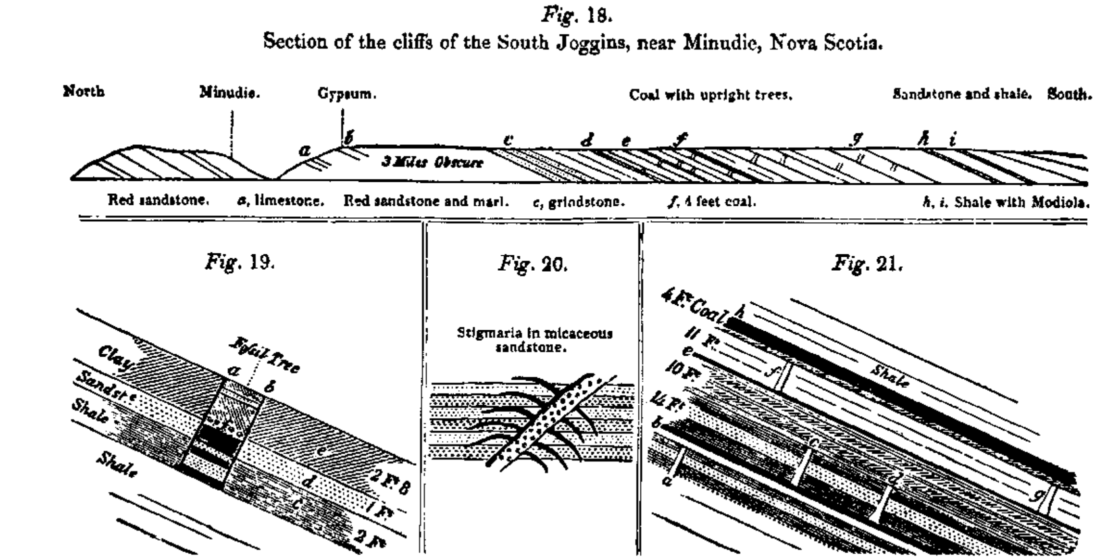


Fig. 3. Charles Lyell's field sketches of upright fossil trees in the Joggins section proved the autochthonous origin of coal once and for all (reproduced from Lyell, 1845).

journal, how the local man 'immediately pointed to the salient and retiring angles of the cliffs, observing, "You see that they jog in and jog out"' (Lyell, 1845, p. 194). It is unclear whether Lyell was entirely convinced by this parochical etymology, but it stands as the earliest published interpretation of the name. A more probable origin, widely held today, is that Joggins derives from the Mi'kmaq Indian word *chegoggin*, roughly translated as the 'great fish weir' (Hennessey, 1988), or 'place to fish' (Legere, 2005).

Lyell's brief observations resulted in the first comprehensive compilation of the Joggins fossil record, thereby proving the close similarity of the Nova Scotia Coal Measures to those of Europe (Lyell, 1845). The significance of this finding was only borne out following the plate tectonics revolution; Nova Scotia and England were, of course, adjacent in Pennsylvanian times (Calder, 1998). More importantly, the 'wonderful phenomenon' of abundant upright fossil trees corroborated Logan's recently acquired data from Wales and Pennsylvania (Logan, 1841, 1842), demonstrating the autochthonous origin of coal once and for all (Fig. 3; Gesner, 1843; Lyell, 1843).

4. LOGAN'S GREAT SECTION

Although Logan appears to have studied the geology of Nova Scotia in 1841–2, it was not until 1843 that he first visited the Joggins section. Thanks to glowing references from Murchison, Sedgwick, De la Beche and Buckland, Logan had just landed the job of Nova Scotia's provincial geologist (Rygel & Shipley, 2005). Who could have turned down a candidate with such referees? This tenure, which was later to develop into the Geological Survey of Canada (GSC), gave him freedom to reconnoitre regional coal reserves, and where better to start than at Joggins:

> I shall pay a visit to the Joggins, where Lyell saw the vertical trees, & I shall endeavour to determine the thickness of the whole deposit there. Dr. Gesner says it is 5 miles thick & Lyell says that it dips one way for a distance of 35 miles (letter to De la Beche, 31 May 1843; cited in Rygel & Shipley, 2005, p. 90).

In the summer of 1843, Logan travelled to Joggins by coach and foot, arriving at nearby Minudie on June 4. Following a one-day delay due to heavy rain, he logged the entire Joggins section, an enormous thickness of strata totalling 14 570 feet, 11 inches, i.e. more than 4 km (Rygel & Shipley, 2005). His biographer described this feat as follows: 'at the South Joggins [Logan] spent several weeks, and it was at this time that he executed his great section of the coal-measures which, as has been truly said, is "a remarkable monument of his industry and power"' (Harrington, 1883, p. 143).

However, this glowing retrospective view fails to stand up to historical analysis. Logan's field notes show that he actually completed his Joggins log in only five days; the great detail of his section is therefore illusionary, representing a rapid reconnaissance (Rygel & Shipley, 2005). Furthermore, to Logan's frustration, his work attracted little interest and, in the end, he resorted to publishing it as an appendix to an annual government report (Logan, 1845). 'Who the devil ever reads a report?' he wrote to De la Beche (10 December, 1846; cited in Rygel & Shipley, 2005, p. 95). Who indeed? For when, a decade later, Lyell was to revisit Joggins, he was unable to find any trace of Logan's work in print, and even his Nova Scotian collaborator, Dawson, was unsure where to find it (Shipley, 2001). Only a short précis was available embedded within the President of the Geological Society's annual address (Horner, 1846).

5. LYELL'S SECOND VISIT

Lyell returned to Joggins in 1852 during a third trip to North America, this time accompanied by Dawson (Dott, 1998). The two men had first met in 1842, Dawson having given Lyell a geological tour of the coal fields of his home town of Pictou, Nova Scotia, and the Shubenacadie Valley (Lyell, 1845). Subsequently, Lyell had taken an interest in Dawson's career, helping him to publish his work on the Pictou coal measures in the Geological Society's *Quarterly Journal* (Dawson, 1845, 1846, 1851) and the two had become friends (Wilson, 1998a). At the time of Lyell's visit, Dawson had risen to be superintendent of education for Nova Scotia, a position that allowed him to travel widely, facilitating his geological work (Sheets-Pyenson, 1996).

In September 1852, Lyell and Dawson made the discovery that was to secure Joggins its present-day legendary status. Within the interior of a sandstone-cast fossil tree near Coal Mine Point they found the skeletal remains of early amphibians (*Dendrerpeton*), as well as land snails (*Dendropupa*). 'We searched diligently for fossils in these stony casts, suspecting that organic bodies' might be found (Lyell & Dawson, 1853); however, it is unclear what gave them this premonition because no previous reports of such discoveries are known. Although Lyell writes that this was 'work of no small bodily labour', most of the perspiration appears to have been on the part of a miner employed to dig out the fossil trees! Ironically, when the discovery was eventually made, the fossils were found within a fallen fossil tree lying on the beach. In later life, Dawson confusingly maintained that the discovery occurred in 1851 (Dawson, 1859). However, this is irreconcilable with the known dates of Lyell's trip to North America (Dott 1998) and a letter from Lyell to his father-in-law, Leonard Horner, on 12 September 1852, confirms the original date (Lyell, 1881).

In his autobiography, written some 40 years later, Dawson gives a retrospective summary of the discovery, one full of awe of Lyell.

> I well remember how, after we had disinterred the bones of *Dendrerpeton* from the interior of a large tree on the Joggins shore, [Lyell's] thoughts ran rapidly over all the strange circumstances of the burial of the animal, its geological age, and its possible relations to reptiles and other animals, and he enlarged enthusiastically on these points, till, suddenly observing the astonishment of a man who accompanied us [the miner], he abruptly turned to me and whispered, 'the man will think us mad if I run on in this way' (Dawson 1901, pp. 54–55).

Lyell and Dawson spent five days at Joggins in 1852 (Dawson, 1868, p. 362; Wilson 1998b). In that time, they began to log the section in detail (Fig. 4), presumably having still having been unable to obtain a copy of Logan's obscurely published work (Rygel & Shipley, 2005).

> Dawson and I set to work and measured foot by foot many hundred yards of the cliffs, where the forests of erect trees and calamites most abound … I never enjoyed the reading of a marvellous chapter of the big volume more (Lyell, 1881).

However, this work was only partially finished before Lyell's other fieldwork arrangements, and his lecturing duties in Boston, called him away from Nova Scotia (Dott, 1998), leaving Dawson to complete the work alone (Dawson, 1853).

Lyell took the Joggins fossils with him to Boston, displaying them as illustrations to his talks and seeking the opinion of North American scientists as to their affinity (Dott, 1998). Professor Wyman of Harvard confirmed that the bones were, as Lyell had suspected, not the remains of fish, but those of 'batrachian reptiles' (Wyman, 1853), a term which then included amphibians (M. J. Benton, pers. comm., 2005). At the time, these were the earliest known tetrapods. Dr Gould of Boston identified the land snails as being closely similar to modern pupiform snails. The fossils continued to cause a sensation when Lyell transported them back to England and were eventually formally described and named by Richard Owen (1804–1892), the famous London anatomist (Owen, 1853).

6. DARWIN'S SILLY NOTION

One man who was particularly fascinated by these ongoing discoveries at Joggins was Lyell's protégée, Charles Darwin (1809–1882). Lyell always made sure that Darwin was kept well informed about progress at the site: 'I shall read a paper on erect N. Scotia trees [at the] next meeting' of the Geological Society he wrote to Darwin following his first Joggins trip (letter, 9 April 1843; Darwin Correspondence: 670). These and subsequent findings were to spark Darwin's interest in the origin of coal. Although upright trees proved that coal had been deposited in place, in what environment did coal originate, Darwin wondered? 'The more I think about coal, the more utterly perplexed the subject appears to me' Darwin wrote to Joseph Hooker (8/15 July 1846; Darwin Correspondence: 986).

Darwin was apparently baffled by the great horizontality and lateral extent of coal seams; surely coal beds should undulate if deposited on land. In his view,

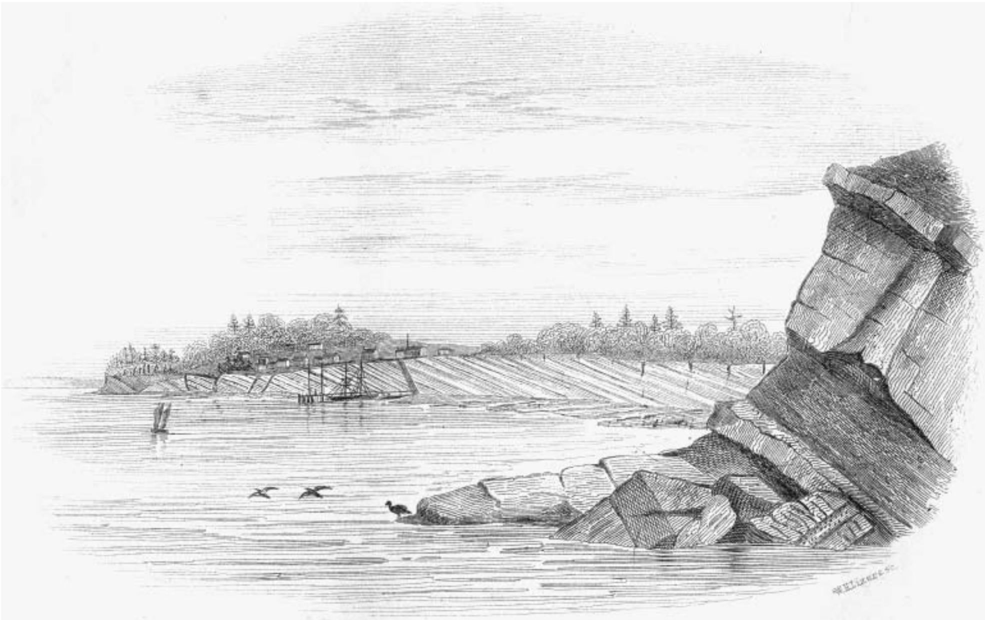


Fig. 4. The Joggins Fossil Cliffs looking northward towards the original wharf at around the time that Dawson and Lyell made their famous discoveries of amphibian bones in a fossil tree at Coal Mine Point. This was part of the section that Dawson logged after Lyell's departure (reproduced from Dawson, 1853).

based on 'simple geological reasoning', only the shallow-marine shelf could have provided a suitably extensive and flat surface for coal accumulation. 'I have for some time been led to suspect that the great (& great & difficult it is) problem of the Coal would be solved on the theory of the upright plants having been aquatic', growing some '5–100 fathoms under water' (letter to Hooker, 1 May 1847; Darwin Correspondence: 1085). He shared his idea that the upright trees of Joggins were submarine plants with Hooker and, in return, received a 'savage letter' dismissing his ideas outright (see letter from Darwin to Hooker, 6 May 1847; Darwin Correspondence: 1086). He did not easily forget this criticism, reminiscing about it in his autobiography (Darwin, 1887).

Darwin seems to have held onto his submarine coal hypothesis for more than a decade, and perhaps longer. In fact, it was only the famous discovery by Lyell and Dawson of land snails (Fig. 5) within an upright tree at Joggins in 1852 that finally convinced him of his folly, and the terrestrial origin of coal. 'What a fact about the coal land snails!' he concluded in a letter to Hooker (22 May 1860; Darwin Correspondence: 2813). By his later years he was fully repentant, sheepishly admitting how he had once entertained 'the silly notion that our coal-plants had lived in shallow water in the sea' (Darwin, 1887, p. 105).

7. DAWSON, FIFTY YEARS OF WORK

After Lyell's second visit, responsibility for continuing Joggins research passed to Dawson. Dawson's autobiography, published posthumously, was entitled *Fifty Years of Work in Canada* (Dawson 1901), but the subject matter could just as appropriately have been Joggins, for in addition to his work on the Devonian

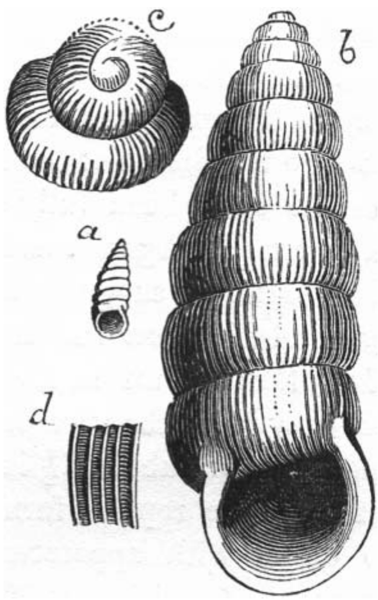


Fig. 5. The presence of *Dendropupa* land snails inside fossil trees at Joggins finally convinced Charles Darwin that his submarine coal hypothesis was incorrect (reproduced from Dawson, 1868, p. 384).

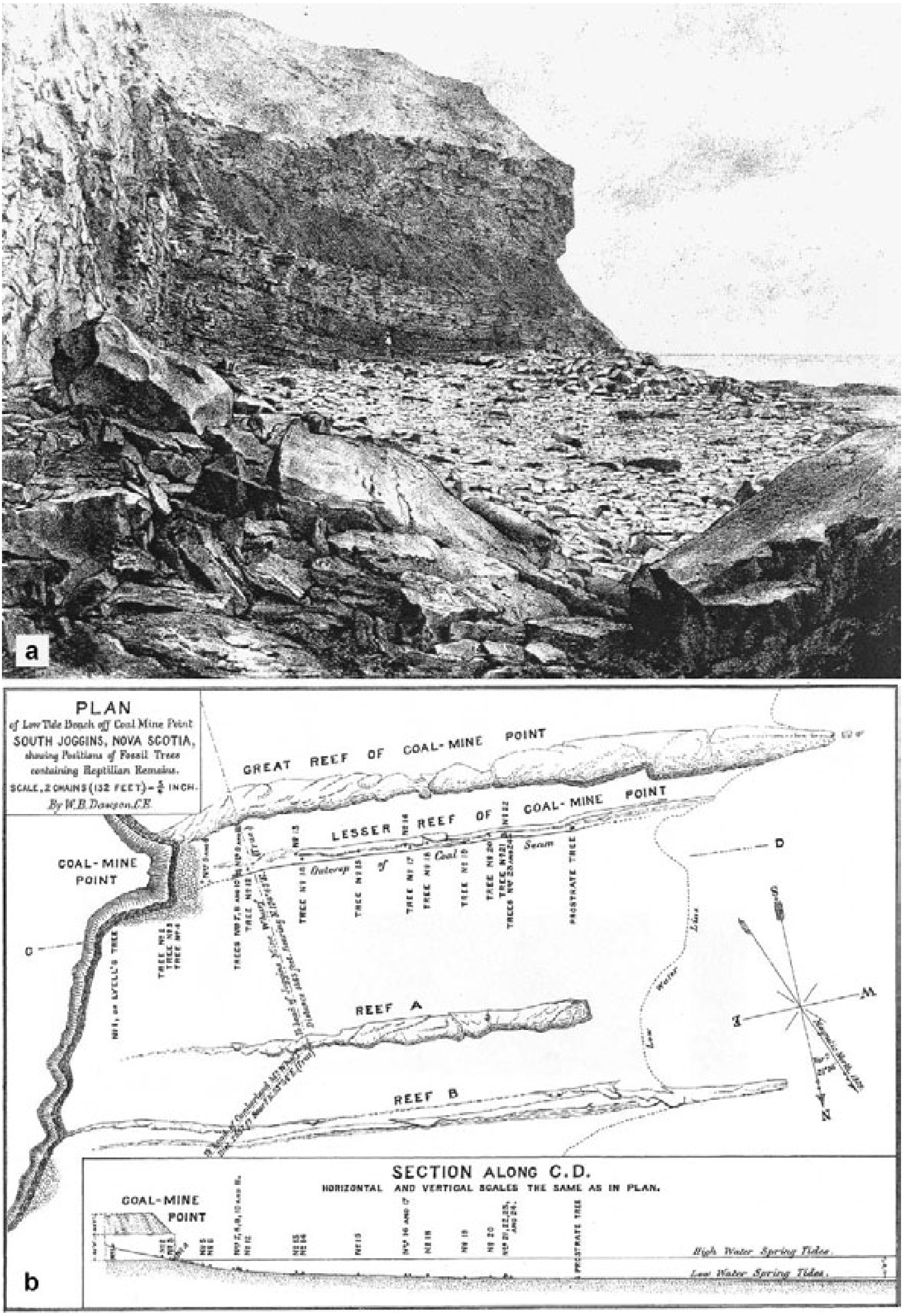
Fig. 6. The new Joggins wharf near Bell's Brook photographed in 1879 by Weston. Note the slide used to transport coal from the mine (just visible over the cliff top) onto waiting ships and the great height of the wharf, designed to deal with 40 ft tides on the Bay of Fundy. Source: GSC/Library and Archives of Canada PA-05119.

Fig. 7. Remains of *Hylonomus lyelli*, discovered by Dawson within a fossil tree in 1859, were recognized to be the earliest known reptile by Alfred Romer and Bob Carroll in the 1950s and 1960s (reproduced from Dawson, 1868, p. 373).

floras of Gaspé, this had been one of his life-long passions. Having published more than 19 major papers about the site between 1853 and 1896, no one since has made a greater contribution to understanding the complexity of this section.

Dawson first visited Joggins as a teenager in the late 1830s. Apparently, like Lyell, he was spurred on by the works of Brown and Gesner and had, in fact, earlier met with both to discuss and exchange fossils (Sheets-Pyenson, 1996). A friend of his father's had taken him to Amherst, Nova Scotia some 14 miles away, and such was Dawson's zeal that he walked the remaining distance, sheltering overnight in a quarryman's cottage. After describing an arduous day in the field, his first person account continues,

> I returned in the evening to the quarrymen's shanty, thoroughly fatigued, but loaded with fossils, delighted with the knowledge I had acquired, and with my enthusiasm for geology raised to a higher point than ever before. Such was my first visit to the celebrated coast-section of the Joggins,


a
b
PLAN
of Low Tide Beach off Coal Mine Point
SOUTH JOGGINS, NOVA SCOTIA,
showing Positions of Fossil Trees
containing Reptilian Remains.
SCALE, 2 CHAINS (132 FEET) = ¾ INCH.
By W. B. Dawson, C.E.
GREAT REEF OF COAL-MINE POINT
LESSER REEF OF COAL-MINE POINT
Outcrop of Coal Seam
COAL-MINE POINT
PROSTRATE TREE
REEF A
REEF B
C
D
Low Water Line
SECTION ALONG C.D.
HORIZONTAL AND VERTICAL SCALES THE SAME AS IN PLAN.
COAL-MINE POINT
PROSTRATE TREE
High Water Spring Tides.
Low Water Spring Tides.

on which I have since spent so many pleasant and profitable days (Dawson 1901, pp. 39–40).

Dawson's first independent project at Joggins was to complete the log, which he had commenced with Lyell. Following a second field season in 1853, the section was finally published, Dawson modestly claiming only to have 'assisted' Lyell in this venture (Dawson, 1853, p. 1). Whereas Logan had logged the entire outcrop belt on the Fundy shore (>4 km stratal thickness), Dawson focused on the <1 km thick coal-bearing unit, which contained the richest fossil record. By this time, he had at last acquired a copy of Logan's log, although only after having completed his own fieldwork (Rygel & Shipley, 2005). Dawson (1853, 1855) noted that his section differed substantially from the equivalent section of Logan, but did not realize the real problem lay with the superficial nature of the former study. He clearly felt a niggling insecurity about these discrepancies and, as Rygel & Shipley (2005) have documented, eventually abandoned many of his own observations in favour of those of Logan in subsequent editions of the log (Dawson, 1865, 1868).

Although coal had been mined sporadically at Joggins in earlier years (Gesner, 1836), it was not until 1847 that the General Mining Association of London opened the first major mine (Copeland 1958). The GMA pulled out of the region in 1857–8, the year it surrendered it is mineral rights to the provincial government (Calder *et al*., 1993). Nevertheless, private mining operations continued to expand, with more pits being sunk and a connecting tramline constructed. The economic instability caused by the withdrawal of the GMA gradually improved following the consolidation, in 1871, of various small enterprises into the Joggins Coal Mining Company. It was about that time that the major new wharf was built (Fig. 6) to facilitate the transport of coal to markets in Saint John, New Brunswick and to New England (Legere, 2005).

This expansion in activity was advantageous to Dawson for he collaborated with a whole generation of Joggins mine workers to locate fossils. This was especially important following 1855 after which he became principal of McGill University in Montreal, and subsequently returned to Joggins only periodically (Sheets-Pyenson, 1996). One of his early collaborators was a Mr Boggs, the superintendent of the Joggins Mine (Dawson, 1853) and official postmaster (Legere, 2005), who alerted him to several important fossils, including new specimens of tetrapods, land snails and other invertebrates (Dawson, 1859, 1861, 1863, 1865, 1868). Struggling to access relevant European scientific literature in Montreal, Dawson sent many of these fossils to experts abroad for formal description and identification (Owen, 1862; Salter, 1863; Carpenter in Dawson, 1867; Scudder, 1873, 1895), some ultimately being deposited in the Geological Society of London's own museum.

Dawson's scientific work at Joggins during this period has been treated in detail recently elsewhere (Falcon-Lang & Calder, 2005) and so only one key event is highlighted here: the discovery in the summer of 1859 of additional tetrapods within a second fossil tree (Fig. 7). This tree was 'much more richly stored with animal remains than that previously found' (Dawson, 1859, p. 259) with Lyell in 1852, and Dawson named one of the new taxa, *Hylonomus lyelli* in honour of his mentor. Although originally thought to be an amphibian (Steen 1934), this animal was later recognized as the earliest known reptile (Romer 1950; Carroll 1964). It is now undoubtedly the most famous fossil from Joggins, having been depicted on a Canadian stamp in 1992 and, as of 2002, designated Nova Scotia's provincial fossil.

Other tetrapod fossils continued to turn up at irregular intervals, but, in 1878, Dawson was awarded a grant of £50 from the Royal Society of London to make further investigations. With the help of Mr Albert Hill, manager of the Cumberland Mine, and Mr Barnhill, the new superintendent of the Joggins Mines and the man who would bring the railway to Joggins in 1887, Dawson made a 'thorough survey and examination' of the main tetrapod-bearing horizon at Coal Mine Point (Fig. 8; Dawson, 1882, p. 621). In fact, what they did would make most modern palaeontologists grimace, using dynamite to blast the section and remove more than twenty fossil trees! Nevertheless, this strategy proved highly successful, resulting in the extraction of most of the two hundred or so tetrapod skeletons now known from Joggins (Milner, 1996). Fortunately, the site has now more or less recovered from these operations thanks to the rapidly eroding nature of the cliffs (Dawson, 1882, cites a rate of 19 cm per year based on a 40-year average).

The house belonging to Albert Hill during his tenure as Cumberland Mine manager still stands close to edge of the Joggins cliffs, some few hundreds metres from Coal Mine Point where most of the major tetrapod discoveries were made (Falcon-Lang *et al*., 2006). In the attic of that house (currently owned by Edna and Mark Boon), the putative signatures of Hill and Dawson appear to be engraved in a plaster wall, although, when viewed in 2005, were in a very poor state of preservation. One can perhaps imagine the two men discussing fossil hunting strategy in the attic room on rainy days!

Fig. 8. The main tetrapod-bearing interval studied by Lyell & Dawson (1853), and subsequently by Dawson (1859, 1882): (**a**) lithograph of Coal Mine Point from a photograph by Weston (figure for scale in centre); (**b**) detailed plan of Coal Mine Point and its sandstone bed that extended out to sea (informally termed a 'reef'). Most Joggins tetrapods came from inside trees preserved in the 'lesser reef' (after Dawson, 1882, plates 46–47).

8. THE DARK AGES

Following the death of Dawson in 1899, field-based research at Joggins effectively ended for a long period (Dawson, 1896 was his last paper on the site). Dawson was the only man who knew the rocks and understood how they related to the logged section. Although others had published on Joggins specimens throughout the late nineteenth century, that material had entirely originated directly from Dawson. A single exception was the chance discovery of a rare giant bivalve, *Archanodon*, in 1893, by Geological Survey of Canada geologist, Thomas Weston (1832–1910) whilst travelling through Nova Scotia (Dawson, 1896). Weston, who had been trained by Logan, was naturally eager to visit Joggins; however, as he was scheduled to retire later that year, it fell to Whiteaves (1893), a marine invertebrate expert, to describe the specimen.

During his lifetime, Dawson had played a huge role in encouraging scientific societies in Canada (Sheets-Pyenson, 1996). One such beneficiary was the Natural History Society of New Brunswick (formerly the Steinhammer Club), which had been formed in 1857 (Miller & Buhay, 1988). George Frederic Matthew (1837–1923), a founding member, was one of the few geologists to continue Joggins research after Dawson's death. He studied the trace fossil record, especially focusing on the tetrapod trackways (Matthew 1903a, b, 1904). However, Matthew relied on Dawson's pre-existing collections in Ottawa and Montreal, and new discoveries by Mr McNaughton, the new Joggins Mine manager, rather than making his own field collections. This marked the beginning of a trend, which lasted many years.

When, in 1913, the Joggins section was visited by the XII International Geological Congress, its classic status was well established (Bell 1913). Perhaps this generation of geologists felt inadequate to follow in the footsteps of Lyell, Logan and Dawson, but, for many decades, most advances in knowledge of Joggins came through re-examination of museum collections (e.g. Petrunkevitch, 1913; Steen 1934; Copeland 1957). Ironically, this was the very approach against which Dawson had warned. Writing to Lyell on August 13 1868, he had argued how it was better to study fossil trees and other remains 'as they stand in the cliffs of Joggins' rather than 'on the shelves of the British Museum' (Falcon-Lang & Calder, 2004).

9. BELL ON BIOSTRATIGRAPY

As the twentieth century dawned, controversy began to erupt about the age of another of Dawson's famous localities, with implications for the revitalization of Joggins research. Members of the Steinhammer Club had intensively collected fossils from the Fern Ledges of Saint John, New Brunswick since the 1860s (Miller & Buhay, 1988), remains that Dawson had pronounced to be Devonian (Dawson, 1862, 1868). After Dawson's death, Matthew went further, positing a Silurian age (Matthew 1910). Most international geologists disagreed, however, pointing to the Pennsylvanian character of the fossils, similar to those of Joggins, just over the border with Nova Scotia (White 1902, 1911).

When sharp disagreements started to break out amongst regional geologists (Ami 1900a, b; Fletcher 1900; Ells 1901), the Geological Survey of Canada invited Marie Stopes (1880–1958), the rising star of British geology, to visit Saint John in 1911, and resolve the debate. Her monograph confirmed the Pennsylvanian age of the Fern Ledges (Stopes 1914) and laid the foundation for a more detailed regional biostratigraphic analysis of the eastern Canadian coal measures. This latter work particularly focused on Joggins and was largely undertaken by Walter Andrew Bell (1889–1969).

Bell, a GSC student assistant, began work at Joggins in 1911, the same year that Stopes visited Fern Ledges (Zodrow, 1995). 'I understand that Mr. W.A. Bell of the Canadian Survey is re-examining the Joggins section, so that the detailed comparison of the [Fern Ledges] with those at Joggins must await his results' wrote Stopes (1914, p. 125); her own schedule allowed only a brief two-day excursion to Joggins (Stopes 1914, p. 52). Bell quickly rose to be an authority on the site, compiling the Joggins field guide for the XII International Geological Congress (Bell 1913) and a subsequent GSC report (Bell 1914). After a long break working on other things, he then went on to compile a massive monograph on the Pennsylvanian floras of northern Nova Scotia (Bell 1943), especially those of Joggins, updating and expanding Dawson's work for the first time.

Bell's fossil plant studies at Joggins were important for three reasons. First, they signalled the start of a renewed interest in field-based studies. Secondly, they lent further support to Lyell's contention that the Nova Scotia coal measures were similar to those of Europe, more so in fact than to those of the USA (Zodrow, 1995); an orographic barrier had separated Nova Scotia from the USA in Pennsylvanian times (Calder, 1998). Thirdly, they permitted the development of a detailed biostratigraphic framework (Bell 1927), proving the age similarity with Fern Ledges and demonstrating an 'early Westphalian B' age for the Joggins Formation (Bell 1943, p. 28). Subsequently, that age has been revised to the Langsettian, the former Westphalian A (Falcon-Lang *et al.*, 2006).

10. RENAISSANENCE

The fame of Joggins continued to attract a steady trickle of visitors through the latter part of twentieth century, but the heady days of Dawson's sustained field programme were long gone. More tetrapod discoveries were made at irregular intervals by Bell in 1911, Charles Sternberg (1885–1981) in 1948, a dinosaur expert with the Geological Survey of Canada and, most notably, in the course of the excursions of Alfred Romer (1894–1973) out of Harvard University (Romer 1963; Carroll 1967). Romer's work latterly became clouded in controversy, some accusing him of plundering the site in an irresponsible fashion. This debacle eventually led the Nova Scotian government to pass strict legislation governing fossil collection in 1970 (Thomas, 2005). During this same period, other field parties, led by Don Baird from Princeton University, made important collections of fossil fish (Baird 1962, 1978), whilst Laing Ferguson, a geologist from New Brunswick, famously recovered *Arthropleura* trackways on a slab weighing eighty tonnes (Ferguson 1966, 1975). Several sedimentological studies were undertaken (Way 1968; Duff & Walton 1973) and regional mapping improved (Ryan *et al*., 1990, 1991).

However, the renaissance in Joggins research, witnessed over the past two decades, can be closely tied to the arrival in Nova Scotia of the British sedimentologist, Martin Gibling. In the mid-1980s he began a programme of research that was to result in a new state-of-the-art understanding of Joggins at a level not achieved since the death of Dawson (Davies *et al*., 2005). His first contribution was a modest Geological Society of America field guide (Gibling, 1987), but within a few short years he was to build up a collaborative team of experts that was to exert a more important long-term influence.

One of Gibling's graduate students was John Calder, a coal geologist who had grown up near Joggins and counted Dawson as a primary influence. As a local, Calder was able to draw alongside and nurture several amateur collectors and, like Dawson before him, promoted their discoveries. Most notable amongst these amateurs were Mr Don Reid, the so-called 'Keeper of the Cliffs' and owner of the Joggins Fossil Center, and Mr Brian Hebert of Lower Cove. The first project of this emerging group was a study of invertebrate trace fossils, partly based on Reid's collections (Archer *et al*., 1995). This was followed up by collaborative studies with University of London geologist, Andrew Scott, focusing on the fossil forests (Fig. 9; Scott & Calder, 1994; Scott, 1998; Calder, 1998; Calder *et al*., 2006) and studies of Hebert's fossil collections (Hebert & Calder, 2004).

During the summers of 1996–7, University of Liverpool sedimentologist, Sarah Davies, working with Gibling, re-logged a substantial part of the Joggins section for the first time since Logan, Lyell and Dawson (Davies & Gibling, 2003). Appropriately this achievement coincided with the bicentennial celebrations of Lyell's birth in 1797. Recognizing the potential utility of generating a complete bed-by-bed section for future palaeontological research, Gibling and Calder completed Davies' log and produced the standard reference section used today (Calder *et al*., 2005; Davies *et al*., 2005). Both Gibling and Calder were recipients of the Gesner Medal of Atlantic Geoscience Society, in 2002 and 2004 respectively, in large part for their Joggins endeavours, awards which were especially poignant given Abraham Gesner's early geological account of the site.

Fig. 9. Palaeobotanist, Auriel Cross, with an upright fossil tree in the early 1990s at about the time that Andrew Scott (University of London) was studying the Joggins fossil forests (courtesy of John Calder).

Very recent research at Joggins (over the past five years) has been intensive and wide ranging, covering a bewildering array of topics, including sedimentology (Rygel, 2005; Calder *et al*., 2005), sequence stratigraphy (Davies & Gibling, 2003; Davies *et al*., 2005), salt tectonics (Waldron & Rygel, 2005), biostratigraphy (Utting & Wagner, 2005; Utting *et al*., 2005), palaeosols (P. McCarthy, pers. comm., 2005), vegetation–sediment interactions (Rygel *et al*., 2004), global change (Falcon-Lang, 2003a), forest fires (Scott, 1998; Falcon-Lang, 1999), terrestrial and aquatic communities (Falcon-Lang, 2003b, 2005; Falcon-Lang *et al*., 2004, 2006; Hebert & Calder, 2004), tetrapod ichnology (Lucas *et al*., 2005), micropalaeontology (Tibert & Dewey, 2006), geoconservation (Falcon-Lang & Calder, 2004; Thomas, 2005) and the history of geology (Rygel & Shipley, 2005; Falcon-Lang & Calder, 2005).

11. CONSERVATION

The most recent chapter in the history of Joggins concerns conservation, a subject that had been given little thought prior to the controversial excursions of Alfred Romer in the 1960s. As mentioned above, in

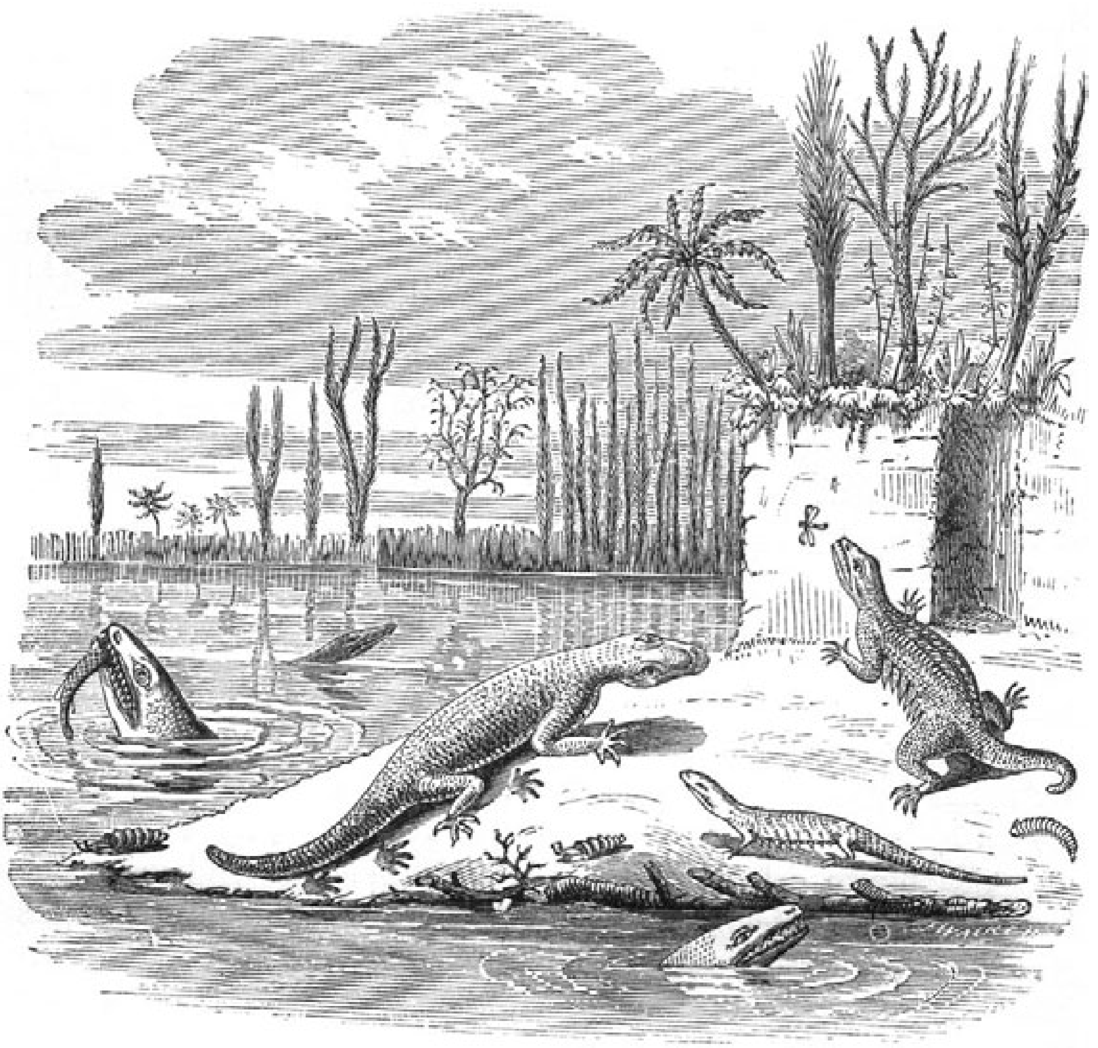


Fig. 10. Joggins represents an unrivalled record of life in the Pennsylvanian 'Coal Age' as reconstructed here by Dawson (1868, p. 352). In addition to the numerous tetrapods, note the various land snails in the foreground and the hollow outline of a buried upright tree (background, right).

1970, the Nova Scotian government passed the Historical Objects Protection Act (largely in response to Romer's work), which protected a 1.6 mile-stretch of the Joggins Fossil Cliffs. In 1980, Joggins was designated a 'Special Place' such that subsequent fossil collection required a formal Heritage Permit (renewable annually) from the Museum of Nova Scotia (Ferguson, 1988; Thomas, 2005).

The past decade has witnessed a concerted effort, led by John Calder and the Cumberland Regional Development Agency (CREDA), to gain international recognition for Joggins as a World Heritage Site. In 2004, the site was placed on the Canadian national short-list for formal presentation to UNESCO (Falcon-Lang & Calder, 2004). The argument for nomination rested on the fact that Joggins provided unrivalled insight into a key period in the Earth's history, namely the Pennsylvanian 'Coal Age' (Fig. 10; Falcon-Lang, 2002). However, a more pragmatic aim was to bring economic renewal to one of Nova Scotia's many depressed ex-mining districts; the last Joggins coal mine and its connecting railway closed in 1961 (Legere, 2005). Planning for a major visitors' centre began in 2005 and this geotourist initiative is scheduled for completion by the time UNESCO assessors arrive in 2007.

One of the great geoconservational strengths of Joggins is its site integrity (Falcon-Lang & Calder, 2004). Unlike many other fossil localities, such as the famous Pennsylvanian Mazon Creek of Illinois, which was located in temporary mining operations (now largely infilled), the rapidly eroding nature of the Joggins section on the Bay of Fundy ensures that these Coal Age deposits will remain the focal point for Pennsylvanian research long into the future. After ten years of research, there still remains a tremendous thrill in walking along the Joggins shoreline. It is a place with a powerful connection with the past, not just to the Pennsylvanian Coal Age, but also in recognition of the great geologists that have walked there before.

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An early Pennsylvanian waterhole deposit and its fossil biota in a dryland alluvial plain setting, Joggins, Nova Scotia

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Abstract: The terrestrial ecology of Pennsylvanian tropical wetlands is understood in detail, but coeval dryland ecosystems remain highly enigmatic. To fill this gap in our knowledge, a Pennsylvanian (Langsettian) continental red-bed succession was studied at the classic Joggins locality, Nova Scotia. These units represent the deposits of seasonally dry, alluvial plains traversed by anastomosed drainage networks. One channel complex informally known as the 'Hebert beds' (the focus of this study) contains an unusual fossil assemblage and is interpreted as an alluvial waterhole deposit that formed following drought-induced cessation of channel flow. Adpressed and charred fossil plant remains indicate that the alluvial plain surrounding the waterhole was covered by fire-prone cordaite vegetation, with hydrophilic lycopsids and sphenopsids restricted to waterlogged riparian niches. Gigantic unionoid freshwater bivalves, locally in life position, and occurring in large numbers in the waterhole, were probably infaunal suspension feeders during periods of fluvial activity, but aestivated in channel bottom muds when flow ceased. Abundant terrestrial gastropods found clustered around fossil plant detritus may have been deposit feeders scavenging dry portions of channel floors. Common partially articulated remains of small to medium-sized tetrapods possibly represent animals drawn to the waterhole during drought when surface water was scarce elsewhere. In terms of both sedimentology and biology, the Hebert beds alluvial complex bears a very close similarity to the seasonal drainages and waterholes of present-day central and northern Australia. This unique deposit sheds significant new light on the nature of Pennsylvanian dryland tropical ecology.

Keywords: Upper Carboniferous, terrestrial environment, alluvial plains, arid environment, palaeoecology.

The popular image of the Pennsylvanian tropics is of humid coastal wetlands and stagnant peat mires densely forested by lycopsid trees and inhabited by gigantic arthropods and primitive tetrapods (DiMichele *et al*. 2001). The fossil site most influential in forming this image is the world-famous Joggins cliffs of Nova Scotia, where spectacular fossil forests of upright lycopsid trees and diverse vertebrate and invertebrate remains have been described from grey coal-bearing strata since the mid-nineteenth century (e.g. Lyell & Dawson 1853; Calder 1998).

However, a much less well-known feature of the Joggins section is the common occurrence of continental red-bed intervals, which are intercalated with the coal-bearing strata and contain evidence for tropical dryland environments. Recent sedimentological and sequence stratigraphic studies have indicated that these red beds originated in a well-drained, seasonally dry alluvial plain during periods of lowered base level (Davies & Gibling 2003) when the Joggins region lay in an intracontinental setting, many hundreds of kilometres from the open ocean (Ziegler *et al*. 2002).

Although Pennsylvanian-aged continental red-bed deposits are widespread across North America and Europe (e.g. Wagner 1973; Gibling & Bird 1994; Glover & Powell 1996), associated fossil ecosystems remain poorly documented (Mapes & Gastaldo 1986; DiMichele & Aronson 1992; Falcon-Lang 2003*a*). To fill this gap, this study analyses the palaeoecology of an unusual assemblage of vertebrate and invertebrate fauna and flora in a single dryland alluvial channel complex at Joggins (Fig. 1). This unit is interpreted as a waterhole deposit, a term employed to mean a ponded water body in a seasonally dry environment that provided a perennial but localized source of water for organisms especially during sustained drought (Jackson 1997). This discovery sheds important new light on Pennsylvanian dryland ecology.

Geological setting

The Joggins Formation is exposed in a spectacular 4 km long sea-cliff between Little River and Hardscrabble Point, near Joggins village, Bay of Fundy, Nova Scotia (Fig. 1; 45°42'N, 64°26'W). This 1433 m thick formation, whose strata dip gently at 21° SW, is assignable to the mid- to late Langsettian stage of the Pennsylvanian based on studies of palynofloral and megafloral assemblages (Fig. 2a; Dolby 1991; Wagner 1999). Strata were deposited close to the palaeoequator in the rapidly subsiding Cumberland Basin, a small strike-slip sub-basin within the regional Maritimes Basin (Gibling 1995; Pascucci *et al*. 2000).

Davies & Gibling (2003) described the sedimentology of the central 600 m of the Joggins Formation in terms of three genetically related facies associations (Fig. 2b): open-water deposits (OW), poorly drained floodplain deposits (PDF) and well-drained floodplain deposits (WDF). These strata are organized into eight sedimentary rhythms, each typically recording an initial phase of drowning (resulting in OW units), followed by shoreline progradation and bay infilling (resulting in PDF units), and subaerial aggradation of the floodplain (resulting in WDF units). An overview of the changing ecosystems that colonized this evolving environment has recently been given by Falcon-Lang (2003*b*).

The fourth sedimentary rhythm in the Joggins Formation is unique in that it is abnormally thick (210 m), lacks OW units except at the base, and contains numerous alternations between

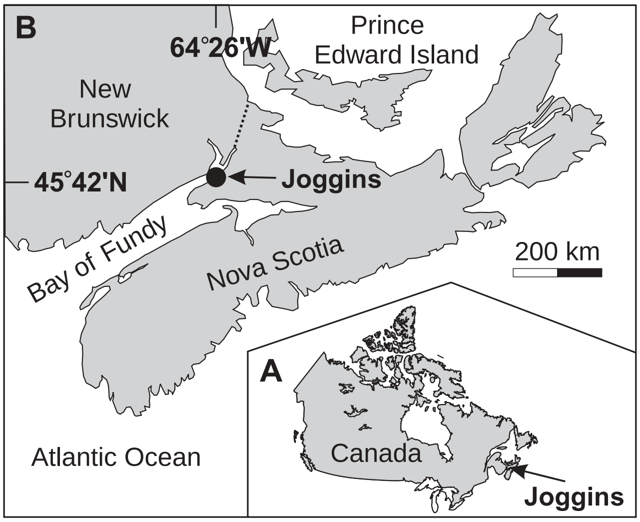


Fig. 1. General locality map. Location of Joggins in (**a**) North America, and (**b**) Nova Scotia.

WDF units (57% of rhythm thickness) and PDF units (41% of rhythm thickness). The rarity of OW units and the predominance of WDF units suggest that this rhythm represents the most sustained period of continental deposition in the Joggins Formation (Davies & Gibling 2003). Within this rhythm, alternations between PDF and WDF units record the interplay between sediment supply, basin subsidence, climate and eustasy, which caused repeated minor progradational and retrogradational rhythms.

Palaeosols from WDF intervals in the fourth rhythm have not been studied in detail, although Smith (1991) documented similar palaeosols in the overlying Springhill Mines Formation. The palaeosols consist of variegated red mudstone with a weak degree of horizonation and contain scattered calcareous nodules (some with manganiferous coatings), cutans of varied composition (argillans, ferrans, calcans), drab mottles and local carbonaceous roots. Smith (1991) interpreted the palaeosols as alfisol-like, formed under warm, relatively humid, but seasonally dry conditions, and, by association, a similar climate is envisaged for the WDF units of the Joggins Formation.

The 9 m thick sedimentary unit that forms the subject of this

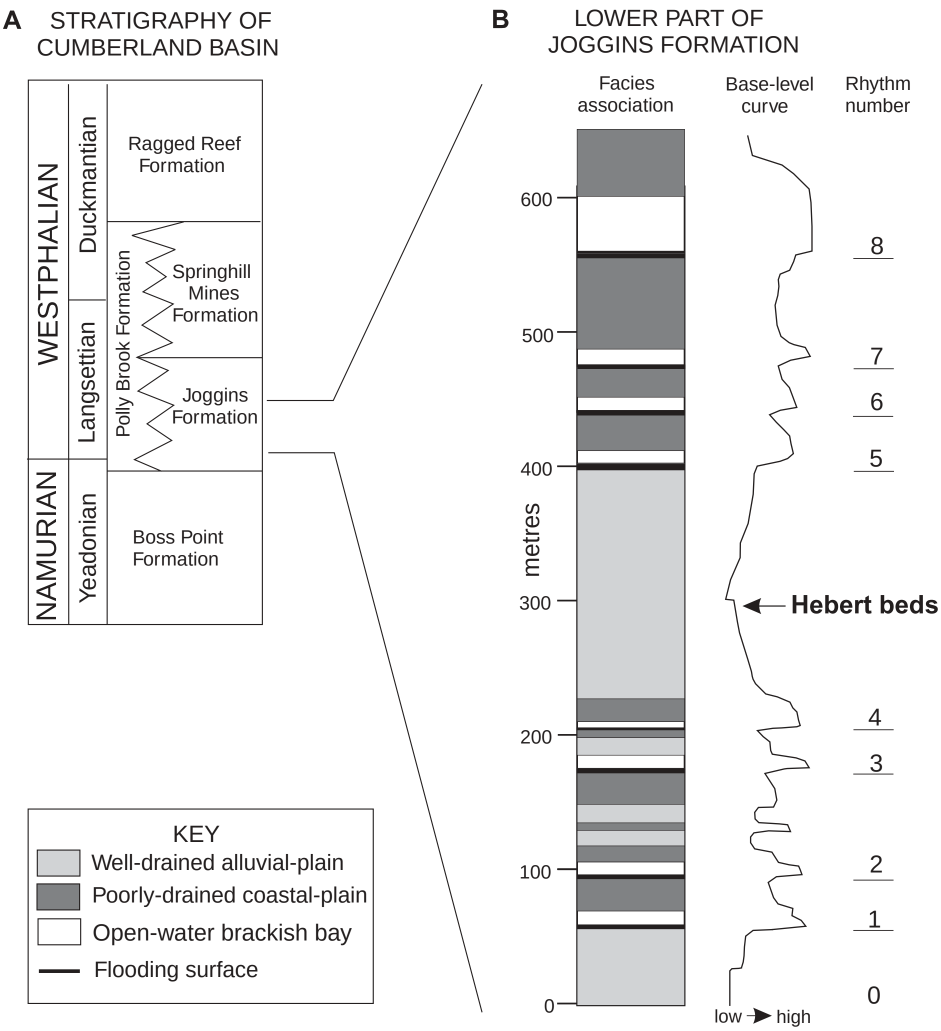


Fig. 2. Stratigraphy. (**a**) Cumberland Basin stratigraphic units, and (**b**) summary log of the central 600 m of the Joggins Formation (Langsettian) showing the three main facies associations and position of the Hebert beds in the thickest well-drained alluvial plain unit (Davies & Gibling 2003).

paper occurs within a 50 m thick WDF interval close to the centre of the fourth sedimentary rhythm (Figs 2b and 3) as defined by Davies & Gibling (2003). Since 1997, this unit has yielded an unusual fossil assemblage, and has been informally termed the ‘Hebert beds’ in honour of Brian Hebert, the discoverer of most of the fossil material (Hebert & Calder 2004). This paper presents a detailed description of the sedimentology of the Hebert beds and its fossil biota.

Sedimentology of the Hebert beds

The WDF interval in which the Hebert beds occur is dominated by small (<5 m thick) isolated channel bodies, sheet-like sandstone to siltstone beds, and red, desiccation-cracked mudstone beds. The Hebert beds themselves consist of five closely spaced channel bodies, numbered 1–5 from oldest to youngest, located between 288 and 297 m above the base of the measured section of Davies & Gibling (2003). The channel bodies are best exposed in the vertical cliff section (Fig. 4), although water-worn outcrops of channel body 1 also exist on the Joggins foreshore. Compositionally, all the sandstone units are sublithic arenites. In the following description of channel architecture the terminology of Miall (1996) is used.

Channel bodies 1–3 are 3.4–5.7 m thick, and composed of fine-grained sandstone. When measured perpendicular to palaeoflow direction, channel body 1 has a width:thickness (W:T) ratio of six, and channel bodies 2 and 3, which are partly preserved, have minimum W:T values of five and four, respectively. Laterally, channel bodies may terminate against a well-defined margin or may be associated with sandy ‘wings’ (Friend *et al.* 1979) at the transition to the overbank. The base of these U-shaped channel bodies is defined by concave-up fifth-order (channel bounding) erosion surfaces, which cut into the underlying red mudstone. Whereas channel bodies 1 and 3 are single storey, channel body 2 has a more complex architecture consisting of two stacked storeys separated by a fifth-order erosion surface. Basal erosion surfaces are locally overlain by a grey pebble-sized lag of mud chip and pedogenic carbonate clasts. Sand-grade channel fill is dominantly subhorizontally bedded, concentric with the channel base, but locally may be organized into <2 m thick macroforms consisting of inclined stratification (IS) dipping perpendicular to the channel margin. Internally IS bedsets may contain abundant concave-up third-order (macroform reactivation) erosion surfaces. Common alluvial lithofacies (abbreviations from Miall 1996) include ripple cross-laminated sandstone (Sr), and horizontal to low-angle laminated sandstone (Sh and Sl) with primary current lineation. A minor portion of the channel fills is composed of lenses of massive to laminated mudrock (Fm and Fl) and small-scale trough cross-bedding (St).

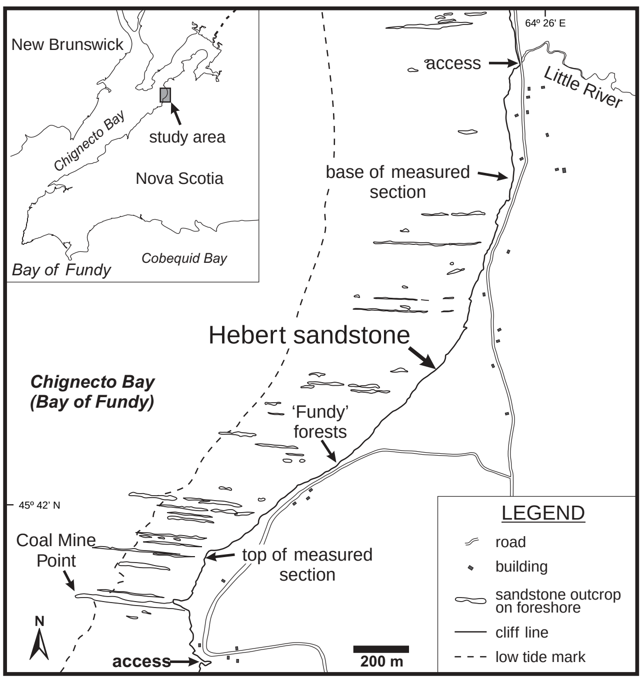


Fig. 3. Outcrop map of the Joggins foreshore showing the precise location of the Hebert beds. Beds dip southwards.

In contrast, channel bodies 4 and 5 are generally thinner (3.5 and 1.8 m thick, respectively) with much greater mud content; they are composed of red mudstone and fine-grained sandstone. Channel body 4, which is partly preserved, has a W:T ratio >6. However, a complete abandonment fill 3.5 m thick and 8.3 m wide (measured perpendicular to palaoflow) is preserved within this unit. When measured perpendicular to palaeoflow, channel body 5, which dies out at present beach level below the cliff, has a W:T ratio of 22. Laterally, both channel bodies truncate against well-defined channel margins and cannot be traced directly into genetically related overbank deposits. The basal surfaces of the channel bodies are concave-up fifth-order erosion surfaces that become flat-based over a distance of *c.* 5 m from the lowest point. Basal erosion surfaces commonly are lined with a *c.* 5 cm thick lag of pebble-sized mud chip and pedogenic carbonate rip-up clasts (including rhizoconcretions), which locally may be matrix-supported. Internally, channel bodies are dominated by macroforms with bedsets of IS and inclined heterolithic stratification (IHS). Both bedset types dip perpendicular to the channel margins, occupy the entire thickness of the channel body, and extend laterally for 10–15 m across the outcrop face. Within the IS–IHS units, common lithofacies include ripple cross-laminated sandstone (Sr) and laminated to massive red mudrock (Fl and Fm). The mudrock portion of the channel fill either occurs as isolated lenses (up to 1.5 m thick) or is interstratified with sandstone as IHS. Grain size commonly decreases from fine-grained sandstone near the base of the channel bodies to sandy siltstone near the top. The upper 1 m of the IS bedset in channel body 5 exhibits raindrop impressions, desiccation cracks, adhesion ripples and drab-haloed root traces, features that are absent closer to the channel base.

Fossil assemblages in the Hebert beds

Fossiliferous beds were observed only in channel bodies 4 and 5, and include an unusual and varied biota of flora, and invertebrate and vertebrate fauna. All figured hand specimens are deposited in the Nova Scotia Museum of Natural History, Halifax, Nova Scotia (specimen prefix NSM), and the Fundy Geological Museum, Parrsboro, Nova Scotia (prefix FGM).

Flora

The species richness of the plant assemblage is very low ($n = 6$), being numerically dominated by the remains of cordaite gymnosperms, as generally seen in the WDF association at Joggins (Falcon-Lang 2003*a*). The most common cordaite fossil consists of compressions and impressions of large (up to 21 cm long), unfragmented, strap-like leaves of *Cordaites principalis* (Germar) Geinitz, which locally occur in both channel bodies associated

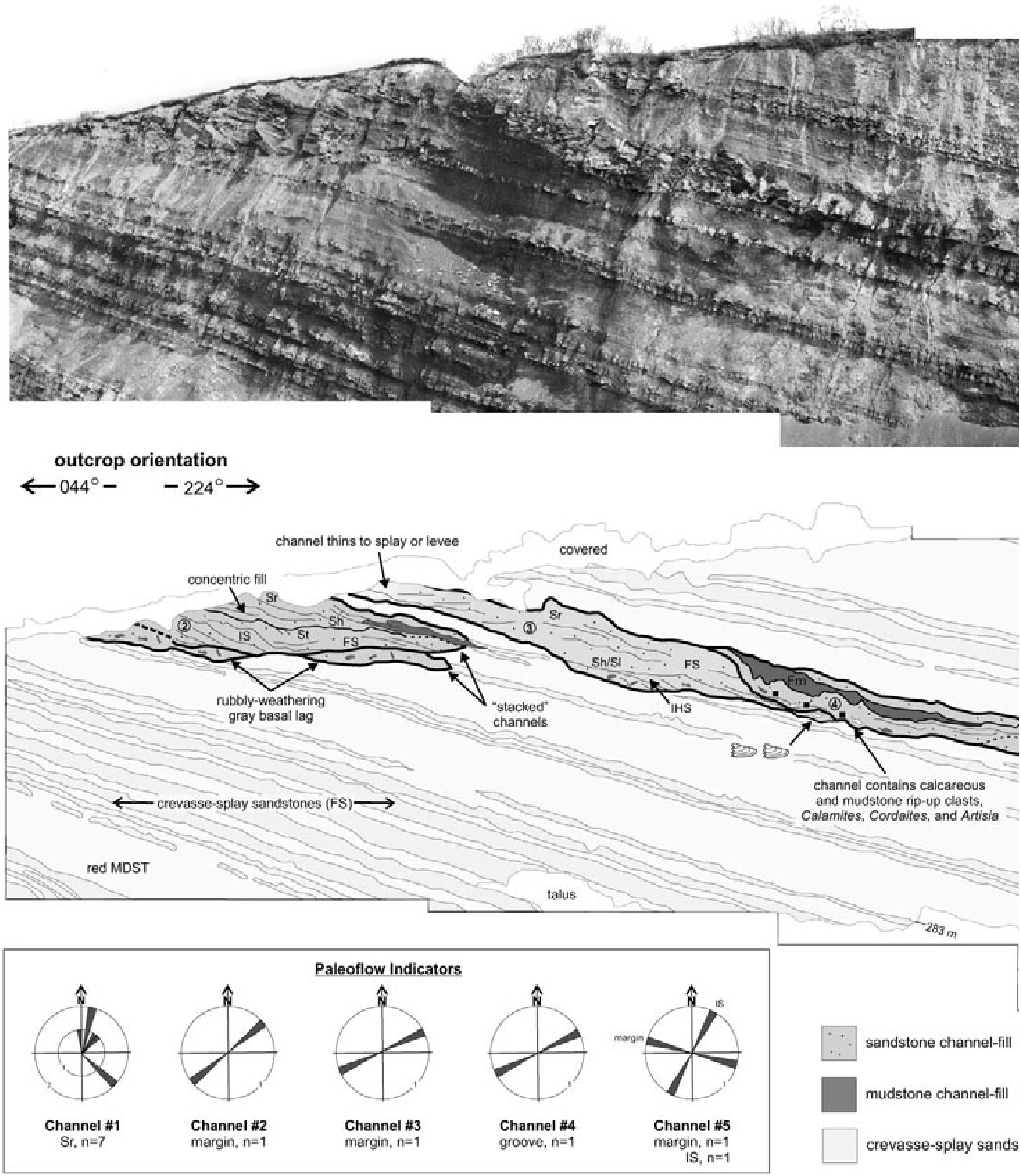
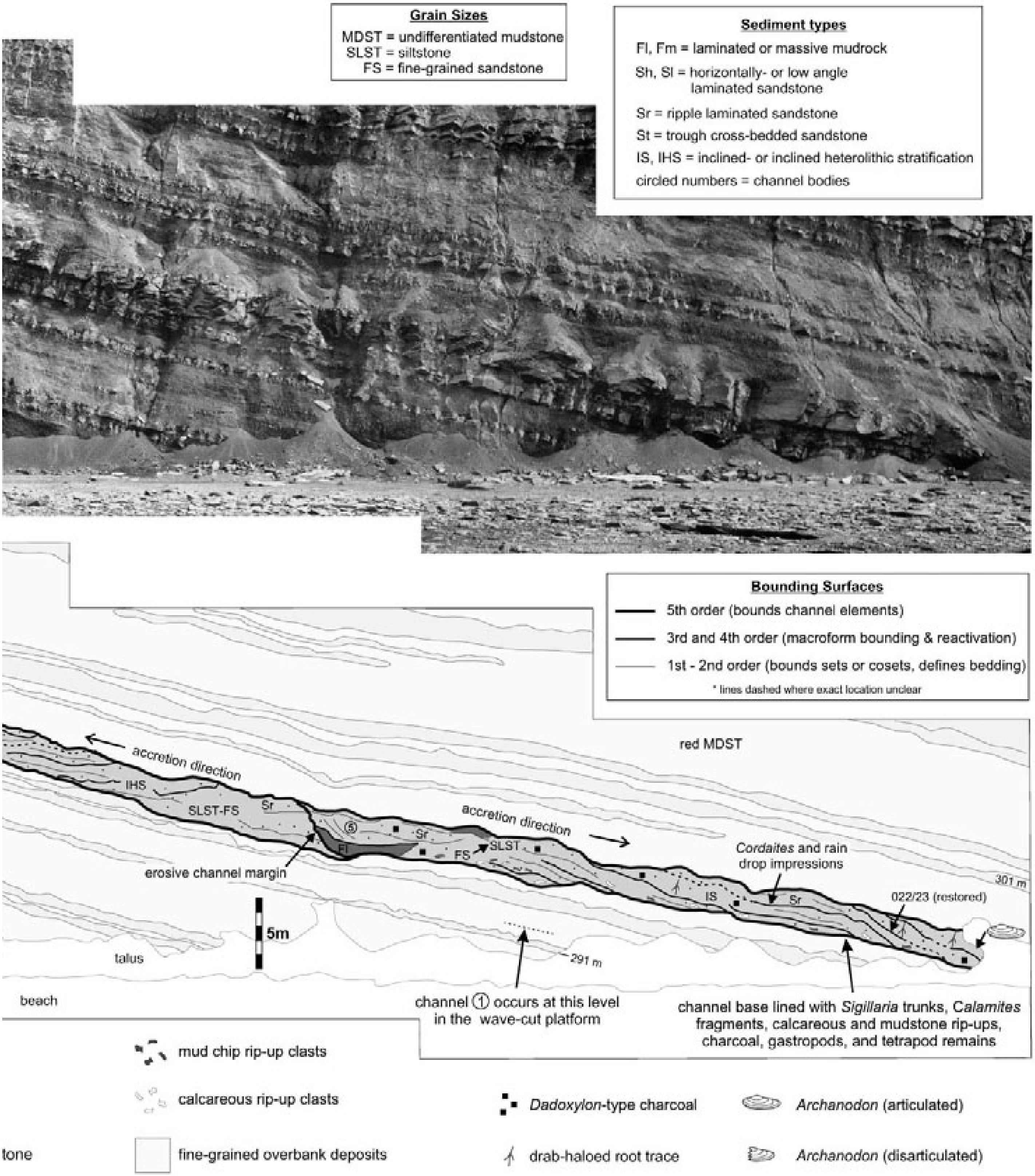


Fig. 4. Photomontage and cliff face tracing of the Hebert beds, 283–301 m above the base of Joggins Formation (Davies & Gibling 2003). The orientation of channel bodies with respect to the cliff line varies from near-normal to near-parallel (see rose diagrams). Dip of inclined surface corrected for tectonic dip. The fossil assemblage is found in channel bodies 4 and 5.


Grain Sizes
MDST = undifferentiated mudstone
SLST = siltstone
FS = fine-grained sandstone
Sediment types
Fl, Fm = laminated or massive mudrock
Sh, Sl = horizontally- or low angle laminated sandstone
Sr = ripple laminated sandstone
St = trough cross-bedded sandstone
IS, IHS = inclined- or inclined heterolithic stratification
circled numbers = channel bodies
Bounding Surfaces
5th order (bounds channel elements)
3rd and 4th order (macroform bounding & reactivation)
1st - 2nd order (bounds sets or cosets, defines bedding)
* lines dashed where exact location unclear
red MDST
accretion direction
IHS
SLST-FS
Sr
5
Fl
FS
SLST
accretion direction
erosive channel margin
Cordaites and rain drop impressions
IS
Sr
301 m
022/23 (restored)
5m
talus
291 m
beach
channel 1 occurs at this level in the wave-cut platform
channel base lined with Sigillaria trunks, Calamites fragments, calcareous and mudstone rip-ups, charcoal, gastropods, and tetrapod remains
mud chip rip-up clasts
calcareous rip-up clasts
Dadoxylon-type charcoal
Archanodon (articulated)
tone
fine-grained overbank deposits
drab-haloed root trace
Archanodon (disarticulated)

with basal lag deposits but are most abundant on the upper parts of IS surfaces (Fig. 5a). These are commonly scattered in random orientations, covering up to 80% of some bedding surfaces. Much less common are fragments of woody, coalified cordaite trunks (up to 9 cm diameter), which are locally branched and may contain sediment-filled pith casts referable to *Artisia transversa* (Artis) Sternberg; these occur in a gravelly lag at the base of channel body 4 (Fig. 5d).

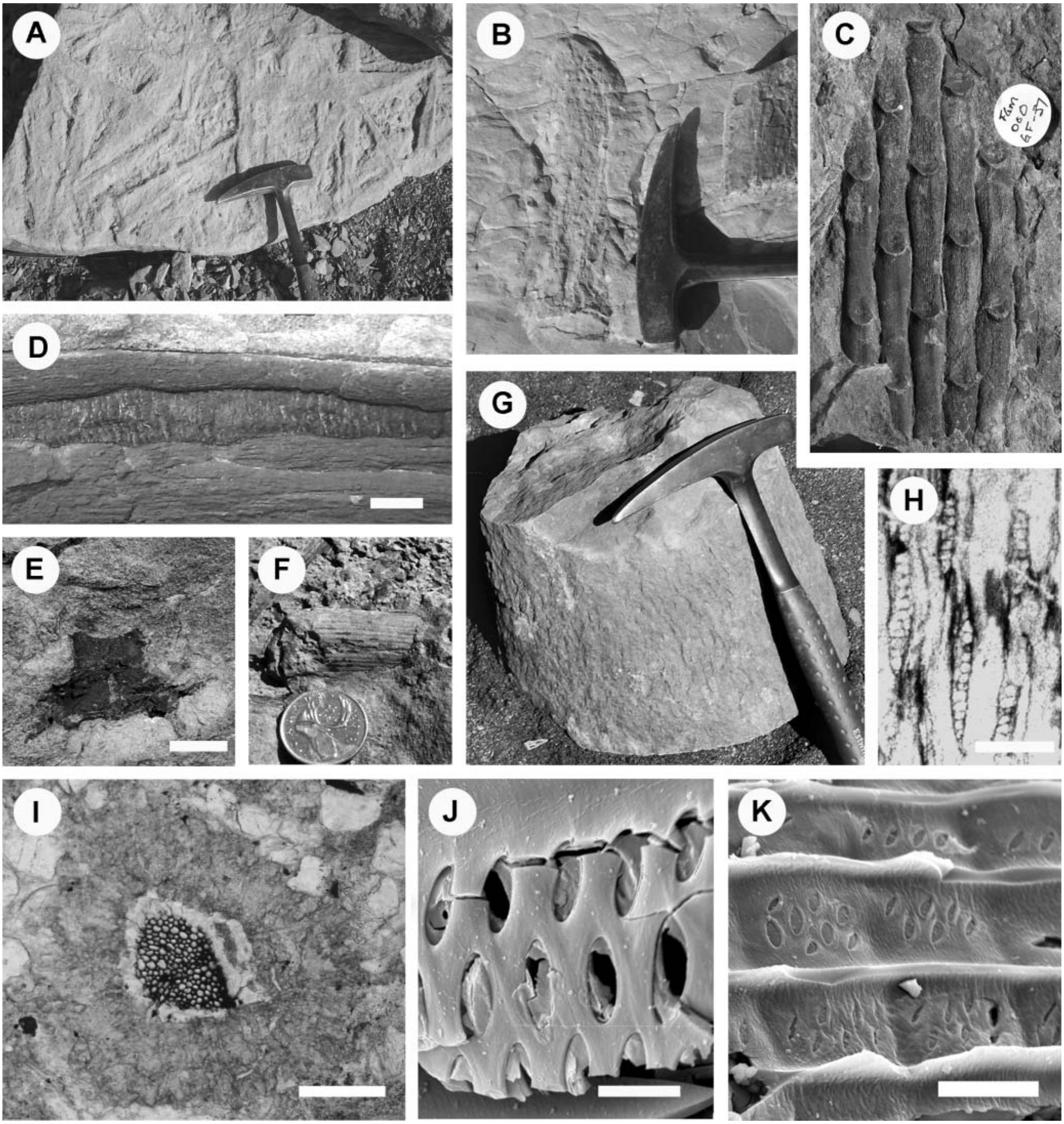


Fig. 5. Fossil plants in and adjacent to the Hebert beds; (**a**, **c**–**f**, **h**–**k**) allochthonous, and (**b**, **g**) autochthonous; hammerhead for scale is 15 cm long. (**a**) Abundant impressions of *Cordaites principalis*leaves, not collected. (**b**) *Stigmaria ficoides* root cast, not collected. (**c**) Lycopsid trunk impression of *Sigillaria scutellata*, FGM000GF37; museum tag is 13 mm in diameter. (**d**) Slender woody cordaite trunk bearing *Artisia* pith; scale represents 1 cm; NSM003GF029.001. (**e**) *Dadoxylon*-type cordaite charcoal; scale represents 5 mm; NSM003GF029.002. (**f**) Fragmentary *Calamites* stems; coin is 20 mm in diameter. (**g**) Sandstone cast lycopsid stump from sheet sandstone beds 4 m below Hebert beds, possibly *Sigillaria*. (**h**) Calcified wood of *Dadoxylon materiarium*; thin section; scale represents 50 µm. (**i**) Calcified gymnosperm roots and rhizoconcretions; scale represents 200 µm; NSM003GF029.003. (**j**) Charred *D. materiarium* cordaite wood showing multiseriate, alternate bordered pitting on tracheids; SEM image; scale represents 15 µm; NSM003GF029.003. (**k**) Charred *D. materiarium* cordaite wood showing araucarioid cross-field pitting; SEM image; NSM003GF029.003; scale represents 40 µm.

Wood fragments are also common, occurring within the gravel lags of channel bodies 4 and 5, but also rarely scattered on IS surfaces in channel body 5. These may be anatomically preserved as fossil charcoal (up to 6 cm diameter; Fig. 5e), the product of ancient wildfires (Scott 1989), or more rarely as calcareous permineralizations (up to 0.5 cm diameter). The charcoal consists entirely of pycnoxylic coniferopsid wood characterized by 30–40 µm diameter tracheids with contiguous, oval, 2–3-seriate, alternate, bordered pitting on their radial walls and blank tangential walls (Fig. 5j). Rays are typically biseriate, 4–56 cells high, and exhibit 2–8 araucarioid pits in the cross-field region (Fig. 5k). This wood is identifiable as *Dadoxylon materiarium*-Dawson, a cordaite wood species known from Joggins (Falcon-Lang & Scott 2000; Falcon-Lang 2003*a*). Permineralized woods belong to the same cordaite species (Fig. 5h).

Non-cordaite remains are relatively rare. A few *Calamites* cf. *C. goeppertii* Ettinghausen stems (up to 50 cm in length) are locally common in the lower and upper part of IS bedsets in channel body 5 (Fig. 5f). In addition, several lepidodendrid trunks (<1.5 m long; 25–30 cm diameter) are preserved on the lower part of an IS surface in channel body 5; most are decorticated but the best-preserved material belongs to *Sigillaria scutellata* Brongniart (Fig. 5c). The only plant remains in growth position consist of two stigmarian roots preserved as impressions within red–green mottled mudstone layers in levee deposits immediately adjacent to channel body 4 (Fig. 5b), within channel body 5, and a single upright sandstone-cast calamitean stem located in channel margin sandstone beds of the latter unit. Centroclinal cross-stratification is well developed around the calamitean. Additionally, an autochthonous sigillarian lycopsid stump occurs 4 m below the Hebert beds within sheet sandstone units (Fig. 5g).

Finally, allochthonous rhizoconcretions are abundant in the gravel lag of channel bodies 4 and 5 (locally composing 15–20% of the lag), and reach dimensions of up to 2 mm diameter and 27 mm long. In thin section, these consist of sparry calcite axes (0.1–0.35 mm diameter) surrounded by a cylinder of fine-grained or sparry calcite (0.2–2.0 mm diameter) containing silt-grade siliciclastic grains. Similar rhizoconcretions from identical WDF channel facies occur at several intervals in the Joggins sections, and locally contain anatomically preserved gymnospermous roots with 8–37 µm diameter tracheids possessing 3–5-seriate alternate pitting (Fig. 5i, see Andrews 1940; Falcon-Lang 2003*a*). Although anatomically preserved tissue is not seen in rhizoconcretions from the Hebert beds, their similar size suggests they also may be gymnospermous, probably belonging to cordaites or pteridosperms.

Invertebrate fauna

An invertebrate fauna with a moderate abundance and low species richness ($n = 2$) also is preserved in the Hebert beds, a detailed taxonomic description of which has been provided by Hebert & Calder (2004). The first taxon is *Archanodon westoni* Whiteaves, a unionoid bivalve endemic to Joggins (Weir 1969). *Archanodon* shells are large (18–23 cm long, 8–9.5 cm high), characterized by 5–15 mm thick valves, and in general form are strongly inequilateral and isomyarian with a depressed umbo. The exterior of the shells exhibit two hierarchies of growth banding; primary well-defined, continuous bands of which there are typically 8–10 on each shell, and secondary subtly defined, discontinuous bands of which there are many tens on each shell. Two disarticulated and partially fragmented *Archanodon* specimens were collected from a fallen block, probably derived from the gravelly basal lag of channel body 4. A further 15 specimens were collected from IS bedsets at the western edge of channel body 5. Some are disarticulated, associated with an intraformational conglomerate lag at the channel base, but others are articulated in fine-grained sandstone units on the medial surfaces of IS bedsets (Fig. 6a and b). One articulated specimen is evidently in life position, vertically orientated posterior-up in the IS bedsets. This specimen and all other articulated specimens are sandstone-cast.

The second invertebrate species is *Dendropupa vetusta* Lyell & Dawson, a small helically coiled pupiform gastropod, which is also apparently endemic to Joggins (Knight *et al*. 1960; Fig. 7). The shells are 5–10 mm high, possess up to eight or nine whorls, and exhibit a fine axial ribbing (collabral threads). Two specimens occur in the coarse channel lag of channel body 5, and at least a further 30–50 specimens occur in a dense accumulation within very fine sandstone to siltstone beds that compose the IS bedsets of the same channel body. In the WDF facies association in general, *Dendropupa* locally occurs as dense agglomerations of up to 20 individuals surrounding plant detritus in green–red mottled mudstone units (Hebert & Calder 2004), although this mode of occurrence is not specifically seen in the Hebert beds.

Vertebrate fauna

At least seven tetrapod skeletal elements also were found in the Hebert beds (Fig. 8). This material, which includes both cranial (jaw) and post-cranial fragments (shoulder and pelvic girdles,

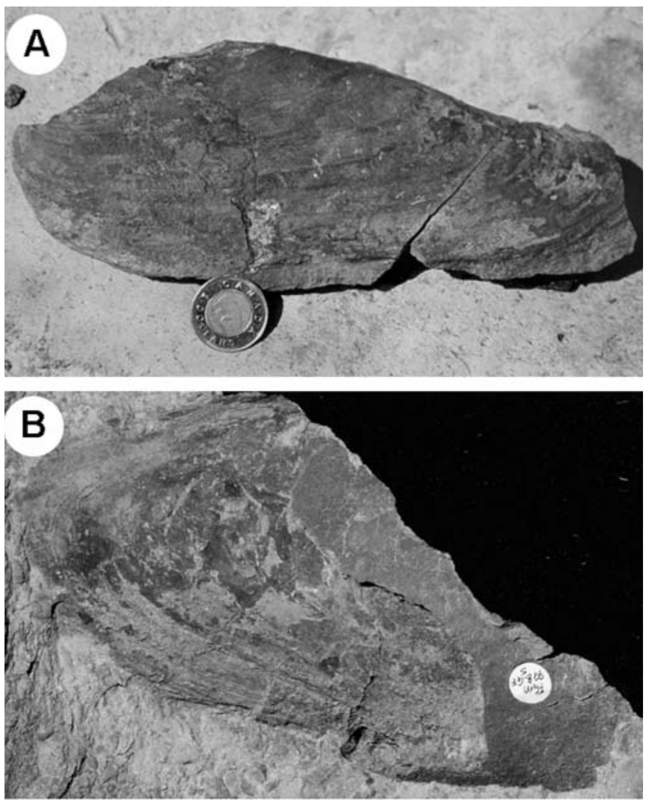


Fig. 6. *Archanodon westoni* unionoid bivalves from channel body 5 of the Hebert beds. (**a**) Articulated specimen similar to the one extracted from life position in IS bedsets; coin is 27 mm in diameter; FGM998GF70. (**b**) Disarticulated specimen from intraformational conglomeratic basal lag; museum tag is 13 mm in diameter; FGM998GF5.

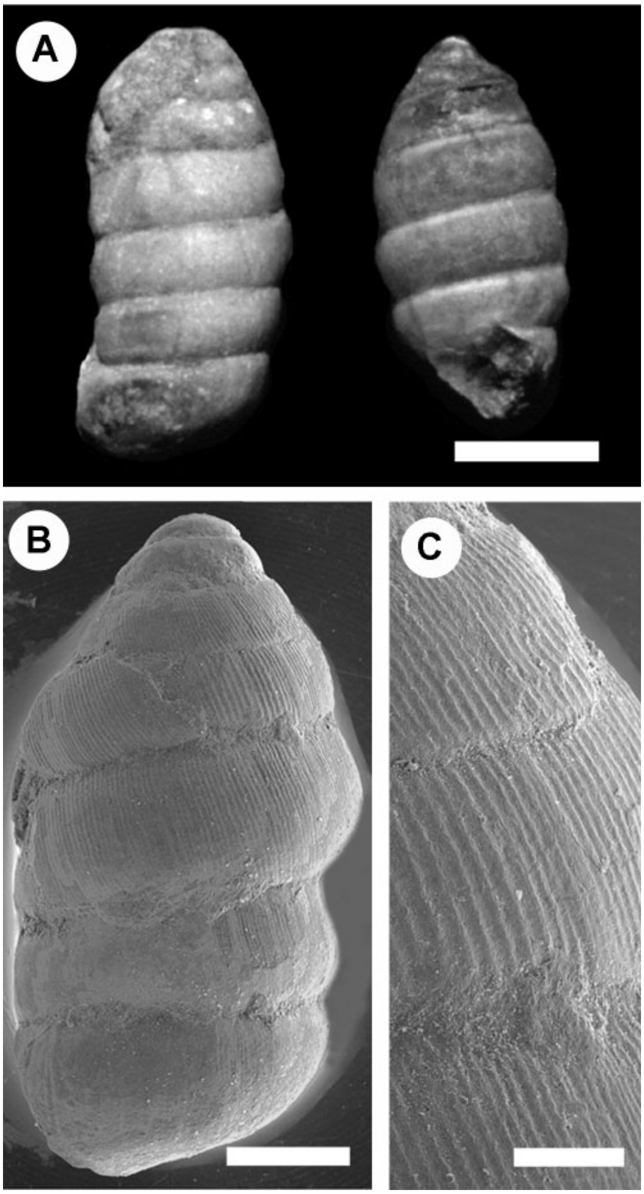


Fig. 7. *Dendropupa vestusta* land snail. (**a**) Photograph of two typically pupiform individuals; scale represents 3 mm; NSM002GF031.189; Hebert beds. (**b**) SEM image of a well-preserved specimen showing fine ribbing; scale represents 2 mm; private collection. (**c**) Detail of ribbing; scale represents 500 µm; private collection. The specimen shown in (**b**) and (**c**) is not from the Hebert beds but from a similar red-bed facies context elsewhere at Joggins.

vertebrae, ribs and limbs), is currently being described by T. Fedak (Fundy Geological Museum) and A. R. Milner (University of London) and is not given systematic treatment here. However, preliminary investigations suggest that three tetrapod families are probably represented, including baphetids, anthracosaurs and microsaurs (Hebert & Calder 2004).

The skeletal elements were found in a dense accumulation in channel body 5 (Fig. 4). Matrix-supported intraformational conglomerates marking the channel base yielded a microsaur jaw (23 mm long) containing nine teeth (Fig. 8a and b), a labyrinthine tooth (Fig. 8c), and a larger (>8 cm long) unidentified jaw exhibiting a single 1.3 mm long conical tooth (putative baphetid–anthracosaur; Fig. 8e). The rest of the skeletal elements were found in very fine sandstone to siltstone units at a medial level in the IS bedsets. Although limited exposure prevented detailed exploration of bone taphonomy, some of the elements were evidently partially articulated (e.g. pelvic girdle assembly; Fig. 8d) whereas others were isolated. None of the material has undergone significant mechanical fracture (the breakages visible in the figured images being created during extraction). In addition, skeletal elements show little sign of weathering (stage 0/1 on the index of Behrensmeyer 1978) in that they show no evidence of surface cracking or flaking, or perhaps only minimal mosaic cracking.

Palaeoenvironmental and palaeoecological interpretation

Davies & Gibling (2003) interpreted the Hebert beds as the alluvial channel deposits of a well-drained alluvial plain. However, analysis of the architecture and sedimentology presented here permits more precise interpretation. In addition, new palaeontological data allow inferences to be made concerning the enigmatic nature of Pennsylvanian dryland ecosystems.

Facies interpretation of Hebert beds

Based on bedset form and sedimentary structures, three types of architectural element (Miall 1996) are identified in these channel bodies. Sandy bedform sheets (element SB) predominate in channel bodies 1–3. Lateral-accretion macroforms (element LA) are present in all channel bodies, but predominate in channel bodies 4 and 5. These are represented by IS and IHS bedsets that dip away from channel margins, with flow-directional sedimentary structures (where measurable) oriented approximately along-strike of the inclined surfaces. Mud-dominated, abandoned channel fills (element FF) occur in channel bodies 4 and 5.

The architecture of channel bodies 1–3 differs from that of channel bodies 4 and 5, indicating that they originated under different, although genetically related, flow conditions. Based on their low W:T ratios and the rarity of channel migration features, channel bodies 1–3 can be classified as ribbon sandstones (*sensu* Friend *et al*. 1979) representing the deposits of fixed channels (Friend 1983) of *c*. 4–6 m deep and *c*. 13 m wide. The incised nature of the channel bodies and the scarcity of extensive, genetically related overbank deposits suggest that the channel bodies represent relatively long-lived river channels rather than secondary crevasse splay channels. The predominance of SB elements and the rarity of LA elements imply that river channels predominantly filled by vertical aggradation of bedforms, with minor contributions from in-channel and bank-attached bars. Stacked storeys within channel body 2 and the high density of channel bodies in this interval further suggest that successive river channels tended to reoccupy old drainage pathways. The homogeneous sandstone fill of these bodies indicates that flows sufficiently vigorous to transport sand dominated throughout the lifetime of the active channels. However, flow strength evidently fluctuated considerably, resulting in the transportation of pebble-sized clasts and the formation of upper-stage plane beds during periods of elevated discharge, and small dunes and ripples in medium-grained sand during periods of subdued discharge. During peak discharge, flow overtopped the channel banks, resulting in the formation of sandy 'wings' (Friend *et al*. 1979). The marked variations in flow strength characteristic of channel bodies 1–3 probably reflect seasonal variations in discharge

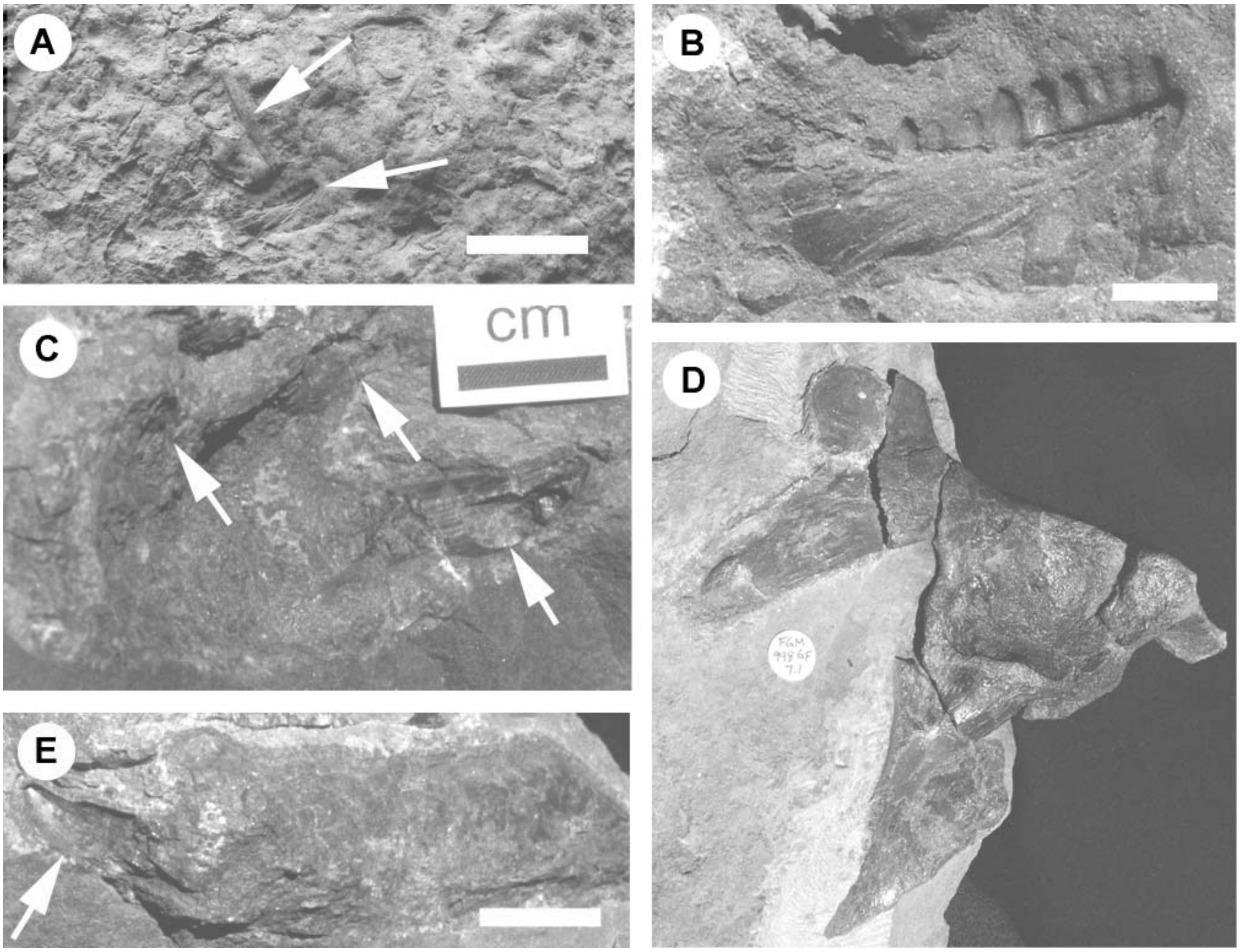


Fig. 8. Examples of tetrapod material from Hebert beds. (**a**) Basal lag of channel body 5 containing elongate rhizoconcretions (upper centre, arrowed) and a microsaur jaw (lower centre, arrowed); FGM000GF19; scale represents 2 cm. (**b**) Enlargement of microsaur jaw shown in (**a**); scale represents 7 mm; FGM000GF19. (**c**) Labyrinthine tooth; FGM000GF104a; three cusps are arrowed. (**d**) Baphetid pelvic girdle assembly; FGM998GF7.1, museum tag is 13 mm in diameter. (**e**) Robust mandible with labyrinthine conical tooth (arrowed); scale represents 3 cm; FGM000GF104b.

given the palaeosol evidence for rainfall seasonality (Smith 1991).

In contrast, channel bodies 4 and 5 probably represent the deposits of more sinuous channels that laterally migrated by cut bank erosion and associated point bar growth, as indicated by their higher W:T ratios, and the ubiquity of LA elements. The active channel responsible for channel body 4 was at least 3.5 m deep and 8.3 m wide given the dimensions of the abandonment fill. Based on the thickness and lateral extent of LA elements (Leeder 1973), the active channel responsible for channel body 5 was probably at least 1.8 m deep and 19 m wide (dimensions corrected for palaeoflow obliquity). Lag deposits along scour surfaces in both channel bodies indicate that occasionally flows were vigorous enough to transport pebble-sized mudstone and carbonate clasts as well as cobble-sized *Archanodon* shell fragments. However, abundant lenses of mudrock and heterolithic channel fill suggest that erratic low-stage flow and ponding was a more common occurrence. Furthermore, raindrop impressions, desiccation cracks and adhesion ripples (which are formed by wind-blown sand across a moist surface) preserved within channel body 5 indicate that water levels were periodically low enough to subaerially expose significant portions of the point bar surface. However, because these features are absent on the lower part of the point bar surface, it is likely that this channel never became completely dry but retained standing water in the thalweg region for most, if not all, of the year. Matrix-supported intraformational conglomerates at the channel base may suggest that seasonal flow resumption was initially characterized for a short time by concentrated slurry-like conditions.

Several characteristics strongly indicate that collectively the Hebert beds originated in an anastomosing fluvial system composed of multiple co-active channels. Key similarities between the channel bodies described in this study (especially 1–3) and those of modern anastomosing fluvial systems include their low W:T ratios, lateral stability and a tendency to reoccupy old drainage paths (Smith & Smith 1980; Nanson & Knighton 1996; Gibling *et al*. 1998). An anastomosed interpretation is further supported by the presence of multiple small channels at precisely the same stratigraphic level at numerous intervals in the Joggins Formation and by the presence of anastomosed channels in the overlying Springhill Mines Formation (Rust *et al*. 1984). The repeated adoption of an anastomosed fluvial morphology may have facilitated maximum sediment transport (Nanson & Knighton 1996; Nanson & Huang 1998) into the rapidly subsiding Cumberland Basin.

Although anastomosed fluvial systems are best described from humid climatic settings (e.g. Smith & Smith 1980), closer analogues for the Hebert beds include the anastomosed drainages of central and northern Australia, where rainfall seasonality is marked, and channel confinement is facilitated by indurated, sun-baked floodplain muds and localized vegetated levees (Fig. 9; Nanson *et al*. 1986; Knighton & Nanson 1994; Gibling *et al*. 1998). The appropriateness of such Australian analogues is investigated below, but first the palaeoenvironment of the fossiliferous channel bodies 4 and 5 is further interpreted.

As already noted, these units represent the deposits of sinuous channels that, following the repeated cessation of fluvial through-flow, became perennially ponded to sluggishly flowing water bodies. Given the evidence for seasonality in rainfall (Smith 1991) and channel discharge, it is highly probable that the perennial ponded bodies on the Joggins alluvial plain acted as ecologically significant sources of water (waterholes *sensu* Jackson 1997), especially during seasonal drought. This interpretation is supported by the abundance of fossils in these units.

Plant ecology

Facies analysis of fossil plants provides insight into the vegetation ecology of the Hebert beds. Rare *Stigmaria* associated with mudstone beds of channel bodies 4 and 5 demonstrate that a few lycopsid trees grew within and immediately adjacent to channels during sustained periods of ponding. Fielding & Alexander (2001) considered the presence of in-channel trees as an important facies criterion for recognizing seasonally flowing river systems; rare *in situ* lycopsids therefore provide further evidence for the seasonal nature of the Hebert bed channels. Although lycopsids possessed a relatively rapid life cycle (Phillips & DiMichele 1992), the existence of large, in-channel trees suggests that, at times, many years must have elapsed without significant channel through-flow, while trees grew to maturity. However, sedimentary facies and other fossil data (below) suggest that it was more normal for rivers to flow seasonally. Facies-associated allochthonous trunks indicate that the drought-tolerant *Sigillaria* was the dominant lycopsid tree in this riparian niche (Phillips & DiMichele 1992; Falcon-Lang 2003*a*).

During more active periods of channel flow, *Calamites* colonized rapidly aggrading channel margins and within-channel bars, as indicated by *in situ* stems rooted in sandstone beds on the edge of channel body 5, and implied by allochthonous stems preserved on point bar surfaces. Like their extant relative *Equisetum*, calamiteans were adapted to disturbed niches because of their prolific ability to resprout from underground rhizomes (Gastaldo 1992).

By far the largest volume of plant material in channel bodies 4 and 5 consists of allochthonous leaves, trunks, pith casts and wood (commonly charred) derived from cordaite trees, together with indeterminate gymnosperm rhizoconcretions. Facies analysis of these remains throughout the WDF facies association suggests that they were transported from ecologically stressed, fire-prone gymnosperm vegetation that occupied well-drained floodbasins between the fluvial channels (Falcon-Lang 1999, 2003*a*), some distance from the alluvial waterholes. The discovery of gymnosperm roots preserved in carbonate concretions confirms that these plants were indeed growing in seasonally dry, carbonate-accumulating soils.

Bivalve ecology

The occurrence of the unionoid bivalve *Archanodon* sheds light on the aquatic ecology of the Hebert bed seasonal drainages and waterholes. Four Devonian–Pennsylvanian species of this bivalve have been previously described, all of which occur in similar facies associations despite their disjunct temporal distribution (Weir 1969).

The first species, *Archanodon catskillensis* Vanuxem, is common in Middle to Upper Devonian successions in eastern USA, associated with the deposits of meandering alluvial channels, crevasse splays, floodbasin mudstones (Friedman & Chamberlain 1995) and ephemeral carbonate lakes (Demicco *et al*. 1987).

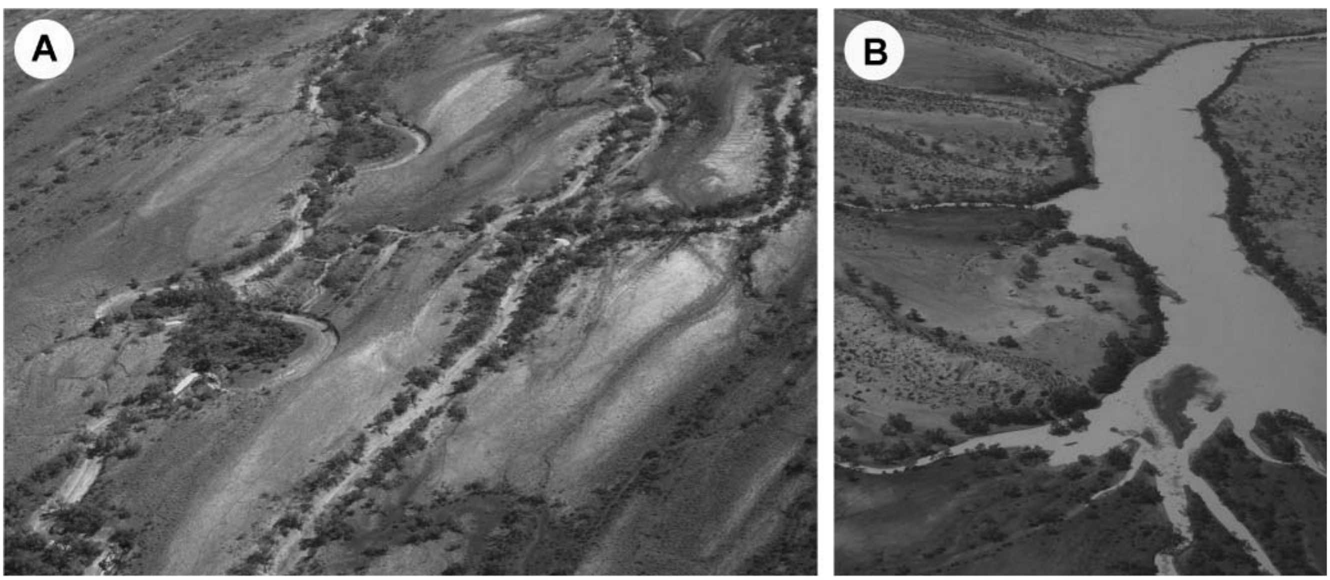


Fig. 9. Anastomosed drainage networks of the Channel Country, Queensland, central Australia offer a good analogue for the Hebert beds palaeoenvironment. (**a**) River channels are analogous to channel bodies 1–3; (**b**) waterholes are analogous to channel bodies 4 and 5.

Burrows, some containing *A. catskillensis* in life position, occur in point bar, levee and proximal splay deposits (Thoms & Berg 1985; Bridge *et al*. 1986) and indicate that organisms were freshwater infaunal suspension feeders (Friedman & Chamberlain 1995). Diminutive *A. catskillensis* specimens associated with leperditiid and beyrichiid ostracodes have led to speculation that some forms may have tolerated brackish water (Knox & Gordon 1999), but supporting facies evidence is equivocal (Friedman & Lundin 2001).

No facies data exist to ascertain the mode of life of a second species, *A. rhenana* Beushausen, from Middle Devonian units of Germany (Thoms & Berg 1985). However, a third species, *A. jukesi* Forbes, found in Upper Devonian–Mississippian strata of the British Isles, is associated with coarse-grained, fresh-to-brackish fluvial channel deposits and ephemeral carbonate lake facies (Howse 1878; Holland 1981; Turner *et al*. 1997).

The fourth species, *A. westoni* Whiteaves, is endemc to Joggins, and prior to this study was known only from two specimens discovered in the nineteenth century (Whiteaves 1893). Almost all Joggins specimens found in more recent times occur in the Hebert beds (Hebert & Calder 2004), and although many are fluvially reworked (disarticulated fragments), some are in life position or parautochthonous, demonstrating that these bivalves lived in river point bars like their Devonian ancestors. Their thick, smooth, elongate valves suggest that they were adapted to periodic high-energy conditions, and were infaunal suspension feeders (Eagar 1948).

Little is known of the ecology of extant unionid bivalves in seasonally dry river channels (McMichael 1952). Limited observations indicate that they exhibit a filter-feeding strategy during periods of bankfull channel flow, but at times of low flow burrow into the muddy channel floor where they remain dormant (aestivate) until flow is resumed in the following wet season (McMichael 1952; Tevesz & Carter 1980). A similar mode of life is envisaged for *Archanodon* at Joggins as Hebert bed drainages periodically oscillated between actively flowing alluvial channels and ponded waterholes. Modern unionids can survive in a dormant state for only a few months (McMichael 1952) before they die of their own toxicity; following death their shells spring open and become filled with sediment. The sandstone-cast nature of the single *Archanodon* specimen in life position therefore suggests that, at times, the length of the droughts must have exceeded the upper tolerance limit of these organisms.

Under favourable conditions, the mantle of modern unionid bivalves continuously secretes shell material, but during ecological disturbance, it contracts, resulting in the formation of a growth band. In seasonal tropical settings, primary bands develop during the summer drought, with secondary bands recording minor environmental fluctuations (Tevesz & Carter 1980). Given the tropical palaeolatitude of Joggins, primary growth bands in *Archanodon* specimens provide further evidence for rainfall seasonality, and indicate that these large bivalves typically lived for around 8–10 seasons, like their long-lived extant relatives (Strayer 1999).

The temporally disjunct nature of *Archanodon* populations, its four species sporadically occurring in the Devonian–Pennsylvanian interval, may provide additional ecological information. Dryland alluvial deposits are preserved infrequently in the geological record, more typically being sites of net erosion than deposition. Temporally disjunct *Archanodon* species therefore may indicate that populations were centred in a seasonal continental-interior setting where long-term preservation potential was low.

Gastropod ecology

The presence of the pulmonate land snail, *Dendropupa vetusta*, provides insight into one part of the terrestrial ecology of the Hebert beds waterhole. *Dendropupa* specimens were first found in the PDF facies association at Joggins, located within the hollow lycopsid trunks (Dawson 1860, 1880; Solem & Yochelson 1979). However, subsequently this species has been found more widely in the WDF facies association, where it predominates in coarse-grained channel lags and as clusters of multiple individuals in mudstone beds associated with fossil plant detritus (Hebert & Calder 2004). Comparison with extant related taxa suggests that *Dendropupa* was a grazing detritivore (Dawson 1860), an interpretation supported by the facies data presented here. Rather than representing allochthonous hydrodynamic concentrations, the most parsimonious explanation for the clusters of multiple gastropods is that they represent life assemblages, preserved when populations grazing on plant debris within the waterhole were buried by the resumption of fluvial flow. Many extant, related viviparid gastropods can resist drought for long periods (>10 months) by burrowing into drying mud, sealing their operculum and aestivating (Withers *et al*. 1997). Given its occurrence in a dryland setting, *Dendropupa* may have had a similar capacity.

Vertebrate ecology

The vertebrate skeletal fragments in channel body 5 provide information about a second facet of the terrestrial ecology of the Hebert beds waterhole. Hebert bed baphetids and anthracosaurs were probably aquatic or amphibious, broad-snouted tetrapods that fed on fish, and, based on skeletal dimensions, were up to 2 m in length. In contrast, Hebert bed microsaurs were salamander-like insectivores, up to 20–30 cm long (Milner 1987; Milner & Lindsay 1998).

The absence of well-developed weathering features (stage 0/1) suggests that the Hebert bed vertebrate remains were subject to a relatively short period of subaerial weathering after death (probably <4 years based on modern weathering rates; Behrensmeyer 1978). This may suggest that animals died near the waterhole, or at least were rapidly transported into it. Vertebrate remains are commonly associated with modern and ancient waterhole deposits because animals are attracted to standing water bodies during severe drought, where they starve to death as local food resources are depleted (Conybeare & Haynes 1984).

Although some skeletal remains are evidently allochthonous (i.e. disarticulated jaws in the channel lag deposits), other remains are probably parautochthonous. This is especially true of the partially articulated pelvic girdle remains that occur in siltstone or very fine sandstone units deposited during ponded to sluggishly flowing conditions. The Hebert bed vertebrate remains therefore probably fall somewhere in the middle of the taphonomic continuum of Behrensmeyer (1988) of fluvial-hosted vertebrate assemblages, material having undergone either little or some transport in the seasonally active Joggins dryland rivers.

Modern analogues

The remainder of this paper is devoted to developing and discussing modern analogues for the Joggins waterhole deposit and its biota. From a purely sedimentological perspective, the anastomosed drainage networks of the semi-arid Channel Country, Queensland, central Australia, offer one analogue in which summer storm-driven floods alternate with winter droughts when flow ceases (Rust 1981). Perennial waterholes (0.1–2 km in length) are common, forming within the deepest channel reaches at points of channel constriction, confluence, or within remnant scours during low-stage flow (Knighton & Nanson 1994, 2000). They are normally stagnant water bodies, but experience gentle flow (typically $<1\ \mathrm{m\ s^{-1}}$) for a few weeks each year when they become connected to active channels (Fig. 9; Nanson *et al*. 1986; Knighton & Nanson 2000). Specific facies characteristics shared with channel bodies 4 and 5 of the Hebert beds include the presence of rain prints, adhesion ripples, desiccation cracks, lateral accretionary bar-forms, the predominance of suspension deposits, and W:T ratios substantially greater than normal active channels (Knighton & Nanson 1994, 2000; Gibling *et al*. 1998).

Despite this general facies correspondence, palaeosol data for the Joggins section suggest a considerably more humid climate than that of the Channel Country, where rainfall ranges from 120 to 150 mm per year (Gibling *et al*. 1998). Consequently, this analogue is probably inappropriate for the biological component of the Hebert beds. However, seasonally flowing rivers with perennial waterholes are also characteristic of more humid parts of Australia. These regions include the Burdekin River of Queensland (Fielding *et al*. 1999) and rivers of the northern Australian coast (e.g. Nanson *et al*. 1993; Wende & Nanson 1998), where rainfall is in the range of 700–1500 mm per year but strongly seasonal (Williams 1983).

Like the Hebert beds, these seasonally humid systems exhibit relatively low-diversity plant communities with vegetation biomass being dominated by ecologically stressed seed-bearing trees. Another similarity is that along waterhole levee to floodplain transects, a pronounced vegetation gradient exists in many places. For example, at Magela Creek, northern Australia, hydrophilic palms and mangroves proximal to the waterhole give way to fire-prone sedges, grasses and paperbark on the dry floodbasin (Williams 1983). A further feature of all Australian seasonal rivers also seen in the Hebert beds is the colonization of channel bases by trees (Williams 1983; Gibling *et al*. 1998; Fielding & Alexander 2001).

Other biological similarities to the Hebert beds include the presence of common large infaunal unionid bivalves in the Australian waterholes, in particular the widespread genus *Velesunio* (Williams 1983; Gibling *et al*. 1998). Like *Archanodon*, these related organisms are active suspension feeders during times of channel through-flow, but remain dormant in the muddy channel floors during drought (McMichael 1952; Gibling *et al*. 1998). Their relatively thin valves, in contrast to *Archanodon,* may be a consequence of the low levels of dissolved carbonate in many Australian watercourses (Bayly & Williams 1973; Tevesz & Carter 1980). Also present around the Channel Country waterholes and in more humid regions are abundant viviparid gastropods such as *Notopala*, which may have an analogous ecology to *Dendropupa*. This extant gastropod, like its Pennsylvanian relative, is dominantly a deposit feeder, grazing on vegetable detritus and algae within seasonal alluvial channels (Gibling *et al*. 1998).

Finally, Australian waterholes also contain common, but relatively low-diversity tetrapod faunas including frogs, lizards, tortoises and crocodiles. Many of these organisms have evolved significant tolerance of drought (for example, the moaning frog can lose up to a quarter of its body weight through water loss during daily foraging, and still survive) or have developed behavioural strategies such as burrowing and aestivation that limit water loss (Williams 1983). Given the close environmental correspondence to Australian waterholes, tetrapods of the Hebert beds may have possessed similar adaptive traits.

It will be clear that the seasonal drainages of the Hebert beds bear a genuinely close similarity to those of present-day northern and central Australia, especially in terms of sedimentology and

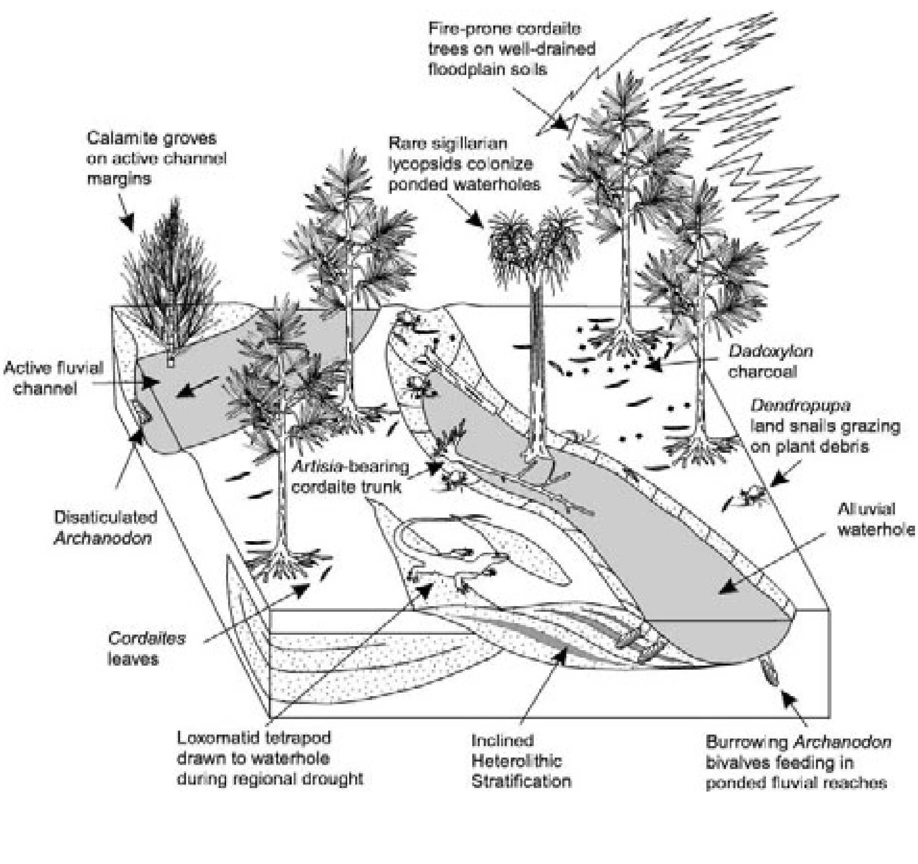


Fig. 10. Palaeoenvironmental synthesis summarizing the main components of the Hebert beds environment and ecosystem (NB: It is not envisaged that the river depicted in the top left (which is representative of channel bodies 1–3) was actively flowing at a time when the channel in the lower right was ponded and partially dry (channel bodies 4 and 5). The two channels depict alternate periods of flow and ponding.)

biology. This is emphasized by two general ecological similarities: both systems exhibit high degrees of endemicity (especially amongst the invertebrate fauna) and possess relatively low species richness. Such features are considered highly characteristic of ecologically stressed biomes (Williams 1983) and this implies that the striking ecological convergence of these two temporally and geographically disjunct regions is probably related to the strong environmental forcing exerted by their common setting.

In conclusion, analysis of the Hebert beds assemblage and comparison with the modern Australian analogues sheds new light on the nature of the enigmatic tropical drylands (summer-wet biome) of Pennsylvanian times (Fig. 10). In the future, study will focus on channel bodies with similar facies characters to the Hebert beds at Joggins in an attempt to locate more of these important assemblages.

Conclusions

(1) An early Pennsylvanian channel complex containing an unusual fossil assemblage has been described at Joggins, Nova Scotia; this unit is informally termed the Hebert beds. Channel architecture and facies analysis suggest that the unit represents a waterhole preserved in seasonally dry alluvial plain deposit.

(2) The Joggins waterhole fossil assemblage, which includes fossil plants, gigantic freshwater unionoid bivalves, terrestrial gastropods and semi-terrestrial tetrapods, is significant because it sheds light on the composition and ecology of the enigmatic Pennsylvanian summer-wet biome.

(3) Results demonstrate that major differences existed between the ecology of Pennsylvanian continental drylands and the better-known peat-forming wetland realm, the former being dominated by low-diversity, ecologically stressed ecosystems.

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REVIEW

Paleontological Evidence to Date the Tree of Life

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The role of fossils in dating the tree of life has been misunderstood. Fossils can provide good "minimum" age estimates for branches in the tree, but "maximum" constraints on those ages are poorer. Current debates about which are the "best" fossil dates for calibration move to consideration of the most appropriate constraints on the ages of tree nodes. Because fossil-based dates are constraints, and because molecular evolution is not perfectly clock-like, analysts should use more rather than fewer dates, but there has to be a balance between many genes and few dates versus many dates and few genes. We provide "hard" minimum and "soft" maximum age constraints for 30 divergences among key genome model organisms; these should contribute to better understanding of the dating of the animal tree of life.

Introduction

Calibrating the tree of life has long been the preserve of paleontology but its place has recently been usurped completely by molecular clocks. Fossil data are fundamental to molecular clock methodology, providing the key means of clock calibration, but their commonplace use is far from satisfactory. We consider the utility and qualities of good calibration dates and, on that basis, we propose a number of well-supported dates, and give ages based on the best current information. In doing this, we argue that paleontological data do not provide actual age estimates for divergence events, but they can provide rather precise minimum constraints on the calibration of molecular clocks, and much looser maximum constraints. The evidence of a "hard" lower bound (minimum constraint) and a "soft" upper bound (maximum constraint) provided from paleontology can then be fed into a molecular clock analysis. It is not our aim to determine the actual timing of divergence events as we do not believe that this is possible using paleontological data alone—though paleontological data can be used to test dates estimated using molecular clock methods (e.g., Foote et al. 1999; Tavaré et al. 2002).

Traditionally, very small numbers of calibration dates have been employed and these have been selected for utility and have rarely been defended. The most commonly used calibration node is the mammal–bird divergence, dated at 310 MYA and accepted in some 500 or more publications since 1990. This date was based on the age of the oldest members of the synapsid and diapsid clades (Benton 1990), and yet these basal fossils have been debated, as has the dating of the rocks from which they come. Recently, authors have suggested an age range from 330 to 288 MYA at most (Lee 1999; Reisz and Muller 2004; van Tuinen and Hadly 2004). So, which date is to be used, and what does that date really represent?

It is clear that the fossil record cannot be read literally (Darwin 1859). There are many gaps, and many organisms, and indeed whole groups of poorly preservable organisms that have never been preserved and are doubtless lost for ever (Raup 1972). Some have even gone so far as to suggest that the fossil record is almost entirely an artifact of the rock record, with appearances and disappearances of fossil taxa controlled by the occurrence of suitable rock units for their preservation (Peters and Foote 2001, 2002), or the matching rock and fossil records controlled by a third common cause (Peters 2005). However, the widespread congruence between the order of fossils in the rocks and the order of nodes in cladograms (Norell and Novacek 1992; Benton et al. 2000) indicates that the order of appearance of lineages within the fossil record is not a random pattern. Furthermore, a fossil of any age demonstrates the divergence of its lineage, and so provides an absolute constraint on the temporal dimension of the tree of life.

Traditionally, calibration dates have been assumed to indicate the timing of an evolutionary divergence event, as a basis for inferring rates of functionally equivalent amino acid or nucleotide substitution (in proteins or genes, respectively), from which the timing of other lineage-splitting events may be deduced (Zuckerkandl and Pauling 1965). However, paleontological data can provide good estimates only for minimum constraints on the timing of lineage divergence events (Benton and Ayala 2003; Hedges and Kumar 2004; Reisz and Muller 2004). Note that relaxed-clock methods can often require at least one point calibration or hard maximum constraint in order for the algorithm to converge on a unique solution. So, debates about the superiority of one "calibration" date or another are irrelevant in the context of a search for the most appropriate distribution of dates and minimum and maximum constraints—the only bad dates are those that predate the evolutionary event upon which they are supposed to provide a minimum constraint.

Deviations from the molecular clock may occur because of changes in selective pressures and mutation rates, and this requires that molecular clock analyses rely upon a law of large numbers in which an average rate may be derived from a data set that is sufficiently large (Rodríguez-Trelles et al. 2003). It is still debated whether an analysis based on many genes and few dates or few genes and many dates is preferable. However, multiple calibration points are particularly helpful in relaxed-clock methods where the rate is allowed to vary among branches in the tree; multiple calibrations throughout the tree act as anchor points, allowing the method to estimate the patterns and degree of rate variation more accurately. Good estimates of rate variation are required from the well-calibrated regions of the tree so that the pattern can be extrapolated to other parts of the tree that

Key words: tree of life, paleontological dating, calibration, quality of fossil record.

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Table 1
Constraints on Calibration Dates for Branching Points in the Tree of Life

Node	Equivalent to Clade	Age-Indicative Fossil	Minimum Age Constraint: Youngest Date (MYA)	Minimum Age Constraint: Recommended Date (MYA)	Maximum Age Constraint: Oldest date (MYA)	Maximum Age Constraint: Recommended Date (MYA)	Evidence
Human–chimp	Homini–*Pan*	*Sahelanthropus*	6.5	6.5	10	10	Biostratigraphy
Human–macaque	Hominoidea–Cercopithecoidea	*Proconsul*	23.5 ± 0.5	23.0	33.8 ± 0.1	33.9	Biostratigraphy
Mouse–rat	*Mus* lineage–*Rattus* lineage	*Progonomys*	11.0	11.0	12.3	12.3	Magnetostratigraphy
Rabbit–mouse	Glires	*Heomys*	61.7 ± 0.2	61.5	99.6 ± 0.9	100.5	Biostratigraphy
Human–mouse	Archonta–Glires (Euarchontoglires)	*Heomys*	61.7 ± 0.2	61.5	99.6 ± 0.9	100.5	Biostratigraphy
Dog–cat	Caniformia–Feliformia	*Tapocyon*	43 ± 0.2	42.8	63.6 ± 0.2	63.8	Bio/Magnetostraigraphy
Dog–horse	Carnivora–Perissodactyla	*Tetraclaenodon*	62.5 ± 0.2	62.3	70.6 ± 0.6	71.2	Bio/Magnetostratigraphy
Cow–sheep	Bovinae–Antilopinae	*Eotragus*	18.3	18.3	28.4 ± 0.1	28.5	Biostratigraphy
Cow–pig	Ruminantia/Tylopoda–Suiformes	*Mixtotherium*	48.5 ± 0.2	48.3	53.5	53.5	Biostratigraphy
Cow–dog	Ferungulata	Zhelestidae	96.2 ± 0.9	95.3	112 ± 1	113	Biostratigraphy
Human–cow	Euarchontoglires–Laurasiatheria	Zhelestidae	96.2 ± 0.9	95.3	112 ± 1	113	Biostratigraphy
Human–armadillo	Boreoeutheria–Xenarthra	Zhelestidae	96.2 ± 0.9	95.3	112 ± 1	113	Biostratigraphy
Tenrec–elephant	Afrosoricida/Tubulidentata–Paenungulata	*Phosphatherium*	48.6 ± 0.2	48.4	112 ± 1	113	Biostratigraphy
Human–tenrec	Boreoeutheria/Xenarthra–Afrotheria	Zhelestidae	96.2 ± 0.9	95.3	112 ± 1	113	Biostratigraphy
Opossum–kangaroo	Ameridelphia–Australidelphia	*Pucadelphys*	61.7 ± 0.2	61.5	70.6 ± 0.6	71.2	Biostratigraphy
Human–opossum	Eutheria–Metatheria	*Eomaia*	124.6 ± 0.01	124.6	136.4 ± 2.0	138.4	Direct date
Human–platypus	Theriimorpha–Australosphenida	*Phascolotherium*	166.5 ± 4.0	162.5	189.6 ± 1.5	191.1	Biostratigraphy
Chicken–zebrafinch	Galloanserae–Neoaves (Neognathae)	*Vegavis*	66	66	85.8 ± 0.7	86.5	Biostratigraphy
Emu–chicken	Palaeognathae–Neognathae (Neornithes)	*Vegavis*	66	66	85.8 ± 0.7	86.5	Biostratigraphy
Bird–crocodile	Avemetatarsalia/Ornithodira–Crurotarsi	*Vjushkovisaurus*	237 ± 2.0	235	249.7 ± 0.7	250.4	Biostratigraphy
Crocodile–lizard	Archosauromorpha–Lepidosauromorpha	*Protorosaurus*	260.4 ± 0.7	259.7	299 ± 0.8	299.8	Biostratigraphy
Mammal–bird	Sauropsida–Synapsida (Amniota)	*Hylonomus*	313.4 ± 1.1	312.3	328.8 ± 1.6	330.4	Biostratigraphy
Human–toad	Reptiliomorpha–Batrachomorpha	*Lethiscus*	332.4 ± 2.0	330.4	348 ± 2.1	350.1	Biostratigraphy

NOTE.—Branching points are indicated for key species, and their larger clade equivalences. The oldest and youngest dates are given, based on the literature, and on the *Cambridge 2004* timescale (Gradstein et al. 2004). The youngest date is given for the minimum age constraint, and the oldest for the maximum age constraint, based on the date of the geological formation containing the age indicative fossil. The recommended dates are the youngest possible (i.e., minimum) date for the minimum constraint, and the oldest possible (i.e., maximum) for the maximum constraint.

are poorly calibrated. Furthermore, molecular clock analyses are rarely, if ever, framed around the availability of reliable calibration dates. Rather, they are characterized by scientifically interesting questions and the availability of appropriate sequence data (Hedges and Kumar 2004). Together, these facts require that well-researched calibration dates are available for the majority of available sequence data and, to this end, we provide detailed assessments of the paleontological data constraining the timing of lineage splits between the main genomic models.

Minimum Constraints on Divergence Dates

The indicated range of minimum branching dates (table 1) reflects both uncertainty in the dates (stratigraphic error) as well as the inferred duration of the fossiliferous unit. Such a small range of dates, less than 1% in many cases, may seem startlingly low, but current geological timescales (Gradstein et al. 2004) offer that level of precision. The quoted age range does not incorporate an estimate of uncertainty about whether the oldest fossil really belongs to the clade or about whether the clade might have originated much earlier. The date arose from a 2-step process: 1) Which is the oldest relevant fossil within the clade in question? 2) What is the best current age estimate for the geological formation that includes that fossil?

The first step relied on our reading of current paleontological data, and wide consultation on each date with relevant experts. We excluded all uncertain or scrappy fossils, and retained only those for which there is definitive anatomical evidence of one or more apomorphies of the clade in question. In all cases, the date is sought for branching between 2 extant species, and so we pursued each of the 2 lineages back to the point at which they shared their last common ancestor, based on current phylogenetic evidence. Having 2 lineages meant, we could select the older of the 2 oldest fossils (table 1).

The second step is to date the geological formation in which the oldest fossil, or fossils, occurs, or occur. The identity of that geological formation is clear in all cases—-the earliest members of the Zebrafish (ostariophysean) and Pufferfish (euteleost) lineages, for example, both date from the lithographic limestones of the Obere Solnhofener Schichten of southern Germany. A geological formation is a well-constrained succession of rocks with a clearly marked base and top. In most cases, there is an extensive biostratigraphic literature devoted to establishing the relative age of the unit in question. For the Solnhofen lithographic limestones, ammonites and other fossils place the unit in the lower Tithonian stage (zeta 2a zone) of the Upper Jurassic. That is a relative age, refined to a zonal level that may be less than 1 Myr in duration. Absolute chronostratigraphic ages are then assigned by reference to the international standard, with precise ages established by radiometric methods. The zeta 2a zone is part of the *Hybonoticeras hybonotum* ammonite zone, the base of which coincides with the base of the normal-polarity Chron M22An magnetozone that is dated at 150.8 MYA ± 0.1 Myr (Ogg 2005); a minimum constraint on its age can be derived from the base of the succeeding, *Semiformiceras darwini* ammonite zone that coincides approximately with the M22n Chronozone, dated at 149.9 MYA ± 0.05 Myr (Ogg 2005). This is the current best estimate of the minimum date of divergence of the Zebrafish and Pufferfish genomes. Here, and in our tabulation of divergence dates, we provide minimum constraints. However, we provide the full range of error for those who wish to perpetuate the use of paleontological dates as direct substitutes for divergence times.

The Nature of Minimum Constraints and the Need for Maximum Constraints

Some molecular clock analyses have been calibrated using a single fossil-based date that was assumed to have no error, or with an error distributed symmetrically on either side and with uniform probability between the minimum and maximum bounds and zero probability that the date falls outside the interval (Hedges and Kumar 2004). However, fossil calibrations are minimum dates that provide asymmetrical constraints, below which probability drops immediately to zero, but above which probability decays more gradually, and probability densities can be modeled in a variety of ways to reflect the quality of fossil calibrations (Hedges and Kumar 2004; Kumar et al. 2005; Drummond et al. 2006). Drummond et al. (2006) outline a number of parametric probability distributions for the ages of nodes, including normal, lognormal, exponential, and uniform distributions, that may be used as priors in Bayesian treatments of relaxed-clock models of sequence evolution. The shape of the probability distribution selected can then reflect current biological understanding of the shape of the base of a clade.

Probability distributions of potential ages for the origin of a clade between the maximum and minimum constraints may be modeled to reflect the postulated shape of the base of the clade in question. Paleontologists have described long, thin, spindle-shaped clades and short, fat clades (Gould et al. 1977). Empirical observations suggest that all clades, whatever their shape, expand from one species to many following a logistic curve (Gould et al. 1977; Sepkoski 1996; Tavaré et al. 2002). There may be a long or short initial phase when diversity is low, and then species are added until some kind of "equilibrium" clade species richness is achieved. The logistic model is in line with expectations from ecological models such as the Lotka-Volterra models of competition and the island biogeography model (MacArthur and Wilson 1967; Rosenzweig 1995). If the logistic model is appropriate, then the initial tail, whether long or short, would generally fall outside the maximum constraint if that were set as a 95% confidence interval.

The ends of such distributions have been termed "hard" and "soft" bounds (Hedges and Kumar 2004; Yang and Rannala 2006). A "hard bound" is absolute, and the date cannot fall beyond it, whereas a soft bound is not, and divergence dates could lie beyond it, to a degree that is dependent upon the probability density modeled. The probability density may be entirely arbitrary, or informed predictions about the shape and extent of the probability tail leading from the hard bound may be made based on the nature of the paleontological data (Hedges and Kumar 2004; Barnett et al. 2005; Yang and Rannala 2006). "Soft bounds" for maximum age constraints allow paleontologists to propose short, but realistic, time extensions below the oldest known fossil in a group; if the maximum age constraint is a hard bound, that estimate has to be very large in some cases just to allow for the faintest possibility of a very ancient fossil. Thus, soft bounds provide not only a means of reflecting the nature of the fossil record beyond providing a minimum date but they also lend themselves well to relaxed-tree algorithms in which some age constraints may be better than others, but which are good and which are bad is not known a priori. In the context of parametric probability distributions, the minimum and maximum constraints could be equated with 95% lower and upper limits, and this would allow the placement of a curve and its mean; we use the terms maximum and minimum constraint bounds for the moment because they could then be set as 99%, 95%, or 90% confidence limits for example.

A number of approaches may be taken in determining soft bounds. One approach is to consider all possible sources of error in estimating the maximum date of origin of a clade of which there are 5 broad categories of error: 1) phylogenetic topology, 2) fossil record sampling, 3) identification, 4) correlation (relative dating), and 5) exact age–date assignment (absolute dating). These errors are nonadditive but some (e.g., phylogenetic topology) may be difficult to constrain. Another approach is to model diversification pattern and preservation probability (Foote et al. 1999; Tavaré et al. 2002). Phylogenetic bracketing has also been used to provide a maximum constraint on divergence events, by bracketing the next node below and above (Reisz and Muller 2004; Müller and Reisz 2005), and even conflated with estimates of errors on each of these dates (van Tuinen and Hedges 2001; van Tuinen and Hadly 2004). However, although this method may be beguiling, all nodes used to constrain the timing of divergence are subject to the usual uncertainties of dating fossil occurrences. There is no reason why the date of the node below should be related in any way to the date of origin of the next clade above.

In seeking to determine a maximum age constraint on the origin of a clade, there is merit in modeling diversification pattern and preservation probability and in phylogenetic bracketing, but neither can ever provide a definitive answer. In practice, the degree of precision provided by some of these approaches is false and is beyond that needed to attain computational feasibility in constraining molecular clock analyses. For the moment, we prefer to use a combined, but intuitive, approach.

Our method uses aspects of phylogenetic bracketing and stratigraphic bounding, namely a consideration of the absence of fossils from underlying deposits. The line of reasoning is broadly the following: 1) the maximum age constraint for the origin of a clade will be older than the oldest definitive fossil in the clade; 2) older fossils that might belong to the clade, or to its stem lineage, can hint at (but never prove) a downward time extension; 3) older fossils in clade C, the nearest outgroup (fig. 1) could also hint at (but never prove) a downward time extension; and 4) an older fossil deposit that ought to contain fossils of the clade in question, but does not, can mark an ultimate maximum bound. We do not, here, guarantee that

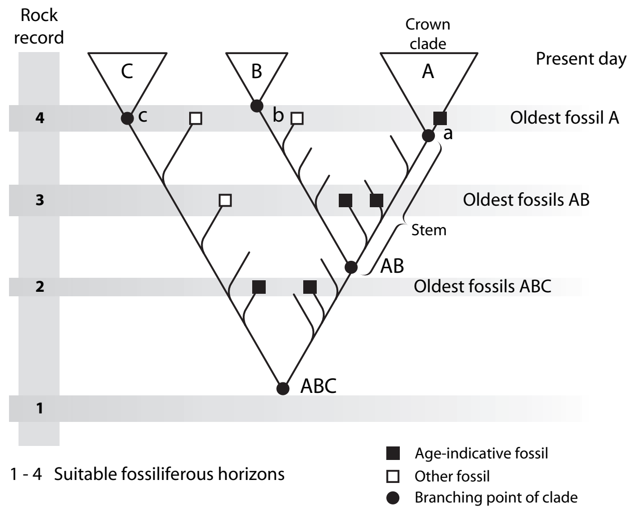

FIG. 1.—Definitions of terms in assigning fossils to clades. The crown clade consists of all living species and their most recent common ancestor, and this is preceded by a stem lineage of purely fossil forms that are closer to their crown clade than to another crown clade. The divergence or splitting point between a species in clade A and a species in clade B is the point AB. This is older than the points of origin of crown clades A and B (indicated as points a and b). Fossils may belong to a crown clade or to a stem lineage, and cladistic evidence should indicate which. Four fossiliferous horizons are indicated, the source of all relevant fossils. Fossiliferous horizon 1 that contains no fossils assignable to the clade ABC marks a maximum constraint (soft bound) on the age of the clade. Fossiliferous horizon 2 marks a maximum constraint on the age of clade AB. Minimum constraints are indicated by the 'oldest fossils' for ABC, AB, and A.

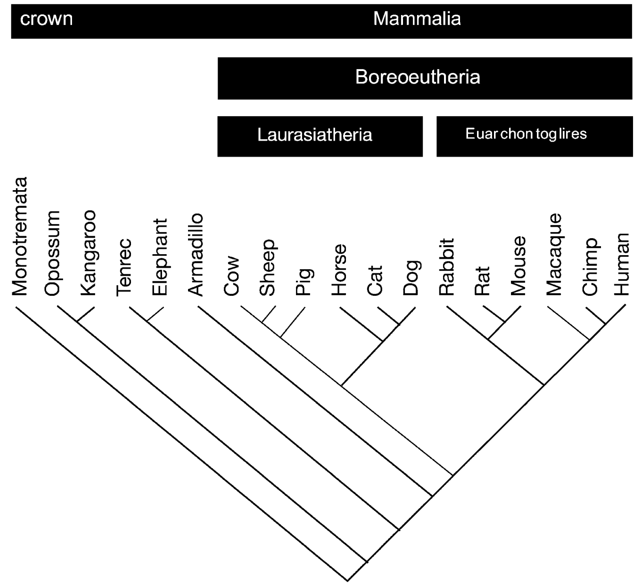

FIG. 2.—Outline relationships of the major clades of mammals, incorporating key genomic organisms. Major clades are named, and numbered nodes correspond to the text.

an older fossil will never be found, but the likelihood is low, and this will be reflected in the probability density (Yang and Rannala 2006). Probability densities have been used in deriving the confidence interval either with (Yang and Rannala 2006) or without (Kumar et al. 2005) the assumption of a molecular clock. The probability density can be modeled accurately on the basis of recovery potential functions that incorporate data on ecological distribution conflated with data on facies variation, outcrop exposure, and even taphonomic controls provided by anatomically similar organisms (Holland 1995; Marshall 1997). Alternatively, the probability density may be entirely arbitrary, for example, described by a lognormal distribution; even such simple models can be readily adapted to approximate reality by, for instance, using fossil and lithostratigraphic data to inform the position of the mean.

We emphasize finally that minimum and maximum constraints on calibration dates should be fully substantiated so that if any of the variables change, such as recently with the publication of the new geological timescale (Gradstein et al. 2004), with a shift in phylogenetic hypothesis, or the discovery of an older member of the clade, the impact of the change upon the calibration date is obvious and may be refined. Thus, minimum age constraints should be justified on the basis of a phylogenetic hypothesis, with reference to the oldest integral member of the clade—on which the date is ultimately based, the justification for its membership of the clade, the means by which the correlation is achieved to a section in which a chronostratigraphic date may be obtained, and the source of the chronostratigraphic date. Maximum age constraints should likewise be justified on the basis of a phylogenetic hypothesis, with reference to fossils belonging to outgroups and to putative stem groups, and to the next oldest fossil horizon that lacks relevant fossils.

Our proposed calibrations are justified below and summarized in table 1 and figure 8.

Dating Divergences among Mammals

Eighteen mammalian genomes have been sequenced, or are in progress (August 2006; http://www.ensembl.org/index.html), namely human (*Homo sapiens*), chimp (*Pan troglodytes*), macaque (*Macaca mulatta*), mouse (*Mus musculus*), rat (*Rattus norvegicus*), rabbit (*Oryctolagus cuniculus*), dog (*Canis familiaris*), cat (*Felis catus*), horse (*Equus caballus*), pig (*Sus scrofa*), sheep (*Ovis aries*), cow (*Bos taurus*), armadillo (*Dasypus novemcinctus*), tenrec (*Echinops telfairi*), African elephant (*Loxodonta africana*), kangaroo (*Macropus eugenii*), opossum (*Monodelphis domestica*), and platypus (*Ornithorhynchus anatinus*). These 18 consist of 1 monotreme (the platypus), 2 marsupials (the opossum and kangaroo) and 15 placental mammals, members of the clade Eutheria. According to current molecular and morphological phylogenies (Madsen et al. 2001; Murphy et al. 2001; Huchon et al. 2002; Springer et al. 2003; Benton 2005), the Eutheria fall into 3 main clades, Afrotheria, Xenarthra, and Boreoeutheria. The 12 placental mammals include 2 afrotherians (tenrec and elephant), 1 xenarthran (armadillo), and the remaining 9 belong to Boreoeutheria that fall into 2 clades, the Laurasiatheria, containing the orders Artiodactyla (pig, cow, and sheep), Perissodactyla (horse), and Carnivora (dog and cat), and the Euarchontoglires, containing the orders Primates (macaque, chimp, and human), Lagomorpha (rabbit), and Rodentia (mouse and rat).

The tree of 18 major mammalian groups (fig. 2) then contains 17 branching points: 7 within major clades (opossum–kangaroo, cow–sheep, cow–pig, cat–dog, human–chimp, human–macaque, mouse–rat) and the other 10 between orders or higher clades, namely human–mouse (i.e., Primates–Rodentia), rabbit–mouse (i.e., Glires), horse–dog (i.e., Perissodactyla–Carnivora), cow–dog (i.e., Ferungulata), human–cow (i.e., Euarchontoglires–Laurasiatheria), human–armadillo (i.e., Boreoeutheria–Xenarthra), tenrec–elephant (i.e., Afrotheria), human–tenrec (i.e., Boreoeutheria–Xenarthra–Afrotheria), human–opossum (i.e., Eutheria–Marsupialia), and human–platypus (i.e., Theria–Monotremata). Other pairings of taxa could be selected, but they are synonymous with 1 of these 10 (e.g., rat–cow is the same as human–cow; dog–opossum is the same as human–opossum).

These 17 branching points will be considered in order (see fig. 2).

Human–Chimp

The dating of the chimp–human split has been discussed for nearly a century. Early paleontological estimates, up to the 1970s, placed the branching point deep in the Miocene, at perhaps 20–15 MYA, but this was revised dramatically upward to about 5 MYA by early molecular studies (Sarich and Wilson 1967), and estimates as low as 2.7 MYA have been quoted (Hasegawa et al. 1985). Paleontological evidence for the branching point was distinctly one-sided until recently, since the only fossils fell on the human line, and so the question of the date of divergence of humans and chimps became synonymous, for paleontologists, with the date of the oldest certain hominin (species on the human, not chimp, line). The recent discovery of the first chimpanzee fossils (McBrearty and Jablonski 2005) does not change much, as they are dated as 545,000 years old at most.

The date of the oldest hominin has extended backward rapidly in the last 25 years. Until 1980, the oldest fossils were gracile and robust australopithecines from 3 MYA. The discovery of "Lucy", now termed *Praeanthropus afarensis* in Ethiopia (Johanson and Taieb 1976) extended the age back to 3.2 MYA at most. Then, 2 further hominin species pushed the age back to over 4 Myr: *Ardipithecus ramidus* from rocks dated as 4.4 MYA from Ethiopia (White et al. 1994) and *Praeanthropus anamensis* from rocks dated as 4.1–3.9 MYA from Kenya (Leakey et al. 1995). More recent finds, remarkably, have pushed the dates back to 6 Myr: *A. ramidus kadabba* from Ethiopia (5.8–5.2 MYA; Haile-Selassie 2001), *Ororrin tugenenis* from Kenya (c. 6 MYA; Senut et al. 2001), and *Sahelanthropus tchadensis* from Chad (6–7 MYA; Brunet et al. 2002). The last 2 taxa have proved highly controversial, with claims that one or other, or both, are not hominin, but ape like. However, the majority view is that *Sahelanthropus* at least is hominin (Wood 2002; Cela-Conde and Ayala 2003), and so its date becomes crucial.

Dating of the *Sahelanthropus* beds in Chad is not direct. Biostratigraphic evidence from mammals in particular, but with cross-checking from fish and reptile specimens, indicates that the unit is definitely late Miocene (i.e., older than 5.33 MYA), and it is older than the Lukeino Formation of Kenya, the source of *Orrorin* (dated at 6.56–5.73 MYA from Ar/Ar dates on volcanic layers; Deino et al. 2002), and may be equivalent to the lower fossiliferous units of the Nawata Formation at Lothagam (dated as 7.4–6.5 MYA; Vignaud et al. 2002). This might suggest a date for the sediments containing *Sahelanthropus* of 7.5–6.5 MYA, based on biostratigraphy and external dating. Thus, we determine a 6.5-MYA age for the minimum constraint on the human–chimp split. Kumar et al. (2005) have recently calculated a range of ages for the human–chimp divergence of 4.98–7.02 MYA; their minimum constraint (4.98 MYA) is younger than the oldest fossils (*Orrorin*, *Sahelanthropus*). However, paleoanthropogists generally accept that *Sahelanthropus* and *Orrorin* were both bipedal, upright forms, and until both are rejected by consensus view of their anatomy, we retain them as the oldest valid hominins.

A soft maximum constraint on the human–chimp divergence is hard to place because the immediate outgroups (gorilla, orang, and gibbons) lack convincing fossil records. Some late Miocene ape fossils, such as *Gigantopithecus* and *Sivapithecus* may be stem-orangs. Nonetheless, a range of such apes, *Ankarapithecus* from Turkey (10 MYA), *Gigantopithecus* from China (8–0.3 MYA), *Lufengopithecus* from China (10 MYA), *Ouranopithecus* from Greece (10–9 MYA), and *Sivapithecus* from Pakistan (10–7 MYA) give maximum ages of 10 MYA, early in late Miocene, and these deposits have yielded no fossils attributable to either chimps or humans. This is taken as the soft maximum constraint on the human–chimp divergence.

Human, Chimp–Macaque

The human–macaque split is equivalent to the branching of Old World monkeys (Cercopithecoidea) and apes (Hominoidea), which together form the clade Catarrhini.

The oldest cercopithecoids are *Victoriapithecus macinnesi* from Kenya, and 2 species of *Prohylobates* from Libya and Egypt. Miller (1999) surveyed all fossils of these 2 genera, and compared ages of their respective deposits. The oldest cercopithecoid fossil is a tooth identified as *Victoriapithecus* sp. from Napak V, Uganda (c. 19 MYA), followed by *Prohylobates tandyi* from Moghara, Egypt (18–17 MYA) and *Prohylobates* sp. from Buluk, Kenya (>17.2 MYA), *P. simonsi* from Gebel Zelten, Libya (c. 17–15 MYA), and *V. macinnesi* from Maboko, Kenya (ca. 16–14.7 MYA). MacLatchy et al. (2003) report an even older cercopithecoid, a fragment of a maxilla from the Moroto II locality in Uganda, that has been radiometrically dated to be older than 20.6 MYA ± 0.05 Myr (Gebo et al. 1997).

The oldest hominoids include *Morotopithecus*, also from the Moroto II locality in Uganda (Gebo et al. 1997). Young and MacLatchy (2004) determined that this taxon is a hominoid, located in the cladogram above the gibbons, and so not the most basal member of the group. Because of incompleteness of the material, Finarelli and Clyde (2004) are less certain of its phylogenetic position, but *Morotopithecus* is certainly a catarrhine. Even older is the first record of the long-ranging hominoid genus *Proconsul* from Meswa Bridge in Kenya, biostratigraphically constrained to c. 23.5 MYA (Pickford and Andrews 1981; Tassy and Pickford

1983). Even older is the purported hominoid *Kamoyapithecus* from the Eragaliet Beds of the Lothidok Formation of Kenya, dated at 24.3–27.5 MYA (Boschetto et al. 1992), but the material is insufficient to determine whether it is a hominoid or a catarrhine, possibly lying below the human–macaque split (Finarelli and Clyde 2004).

So, the minimum constraint on the human–macaque split is 23.5 MYA, based on the oldest record of *Proconsul*, or perhaps 23.5 MYA ± 0.5 Myr, based on biostratigraphy and external dating.

The soft maximum constraint is based on members of the stem of Catarrhini, namely the families Propliopithecidae (*Propliopithecus*, *Aegyptopithecus*) and Oligopithecidae (*Oligopithecus*, *Catopithecus*) that are basal to the cercopithecoid–-hominoid split (Rasmussen 2002). These are represented in particular from the rich Fayûm beds in Egypt, dated as early Oligocene (33.9–28.4 MYA ± 0.1 Myr), and so 28.3 MYA, deposits that have produced many primate, and other mammal, fossils, but no hint of a crown-group catarrhine.

Mouse–Rat

The mouse (*M. musculus*) and rat (*R. norvegicus*) are both the members of the subfamily Murinae within the family Muridae, members of the larger clade of muroid rodents. The Old World rats and mice are hugely diverse, with over 500 species, and they appear to have radiated relatively rapidly in Europe, Africa, Asia, and Australia.

The phylogeny of all genera within Murinae has not been determined, so the location of the split between *Mus* and *Rattus* is somewhat speculative at present. However, all current morphological and molecular phylogenies (Michaux et al. 2001; Jansa and Weksler 2004; Steppan et al. 2004; Chevret et al. 2005) indicate that *Mus* and *Rattus* diverged early in the evolution of Murinae, but not at the base of the divergence of that clade. A lower limit to the mouse–rat divergence is indicated by the oldest known murine fossil, *Antemus chinjiensis* from the middle Miocene Chinji Formation of Pakistan, dated at about 14.0–12.7 MYA on the basis of magnetostratigraphy and radiometric dating (Jacobs and Flynn 2005).

The oldest fossil example of *Mus* dates from 7.3 MYA, a specimen of *Mus* sp. from locality Y457 in the Siwaliks (Jacobs and Flynn 2005). Fossils of *Rattus* are not known until the latest Pliocene and the Pleistocene of Thailand (Chaimanee et al. 1996) and China (Zheng 1993), no more than 3 MYA.

The divergence of the 2 lineages leading to *Mus* and *Rattus* was stated to be 14–8 MYA by Jacobs and Pilbeam (1980), in a first review of the fossil evidence. This range was narrowed down at its older end to 12 MYA in subsequent studies (Jaeger et al. 1986; Jacobs and Downs 1994), based on the first appearance of the fossil genus *Progonomys*, early members of which were assumed to include the common ancestor of *Mus* and *Rattus*. The 12 MYA figure has most commonly been selected as the mouse–rat calibration point, but dates in the range from 16 to 8.8 MYA have been used in recent molecular studies.

In a thorough review of the fossil evidence, Jacobs and Flynn (2005) show that records of *Progonomys* in the Siwalik succession extend from 12.3 to 8.1 MYA, with the later forms (10.4–8.1 MYA) assumed to lie on the *Mus* lineage. The extinct genus *Karnimata* (11.1–6.4 MYA) is interpreted as a member of the lineage leading to *Rattus*. The oldest record (11.1 MYA) is uncertain, but the next (at 10.4 MYA) is unquestionable. The early species, *Progonomys hussaini* (11.5–11.1 MYA) is interpreted as an undifferentiated basal murine antedating the common ancestor of *Mus* and *Rattus* by Jacobs and Flynn (2005), and so they place the *Progonomys–Karnimata* split (equivalent to the *Mus–Rattus* split) at not much beyond 11 MYA, "although it may be younger." The dating is based on detailed field stratigraphic study of the long Siwaliks sedimentary sequence, with dating from magnestostratigraphy and radiometric dating (Johnson et al. 1985; Barry et al. 2002). The soft maximum constraint on this date is taken as the oldest record of *Progonomys* at 12.3 MYA.

Rabbit–Mouse, Rat

The rabbit–mouse basal node is synonymous with the clade Glires, comprising orders Rodentia plus Lagomorpha. The date would have been assumed traditionally to lie at 65 MYA, or younger, marking the time of purported placental mammal radiation after the extinction of the dinosaurs.

There have never been any records of Cretaceous rodent fossils, even though some molecular studies have placed the origin of the order deep within the Cretaceous. The oldest fossil rodents are known with confidence from the Thanetian (late Paleocene, 58.7–55.8 MYA), members of the family Ischyromidae from North America and Europe (Stucky and McKenna 1993), after which the clade expanded enormously to its present huge diversity. An older putative rodent might be *Heomys*, a eurymylid from the Danian (early Paleocene, 65.5–61.7 MYA) of China (McKenna and Bell 1997). The eurymylids may not be proper rodents, but members of a larger including clade Simplicidentata, or they may fall outside Simplicidentata, but within Glires, as outgroup to rodents and rabbits (Asher et al. 2005). Either way, the oldest members of Glires are post-Cretaceous in age ($<$65 MYA). Whether the Late Cretaceous zalambdalestids are related to Glires or not (see below) is irrelevant to this node.

The oldest lagomorphs are somewhat younger. Stucky and McKenna (1993) indicate several Eocene rabbits from the Lutetian: *Lushilagus* from China, *Procaprolagus* from Canada, and *Mytonolagus* from the United States. Meng and Wyss (2005) note an older possible lagomorph, *Mimotona* from the early to late Paleocene (Doumu Formation, Nonshangian, Qianshan Basin, China), the same unit that yielded the putative earliest rodent *Heomys*.

The minimum constraint on the age of clade Glires, and so for the rabbit–mouse split, is 61.7 MYA. The nearest outgroups of Glires (Meng and Wyss 2005) and forms such as *Pseudictops*, *Anagale*, and *Hyopsodus* are later Paleocene than *Heomys*, and so of little assistance in indicating a possible soft maximum constraint. The next outgroups, possibly the zalambdalestids, set a much older soft maximum constraint of 99.6 MYA ± 0.9 Myr to 96.2 MYA ± 0.9 Myr.

Human, Chimp, Macaque–Rabbit, Mouse, Rat

The human–mouse split is synonymous with the latest branching point between the mammalian orders Primates and Rodentia. Both orders are members of the clade Euarchontoglires. Euarchontoglires is composed of 2 clades, the Archonta and the Glires, and Primates belongs to the former, Rodentia to the latter. Thus, the human–mouse split becomes synonymous with the origin of Euarchontoglires.

Traditionally, this branching point would have been set at 65 MYA, the beginning of the Paleogene (base of Cenozoic, base of Tertiary), and corresponding to the extinction of the dinosaurs and the beginning of the radiation of placental mammal orders. This view has been challenged since 1995 as a result of 2 factors: 1) the discovery of major supraordinal clades within Eutheria, as noted earlier and 2) the repeated discovery from molecular analyses that the eutherian orders and the larger clades might have their origin at some point in the Cretaceous, whether rather early (Hedges et al. 1996; Janke et al. 1997) or rather later, and more in line with the fossils (Murphy et al. 2001; Arnason et al. 2002; Springer et al. 2003), evidence perhaps of a rapprochement between molecular and paleontological evidence (Archibald 2003; Benton and Ayala 2003).

There are no confirmed fossils of Primates or Rodentia in the Cretaceous (i.e., >65 MYA). An isolated tooth from the latest Cretaceous Hell Creek Formation (c. 67 MYA) of North America was assigned to the plesiadapiform taxon *Purgatorius*, and has been cited as the oldest primate (Van Valen and Sloan 1965). However, the phylogenetic position of the plesiadapiforms is debated—they were probably close relatives of primates, but not primates proper (Bloch and Boyer 2002). Further, the single tooth is arguably too little evidence for a firm record (Archibald 2003). The oldest confirmed primates are from the Paleocene–Eocene transition, some 55 MYA (Bloch and Boyer 2002), and the oldest plesiadapiform is *Subengius* from the late Paleocene of China (Smith et al. 2004). It comes from the Nomogen Formation, assigned to the Gashatan Land Mammal Age (latest Paleocene, 57–56 MYA).

As noted above, the oldest fossil rodents are known with confidence from the Thanetian (late Paleocene, 58.7–55.8 MYA), members of the family Ischyromidae from North America and Europe (Stucky and McKenna 1993), after which the clade expanded enormously to its present huge diversity.

Some Cretaceous fossils might be relevant to the node at the base of Euarchontoglires, however: the zalambdalestids, a group of small, long-legged jumping mammals known from excellent fossils from the Late Cretaceous of Mongolia and Central Asia (Kielan-Jaworowska et al. 2000; Archibald et al. 2001). They have been assigned numerous phylogenetic positions, but were found to be outgroup of rodents and rabbits, either members of the clade Glires or close to it (Archibald et al. 2001). Until recently, the zalambdalestids from the Bissekty Formation of Dzharakuduk, Kyzylkum Desert, Uzbekistan, were the oldest known of this clade, but they are now thought to come from the older Khodzhakul Formation at Sheikhdzheili, Kyzylkum Desert, Uzbekistan. There are 3 sets of localities in the Kyzylkum Desert that have yielded mammals. Based on biostratigraphic studies of intercalated marine units with invertebrate fossils (Averianov 2000; Archibald et al. 2001; Archibald 2003), these 3 local faunas are early Cenomanian (about 97 MYA), late Turonian (about 90 MYA), and possibly Coniacian (about 87 MYA). The age of the Khodzhakul Formation is particularly crucial: a reworked, early placenticeratid ammonite from the base of the formation suggests an early Cenomanian age, whereas an inoceramid bivalve from just above the Khodzhakul Formation suggests a late Cenomanian age (Averianov and Archibald 2005). So, the oldest zalambdalestids are from the early Cenomanian that corresponds to 99.6 MYA $\pm$ 0.9 Myr to 96.2 MYA $\pm$ 0.9 Myr.

This phylogenetic position has been challenged (Meng et al. 2003; Asher et al. 2005), and these authors place zalambdalestids outside the clade Placentalia, and certainly below Afrotheria in the cladogram of mammals. In this view, zalambdalestids would say nothing about the date of origin of either Glires or Euarchontoglires, both of which would revert to minimum origin dates of basal Paleocene (61.7 MYA). For the present, and until the contradictory views (Archibald et al. 2001; Meng et al. 2003; Asher et al. 2005) are resolved, we take a conservative view and place a minimum constraint on the human–mouse split in the early Paleocene, at 61.7 MYA. The soft maximum constraint is based on the assumption that zalambdalestids are close to Glires that corresponds to 99.6 MYA $\pm$ 0.9 Myr to 96.2 MYA $\pm$ 0.9 Myr. This soft maximum constraint is a long time before the minimum constraint.

Dog–Cat

The dog–cat split is equivalent to the branching point between the clades Caniformia (dogs, bears, raccoons, and seals) and Feliformia (cats, mongooses, and hyaenas), the major subdivisions of the Order Carnivora (Flynn and Wesley-Hunt 2005).

The oldest carnivores are members of the families "Miacidae" (paraphyletic) and Viverravidae, known from the early Paleocene onward (Stucky and McKenna 1993), but these lie outside the Caniformia–Feliformia clade (Flynn and Wesley-Hunt 2005), and so cannot provide a minimum date for the dog–cat split.

The oldest caniforms are amphicyonids such as *Daphoenus* and canids such as *Hesperocyon*, known first from the earliest Duchesnean North American Land Mammal Age (NALMA) that corresponds to magnetochron 18N, and is dated as 39.74 MYA $\pm$ 0.07 Myr, based on radiometric dating of the LaPoint Tuff (Robinson et al. 2004). *Tapocyon* may be an even older caniform; it comes from the Middle Eocene, Uintan, dated as 46–43 MYA (Wesley and Flynn 2003), although Flynn and Wesley-Hunt (2005) place this taxon outside the Carnivora.

The oldest feliforms may be the nimravids, also known first from the White River carnivore fauna of the Chadronian NALMA, with uncertain records extending to the base of that unit (Hunt 2004). The earliest Chadronian corresponds to the top of magnetochron 17N, and an age of 37.2–36.7 MYA (Hunt 2004; Prothero and Emry 2004).

Flynn et al. (2005) suggest a caniform–feliform split around 50 Myr, but the evidence at present suggests a minimum constraint of 43 MYA, based on magnetostratigraphy and radiometric dating of the Uintan NALMA. The soft maximum constraint is based on the occurrence of the oldest stem carnivores (miacids, viverravids) in the Torrejonian NALMA of the early Paleocene (see dog–horse below), so 63.8 MYA.

Dog, Cat–Horse

The dog–horse split is equivalent to the branching point between the orders Carnivora and Perissodactyla, that together form an unnamed clade. The minimum age will be determined from the oldest member of the carnivore and perissodactyl lineages.

Flynn et al. (2005) and others, have modified the meaning of Carnivora so that it is restricted by them to the crown clade consisting of Caniformia + Feliformia. They rename the more inclusive clade traditionally called Carnivora as Carnivoramorpha. They rename the more inclusive clade traditionally called Carnivora as Carnivoramorpha. The oldest carnivoramorphans are the viverravids. The oldest generally accepted viverravid is *Protictis* from the Fort Union/Polecat Bench Formation, assigned to the basal Torrejonian (To1) NALMA, and dated as 63.6–62.5 MYA (Lofgren et al. 2004). If *Ravenictis* from Canada is also a carnivoramorphan (Flynn 1998), and that is debated (Flynn and Wesley-Hunt 2005), it extends this date back to at least the Puercan (Pu2), 65.4–64.3 MYA ± 0.3 Myr. Most authors also agree that the extinct group Creodonta is sister group to Carnivoramorpha (Flynn and Wesley-Hunt 2005), and these date back to the Thanetian, 58.7–55.8 MYA ± 0.2 Myr, younger than the oldest carnivormorphans.

The oldest perissodactyl is represented by fragmentary teeth that resemble the brontotheriid *Lambdotherium* from the late Paleocene site of Bayan Ulan in China (Beard 1998), but the perissodacyl lineage may be extended further back in time. Among basal outgroups of Perissodactyla, Hooker (Hooker 2005) includes the phenacodont "condylarths" such as *Ectocion*, *Phenacodus*, and *Tetraclaenodon*. These all extend back into the Paleocene, and the oldest is *Tetraclaenodon*, known first from the basal Torrejonian (To1) of North America, the same age as the oldest creodont (above).

This places the dog–horse split minimally at the basal Torrejonian, and so 62.3 MYA. The soft maximum constraint is determined from the diverse fossiliferous units of similar facies in the North American Maastrichtian (70.6 MYA ± 0.6 Myr to 65.5 MYA ± 0.3 Myr) that have not produced remains identifiable to Carnivoramorpha or Perissodactyla, or to the stem lineages or either, providing a date of 71.2 MYA.

Cow–Sheep

The branching between the cow (*Bos*) and sheep (*Ovis*) is an intrafamilial split within the family Bovidae. *Bos* is a member of the Tribe Bovini and *Ovis* is a member of the Tribe Caprini that belong, respectively, to the subfamilies Bovinae and Antilopinae (Hassanin and Douzery 1999), although the monophyly of Antilopinae is questioned (Fernandez and Vrba 2005). These 2 subfamilies comprise the family Bovidae, so the cow–sheep split corresponds to the point of origin of the extant Bovidae.

Fernández and Vrba (2005) point to a major series of splits within Bovidae, that gave rise to the major subfamilies 25.4–22.3 MYA, and they link this to a major climatic change at the Oligocene/Miocene boundary. This date is, however, not based directly on fossil evidence, but upon a number of best-fitting dates from published morphological and molecular phylogenies.

A number of putative late Oligocene bovids (Stucky and McKenna 1993) have since been rejected. The oldest putative bovid was *Palaeohypsodontus zinensis* from the Oligocene of the Bugti Hills, Bolochistan, Pakistan, and the early Oligocene of Mongolia and China. This is identified as a ruminant, and was formerly at times assigned to Bovidae. However, it lacks unequivocal anatomical features of Bovidae, and is currently excluded from that family (Metais et al. 2003; Barry et al. 2005).

Fossil bovids may be identified in the fossil record by the presence of horn cores. The oldest such records, ascribed to *Eotragus*, come from the Early Miocene of Western Europe and Pakistan. For example, *Eotragus noyi* from the base of the terrestrial sequence on the Potwar Plateau is dated at approximately 18.3 MYA (Solounias et al. 1995).

Eotragus is attributed to Boselaphini, a tribe within the subfamily Bovinae consisting of the nilgai and other 4-horned antelopes. The oldest members of Antilopinae appear to come from the middle Miocene of 3 continents: *Caprotragoides* from Asia (India and Pakistan), *Tethytragus* from Europe (Spain and Turkey), and *Gentrytragus* from Africa (Kenya and Saudi Arabia), all dated at approximately 14 MYA (Vrba and Schaller 2000). The oldest firmly dated bovid then places the minimum constraint on the origin of the family at 18.3 MYA, and we set the soft maximum constraint as late Oligocene, the time of putative bovid fossils, so 28.5 MYA.

Cow, Sheep–Pig

The cow–pig split is equivalent to the major division in Artiodactyla between Ruminantia-Tylopoda and Suiformes. The oldest artiodactyls, such as *Diacodexis* from the Early Eocene of North America, fall outside this clade.

The oldest member of the Ruminantia-Tylopoda clade, the cows, deer, and camels, is the family Mixtotheriidae, represented by the single genus *Mixtotherium* (Theodor et al. 2005). The oldest records of *Mixtotherium* are from the Early Eocene (McKenna and Bell 1997), from the Cuisian mammalian fauna of France and Spain (Savage and Russell 1983). The Cuisian mammal age is the upper part of the Ypresian stage, equivalent to the Grauvian European Land Mammal Age (MP 10), dating from 51.0 to 48.5 MYA ± 0.2 Myr (Gradstein et al. 2004).

The Suiformes, or pig-like artiodactyls, include extant pigs, peccaries, and hippos, as well as the extinct raoellids and choeropotamids, of which the raoellids extend back to ca. 54 MYA (Theodor et al. 2005). The oldest raoellids include *Khirtharia* and *Indohyus* from the Early Eocene Kuldana Formation of Pakistan, dated to tethyan biozone P10, lower Lutetian, and dated as about 48 MYA (Gingerich 2003).

A confounding factor here is the suggestion that whales may be sister group to hippos (e.g., Ursing and Arnason

1998). So, if hippos are suiforms, are cetaceans also suiforms? In this case, the branching point in question would correspond to the split of whales and hippos. The alternative, and more likely, view (Theodor et al. 2005) is that whales and artiodactyls as a whole are sister groups, forming the larger clade Cetartiodactyla that split some 53.5 MYA (Gingerich 2005). This predates the cow–pig node, however.

So, based on *Mixtotherium* and the Indo-Pakistani raoellids, the cow–pig division is dated minimally at 48 MYA. The soft maximum constraint is selected as the putative date of splitting of Cetartiodactyla, so 53.5 MYA.

Cow, Sheep, Pig–Dog, Cat, Horse

The cow–dog split is equivalent to the branching point between the clades containing the orders Artiodactyla (even-toed ungulates) and Carnivora (flesh-eating placental mammals). This is synonymous with the point of origin of the clade Ferungulata, a clade within Laurasiatheria.

The oldest artiodactyl is *Diacodexis* from the Early Eocene of North America (c. 55 MYA). Artiodactyls are part of a larger clade Cetartiodactyla, with the Cetacea, whales and relatives, and these date back to the Early Eocene as well, at about 53.5 MYA (Theodor e al. 2005). The clade may also include the extinct mesonychids that are known first from the Danian/Thanetian, some 62 MYA (Stucky and McKenna 1993). The oldest carnivoramorphan is the miacoid *Ravenictis* from the Danian (Puercan, early Paleocene) of North America, and several carnivoran families radiated in the mid to late Paleocene of that continent (Meehan and Wilson 2002).

The clade Ferungulata includes also the orders Perissodactyla and Pholidota, but neither of these dates back before the early Eocene. The oldest fossil ferungulates by a long way may be the zhelestids from the Khodzhakul Formation of Dzharakuduk, Kyzylkum Desert, Uzbekistan. These were assigned to Laurasiatheria as basal "ungulatomorphs" (Archibald et al. 2001; Archibald 2003), that is, basal to the hoofed artiodactyls and perissodactyls. Averianov and Archibald (2005) reject Ungulatomorpha, as a polyphyletic group, and place Zhelestidae in Laurasiatheria; (J.D. Archibald, personal communication) further places Zhelestidae within Ferungulata. This then provides a minimum constraint on the human–cow split based on biostratigraphy and external dating evidence. As noted above, the Khodzhakul Formation is dated to the early Cenomanian (99.6 MYA ± 0.9 Myr to 96.2 MYA ± 0.9 Myr), hence 95.3 MYA.

The soft maximum constraint on this, and other basal dates among crown-group placentals, is the series of latest Early Cretaceous localities from North America and Mongolia, dated as Aptian and Albian. The Albian is dated as 112 MYA ± 1 Myr to 99.6 MYA ± 0.9 Myr, providing a date of 113 MYA.

Human, Chimp, Macaque, Rabbit, Mouse, Rat–Cow, Sheep, Pig, Rabbit, Dog, Cat

The human–cow divergence is synonymous with the origin of Boreoeutheria. This clade is composed of the clades Euarchontoglires (human) and Laurasiatheria (cow).

The oldest members of Euarchontoglires were noted above as the zalambdalestids from Uzbekistan, dated at 90–85 MYA (Archibald et al. 2001), although doubt has been expressed about their phylogenetic placement (Asher et al. 2005; Averianov and Archibald 2005).

A number of Late Cretaceous putative laurasiatherians have been cited. Although most orders within Laurasiatheria (Artiodactyla, Cetacea, Carnivora, Perissodactyla, Pholidota, Chiroptera) do not have fossil records older than Eocene or Paleocene, the Lipotyphla, the insectivores, may have Late Cretaceous representatives. McKenna and Bell (1997) reported the oldest lipotyphlan as *Otlestes* from the Cenomanian (99.6–93.5 MYA) of Uzbekistan, but Archibald (2003) regarded it as a basal eutherian, lacking apomorphies of Lipotyphla, or any other modern order. Most recently, Averianov and Archibald (2005) synonymized it with *Bobolestes* (from the same local fauna) and regarded it as a questionable zalambdalestoid. Next in time is *Paranyctoides* from the Turonian (93.4–89.3 MYA) of Asia and the Campanian (83.5–70.6 MYA) of North America, and *Batodon* from the Maastrichtian (70.6–65.5 MYA) of North America, both regarded as lipotyphlans by McKenna and Bell (1997). Archibald (2003) is uncertain, but retains these records pending discovery of further specimens.

More significant though are the zhelestids from the Bissekty Formation of Dzharakuduk, Kyzylkum Desert, Uzbekistan, and the even older Khodzhakul Formation at Sheikhdzhili. Zhelestids are assigned to Laurasiatheria (Archibald et al. 2001; Archibald 2003; Averianov and Archibald 2005; Wible et al. 2005), that is, basal to the hoofed artiodactyls and perissodactyls. Wherever Zhelestidae are assigned in the new conception of Laurasiatheria, they do apparently belong to that clade, and hence they provide a minimum age for the human–cow split based on biostratigraphy and external dating evidence. As noted above, the Khodzhakul Formation is dated to early Cenomanian; hence we propose a minimum constraint of 95.3.

The soft maximum constraint is, as for the cow–dog split above, 113 MYA.

Human, Chimp, Macaque, Mouse, Rat, Rabbit, Dog, Cat, Horse, Pig, Sheep, Cow–Armadillo

The human–armadillo split is equivalent to the origin of the clade comprising Boreoeutheria and Xenarthra. The oldest boreoeutherians are, as already noted, the zalambdalestids and zhelestids from the Khodzhakul Formation of Uzbekistan, dated to early Cenomanian, hence 99.6–96.2 MYA ± 0.9 Myr. The oldest reported xenarthrans are much younger, dating from the Paleocene. *Riostegotherium* is dated as Itaboraian (Rose et al. 2005), equivalent to the later Selandian (61.7–58.7 MYA ± 0.2 Myr).

The minimum constraint for the Boreoeutheria–Xenarthra split is then 95.3 MYA, and the soft maximum constraint is, as for the cow–dog split above, 113 MYA.

Tenrec–Elephant

The tenrec–elephant split represents a deep division within Afrotheria. According to current phylogenies, the tenrec, golden moles (Macroscelidea) and aardvark

(Tubulidentata) may form one clade within Afrotheria, and the elephants, hyraxes, and sirenians form the other, termed Paenungulata. Paenungulata is widely accepted as a valid clade, having been established on morphological characters, and now confirmed by molecular analyses. Many systematists accept a grouping of tenrecs and golden moles in the clade Afrosoricida, and aardvarks may be sister to these, but that is unclear. In any case, the last common ancestor of tenrec and elephant corresponds to the base of crown-clade Afrotheria.

The oldest fossil aardvarks, tenrecs, and golden moles are all Miocene (McKenna and Bell 1997), with a possible older golden mole, *Metoldobotes* from the Late Eocene Jebel Qatrani Formation of Egypt. These are equaled or predated by the oldest paenungulates. The oldest hyraxes are known from the Eocene of North Africa (Gheerbrandt et al. 2005). The oldest sirenians are *Prorastomus* and *Pezosiren* from early middle Eocene of Jamaica (Gheerbrandt et al. 2005). The oldest proboscidean fossils are *Phosphatherium* and *Daouitherium* from Ypresian (lower Eocene) phosphorites of the Ouled Abdoun Basin of Morocco (Gheerbrandt et al. 2005). Extinct putative outgroups of crown-group Paenungulata such as Desmostylia and Embrithopoda (*Arsinoitherium*) are younger, being Oligocene in age, whereas the Anthracobunidae date back to the early Eocene.

At present, no extant clade within Afrotheria or any confirmed extinct afrothere clade predates the Ypresian (early Eocene) dated as 55.8–48.6 MYA ± 0.2 Myr, and this must be used as the basis of a minimum age constraint for the tenrec–elephant split of 48.4 MYA. Further study might reveal that certain Paleocene groups belong within one or other afrothere branch, and that could increase the minimum age constraint.

The maximum constraint is determined as equivalent to the maximum constraint on the age of Boreoeutheria and Xenarthra, because Afrotheria must be at least as old as its sister clades, although the large age extension might in the end consist of stem-afrotherians that do not belong to either the Afrosoricida–Tubulidentata or the Paenungulata clades within Afrotheria, and hence would considerably overestimate the age of the tenrec–elephant split. The soft maximum constraint is then the soft maximum constraint on the age of Boreoeutheria, as noted above, namely 113 MYA.

Tenrec, Elephant–Human, Chimp, Macaque, Mouse, Rat, Rabbit, Dog, Cat, Horse, Pig, Sheep, Cow, Armadillo

The human–tenrec split is equivalent to the origin of the clade comprising Boreoeutheria, Xenarthra. and Afrotheria. The oldest boreoeutherians are, as already noted, the zalambdalestids and zhelestids from the Khodzhakul Formation of Uzbekistan, dated to early Cenomanian, hence 99.6–96.2 MYA ± 0.9 Myr. The oldest reported afrotherians are much younger, dating from the Eocene, as just noted. The oldest are *Phosphatherium* and *Daouitherium* from Ypresian (lower Eocene) phosphorites of the Ouled Abdoun Basin of Morocco (Gheerbrandt et al. 2005).

The minimum constraint for the Boreoeutheria/Xenarthra–Afrotheria split is then 95.3 MYA, and the maximum constraint is, as for the cow–dog split above, 113 MYA.

Opossum–Kangaroo

The opossum–kangaroo split is equivalent to the deep divergence among marsupial mammals between the clades Ameridelphia, the South American marsupials, and Australidelphia, the Australian marsupials (Amrine-Madsen et al. 2003; Nilsson et al. 2004). There are older marsupials from the Mid to Late Cretaceous, but these lie outside the split between the extant clades.

Until recently, the oldest ameridelphians came from the Tiupampa fauna from Bolivia (de Muizon and Cifelli 2000, 2001), type locality of the Tiupampan South American Land Mammal Age, and dated as 60.4–59.2 MYA ± 0.2 Myr (Gradstein et al. 2004), not 64.5–63 MYA, as is sometimes quoted (Nilsson et al. 2004). The fauna contains 11 ameridelphian marsupials, with representatives of several major lineages (didelphimorphs, sparassodonts), so the clade was already moderately diverse by this point. A new find of a possible polydolopimorphian, *Cocatherium*, extends the age back to Danian (Goin et al. 2006). *Cocatherium* is reported from the Lefipán Formation of Chubut, Argentina, a marine unit dated as basal Paleocene (basal Danian). The Late Cretaceous (possibly Campanian) La Colonia and Los Alamitos faunas do not contain marsupials, and the Laguna Umayo fauna (sometimes dated as latest Cretaceous) has been said to contain dental remains of the didelphid *Peradectes* in association with dinosaur eggs. However, the unit is now dated as late Paleocene to early Eocene, and it has not yielded dinosaurs. Various Cretaceous marsupials from North America have been included in Ameridelphia from time to time (Kielan-Jaworowska et al. 2005), but this is not supported by current cladistic analysis.

The oldest Australian marsupials are *Thylacotinga* and *Djarthia* from the Early Eocene Tingamarra local fauna from Murgon, Queensland, dated radiometrically at 54.6 MYA ± 0.5 Myr, indicating an Early Eocene age, and supported by biostratigraphy (Godthelp et al. 1999). The Australidephia date back further because, oddly, within this clade is the South American family Microbiotheriidae (and a putative microbiotheriid has been noted from the Murgon locality). The oldest microbiotheriid is *Khasia* from the Tiupampa fauna of Bolivia.

So, the oldest crown-group marsupial known to date is *Cocatherium*, an ameridelphian that is older than the oldest australidelphian, from the Danian (65.5 MYA ± 0.3 Myr to 61.7 MYA ± 0.2 Myr), providing the minimum constraint of 61.5 MYA on the opossum–kangaroo split.

The soft maximum constraint is determined as 71.2 MYA from the diverse fossiliferous units of similar facies in the North and South American Maastrichtian (70.6 ± 0.6 to 65.5 ± 0.3 MYA) that have not produced remains identifiable to either modern group of marsupials, or to the stem taxa, or either.

Opossum, Kangaroo–Human, Chimp, Macaque, Mouse, Rat, Rabbit, Dog, Cat, Horse, Pig, Sheep, Cow, Armadillo, Tenrec, Elephant

The human–opossum branching point is of course synonymous with the split of marsupials and placentals.

The earliest unequivocal marsupial dental fossils come from the mid Cretaceous of North America. The oldest of these is *Kokopellia juddi* reported (Cifelli 1993) from the Mussentuchit Member, in the upper part of the Cedar Mountain Formation, Utah, that is dated as middle to late Albian on the basis of bivalves and palynomorphs, and a radiometric date of 98.37 MYA ± 0.07 Myr was obtained from radiometric dating of zircons in a bentonitic clay layer. This suggests that the Mussentuchit Member extends to the Albian/Cenomanian boundary (99.6 MYA ± 0.06 Myr), but that the bulk of the unit is late Albian. Even older is the boreosphenidan *Sinodelphys szalayi* from the Yixian Formation, Liaoning Province, China, that is placed phylogenetically closer to marsupials than to placentals by Luo et al. (2003). This then has taken the root of the marsupial clade back to 125 Myr.

The oldest placentals were also, until recently, restricted to the mid and Late Cretaceous (Stucky and McKenna 1993), but subsequent finds have pushed the age back step-by-step deeper into the Early Cretaceous. First were *Prokennalestes trofimovi* and *P. minor*, reported from the Höövör beds of Mongolia (Kielan-Jaworowska and Dashzeveg 1989), and dated as either Aptian or Albian. Then came *Montanalestes keeblerorum* (Cifelli 1999) from the Cloverly Formation (late Aptian to early Albian, c. 100 MYA). Then, *Murtoilestes abramovi* was named (Averianov and Skutschas 2001) from the Murtoi Svita, Buryatia, Transbaikalia, Russia, being dated as late Barremian to middle Aptian (say, 128–120 MYA). These 3 taxa were based on isolated jaws and teeth. These were all topped by the spectacular find of *Eomaia scansoria* in the Yixian Formation of Liaoning Province, China (Ji et al. 2002), a complete skeleton with hair and soft parts preserved. Dating of the Jehol Group of China has been contentious, with early suggestiuons of a Late Jurassic age for some or all of the fossiliferous beds. Biostratigraphic evidence now confirms an Early Cretaceous (Barremian) age, with several radiometric dates, using different techniques, on 3 tuff layers that occur among the fossil beds of 124.6 MYA ± 0.1 Myr, 125.0 MYA ± 0.18 Myr, 125.2 MYA ± 0.9 Myr (Zhou et al. 2003). This gives an encompassing age designation of 125.0 MYA ± 0.7 Myr for the span of the 3 tuff layers, and for the fossiliferous beds of the Yixian Formation, based on direct dating. Thus, we conclude a minimum constraint of 124.3 MYA.

The soft maximum constraint is set by older fossiliferous beds with fossil mammals, but not placentals or marsupials, or members of the stem groups of either clade. For example, an older therian, neither marsupial nor placental, is *Vincelestes* from the La Amarga Formation of Argentina, dated as Hauterivian (136.4 MYA ± 2.0 Myr to 130.0 MYA ± 1.5 Myr. Thus, our soft maximum constraint is 138.4 MYA. Beds of similar age in North America and Europe have also produced such basal therians that are neither marsupials nor placentals according to present evidence.

Platypus–Opossum, Kangaroo, Human, Chimp, Macaque, Mouse, Rat, Rabbit, Dog, Cat, Horse, Pig, Sheep, Cow, Armadillo, Tenrec, Elephant

The base of the crown clade of modern mammals, marking the split between Monotremata, represented by the platypus, and Theria, represented by the human, might have a number of positions, depending on how many of the extinct Mesozoic mammal groups are included in the clade.

As noted above, the oldest marsupial, *Sinodelphys*, and the oldest placental, *Eomaia*, take the age of Theria back to about 125 MYA. *Vincelestes* from the La Amarga Formation of Argentina, as noted above, is dated as Hauterivian, and takes the age of Theria back to 136.4 MYA ± 2.0 Myr to 130.0 MYA ± 1.5 Myr.

According to a widely accepted cladogram of Mesozoic mammals (Luo et al. 2002, 2003; Kielan-Jaworowska et al. 2005), the Theria are part of a larger clade Theriimorpha that includes further extinct clades: Triconodonta, Multituberculata, Symmetrodonta, and Dryolestoidea. Most of these originated in the Late Jurassic, but triconodonts and dryolestoids began earlier, in the Middle Jurassic. Basal triconodonts include *Amphilestes* and *Phascolotherium* from the Stonesfield Slate, referred to the *Procerites progracilis* zone of the lower part of the middle Bathonian stage on the basis of ammonites (Boneham and Wyatt 1993), and so dated as 166.9 to 166.5 MYA ± 4.0 Myr (Gradstein et al. 2004). Tooth-based mammal taxa from the Early Jurassic of India (*Kotatherium*, *Nakundon*) and North America (*Amphidon*) that have been ascribed to Symmetrodonta (e.g., Asher et al. 2005) are not convincingly members of the clade (Averianov 2002), and so are ignored here. The oldest dryolestoid appears to be *Amphitherium*, also from the Stonesfield Slate.

The oldest monotremes are *Steropodon* and *Kollikodon* from the Griman Creek Formation, Lightning Ridge, South Australia, and dated as middle to late Albian, 109–100 MYA. *Teinolophos* is from the Wonthaggi Formation, Flat Rocks, Victoria, and is dated as early Aptian, 125–121 MYA.

In the new cladistic view (Luo et al. 2002, 2003; Kielan-Jaworowska et al. 2005), the Ausktribosphenida from Gondwana are immediate sister group of Monotremata, forming together the Australosphenida. Oldest are *Asfaltomylos* from the late Middle Jurassic (Callovian) Cañadon Asfalto Formation of Cerro Condor, Argentina (Rauhut et al. 2002), and *Ambondro* from the upper part of the Isalo "Group" (Middle Jurassic, Bathonian) of Madagascar (Flynn et al. 1999). The position of the Madagascar find in the Bathonian is uncertain, so the age range is 167.7 MYA ± 3.5 Myr to 164.6 MYA ± 4.0 Myr.

The human–platypus split is then dated on the oldest theriimorph from 166.9 to 166.5 MYA ± 4.0 Myr, similar in age to the less well-dated oldest australosphenidan. If the Theriimorpha–Australosphenida cladistic hypothesis of Luo et al. (Luo et al. 2002, 2003; Kielan-Jaworowska et al. 2005) is incorrect, and monotremes and therians form a clade exclusive of all extinct groups, the human–platypus split date could be as young as 130 MYA, the minimal age of the therian *Vincelestes*.

If this date is not too ancient, a soft maximum constraint can be considered. The sister group of Australosphenida + Theriimorpha is Docodonta, and the oldest docodonts are from the Bathonian of Europe, with a possible earlier form from the Kota Formation of India. Further outgroups, Morganucodontidae, *Sinoconodon*, and *Adelobasileus*,

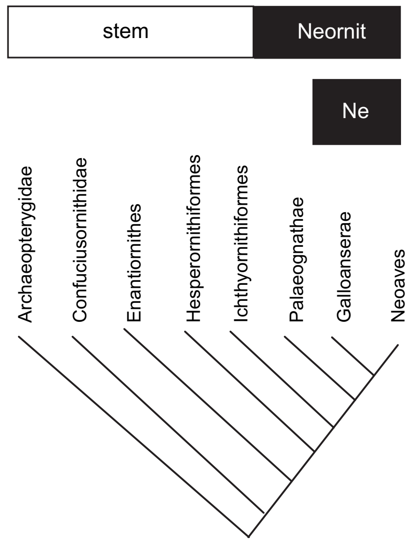

FIG. 3.—Outline relationships of the major clades of birds. Abbreviations: Ne, Neognathae; Neornith, Neornithes.

are known from the Late Triassic and Early Jurassic. The Kota Formation and several other units from other parts of the world that have yielded fossil mammals, but nothing assignable to the Australosphenida or Theriimorpha, date to the later half of the Early Jurassic, equivalent to the Pliensbachian and Toarcian stages (189.6 MYA ± 1.5 Myr to 175.6 MYA ± 2.0 Myr), and so 191.1 MYA should be used as a maximum constraint.

Birds and Reptiles

Only 2 divergence dates will be presented for birds, partly because there has been less gene sequencing than for mammals, but also because most details of the branching pattern of the tree of extant birds are still disputed (Cracraft et al. 2004; Dyke and Van Tuinen 2004). The selected divergence dates are between Galloanserae and Neoaves within Neognathae (the chicken–zebrafinch split) and between Palaeognathae and Neognathae within Neornithes (the emu–chicken split). The cladogram (fig. 3) is based on a consensus of recent work (Chiappe 2002; Cracraft et al. 2004).

Chicken–Zebrafinch

The phylogeny of major groups of modern flying birds (clade Neognathae) has been hard to resolve. Recent morphological and molecular analyses now agree on a deep divergence between the clade Galloanserae, comprising Galliformes (chickens and game birds) and Anseriformes (ducks) on the one hand, and Neoaves (all other flying birds) on the other (Cracraft et al. 2004; Dyke and Van Tuinen 2004).

The oldest purported galloanserine is *Teviornis gobiensis*, a presbyornithid anseriform from the Gurilyn Tsav locality of Mongolia (Kurochkin et al. 2002). Sediments here come from the lower portion of the Nemegt Horizon, at the base of the Nemegt Formation. The Nemegt Formation is assigned to the early Maastrichtian (Lillegraven and McKenna 1986), dated as 70.6 MYA ± 0.6 Myr to 69.6 MYA ± 0.6 Myr. Doubt has been cast, however (Clarke and Norell 2004), on whether *Teviornis* is a neognath, letalone a galloanserine, so the next youngest purported neognath should be selected until this issue is clarified. A further latest Cretaceous anseriform is *Vegavis iaai* from lithostratigraphic unit K3 of Vega Island, Antarctica, dated as mid to late Maastrichtian, c. 68–66 MYA (Clarke et al. 2005). The oldest galliform fossil that can be identified with confidence is much younger, Early Eocene (Dyke and Van Tuinen 2004).

The oldest neoavian is debated, with dozens of records of gaviiforms, pelecaniforms, charadriiforms, procellariiforms, and psittaciforms from the latest Cretaceous (most are close to the Cretaceous Tertiary boundary, 65.5 MYA; Dyke 2001; Hope 2002). The most complete fossil is *Polarornis gregorii*, described as a loon (gaviiform) from the Lopez de Bertodano Formation of Seymour Island, Antarctica (Chatterjee 2002). This stratigraphic unit is dated as mid to late Maastrichtian on the basis of microplankton (Pirrie et al. 1997), so 69.6–65.5 MYA ± 0.3 Myr. Dyke and Van Tuinen (2004) indicate some doubt about the taxonomic assignment of the specimen and about its geological provenance.

Even if the various neoavian specimens fall close to the Maastrichtian–Danian boundary, and if there is some doubt about *Polarornis* and *Teviornis*, the galloanserine record of *Vegavis* is older, and dates the minimum constraint on chicken–zebrafinch divergence at 66 MYA, on the basis of biostratigraphy and indirect dating.

The soft maximum constraint is based on older bird-bearing deposits that match some at least of the facies represented in the late Maastrichtian, that are broadly from the shallow marine to coastal belt. Fossil birds, most notably, hundreds of specimens of *Hesperornis*, *Baptornis*, and *Ichthyornis* (members of the clades Ichthyornithiformes and Hesperornithiformes, both outgroups to Neornithes) have been recovered in abundance from the Niobrara Chalk Formation of Kansas and neighboring states, dated as Santonian (85.8–83.5 MYA ± 0.7 Myr), and so 86.5 MYA.

Emu–Chicken, Zebrafinch

The divergence of emu and chicken is synonymous with the deep divergence between clades Palaeognathae (the ratites, or flightless birds) and the Neognathae (all other, flying, birds).

The oldest palaeognaths are the lithornithids, a family known from the Paleocene and Eocene of North America. A putative latest Cretaceous lithornithid was reported by Parris and Hope (2002) from the New Jersey greensands. The age of these deposits has been much debated (Dyke and Van Tuinen 2004), and they fall either below or above the KT boundary (65.5 MYA ± 0.3 Myr). An older specimen might be mistakenly assigned here: the pelvis of a large flightless bird, *Gargantuavis philoinos*, reported (Buffetaut and Le Loeuff 1998) from the base of the Marnes de la Maurines Formation, in association with dinosaurs of late Campanian to early Maastrichtian aspect. These authors were clear that *Gargantuavis* was not a palaeognath, and suggested that it might be related to the nonneornithine *Patagopteryx*.

As just noted, the oldest confirmed neognath fossil is the anserfirom *Vegavis* from 66 MYA, and this has to be the minimum constraint on the divergence date for palaeognaths and neognaths. The maximum constraint is currently the same as for the chicken–zebrafinch split above, namely the clades Ichthyornithiformes and Hesperornithiformes of the Niobrara Chalk Formation, dated as Santonian (85.8–83.5 MYA ± 0.7 Myr), and so 86.5 MYA.

Crocodile–Emu, Chicken, Zebrafinch

The most recent common ancestor of crocodiles and birds was an archosaur that lay at the deep junction of the 2 major clades within Archosauria: Avemetatarsalia/Ornithodira, the "bird" line and Crurotarsi, the "crocodile" line (Gauthier 1986; Sereno 1991; Benton 1999). These 2 clades together form the Avesuchia (="crown-group Archosauria").

The basal crurotarsans are the poposaurid *Bromsgroveia* from the Bromsgrove Sandstone Formation of England, and the "rauisuchians" *Wangisuchus* and *Fenhosuchus* from the Er-ma-Ying Series of China, *Vjushkovisaurus* from the Donguz Svita of Russia, and *Stagonosuchus* and "*Mandasuchus* from the Manda Formation of Tanzania (Benton 1993). All these records are dated as Anisian, but at present it is hard to be more precise. This gives an age range of 245 MYA ± 0.5 Myr to 237 MYA ± 2.0 Myr.

The basal avemetatarsalian is *Scleromochlus* from the Carnian of Scotland, but older relatives are *Marasuchus*, *Lagerpeton*, and *Pseudolagosuchus* from the Chañares Formation of Argentina, dated as Ladinian, so 237 MYA ± 2.0 Myr to 228.0 MYA ± 2.0 Myr.

The minimum constraint on the divergence date for birds and crocodiles then falls at the top of the Anisian (245 MYA ± 1.5 Myr to 237 MYA ± 2.0 Myr), and so 246.5 MYA.

The soft maximum constraint may be assessed from the age distribution of immediate outgroups to Avesuchia, the Proterochampsidae, Euparkeriidae, Erythrosuchidae, and Proterosuchidae (Gauthier 1986; Sereno 1991; Benton 1999). Numerous fossil sites from around the world in the Olenekian, the stage below the Anisian, have produced representatives of these outgroups, but not of avesuchians, and so the Olenekian (249.7 MYA ± 0.7 Myr to 245 MYA ± 1.5 Myr), and so 250.4 MYA.

Lizard–Crocodile, Emu, Chicken, Zebrafinch

The clades Crocodylia (modern crocodiles and extinct relatives) and Squamata (modern lizards and snakes and their extinct relatives) are members, respectively, of the larger clades Archosauromorpha and Lepidosauromorpha (fig. 4). The ultimate split between crocodilians and lizards then is marked by the split between those 2, and they, together with a number of basal outgroups, form the major clade Diapsida. Through a series of cladistic analyses (Benton 1985; Evans 1988; Gauthier et al. 1988; Laurin 1991; Laurin and Reisz 1995; deBraga and Rieppel 1997; Dilkes 1998), the topology of the basal region of the cladogram around the split of Archosauromorpha and Lepidosauromorpha has been agreed (although some higher parts of the cladogram are still much debated, especially the placement of Sauropterygia and Ichthyosauria).

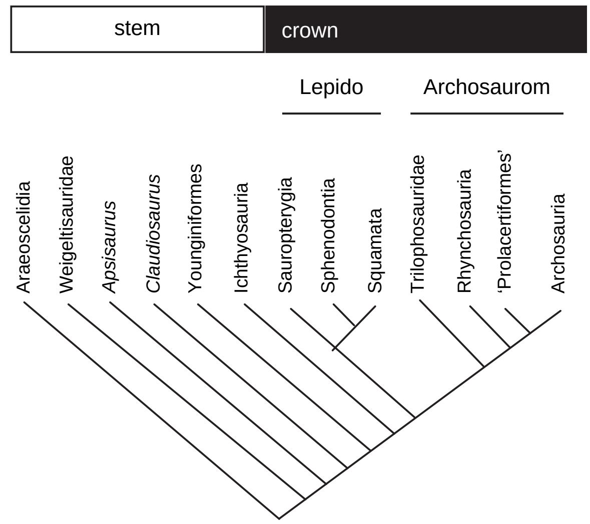

Fig. 4.—Outline relationships of the major clades of Diapsida. Abbreviations: Archosaurom, Archosaurmorpha; Lepido, Lepidosauromorpha.

The most ancient archosauromorph is the "prolacertiform" *Protorosaurus speneri* from the Kupferschiefer of Germany and the Marl Slate of NE England (Evans and King 1993). Both geological units are correlated with each other on independent geological evidence, and defined as the basal unit of the Zechstein 1 (EZ1; Werra Folge) depositional cycle. The 2 units were generally assigned to the Kazanian (e.g., Benton 1993, p. 695), but subsequent stratigraphic revisions have shown that the Zechstein falls above the Illawarra Reversal, which is at the Wordian–Capitanian boundary, and the Zechstein I contains fossils characteristic of the Capitanian (Gradstein et al. 2004). It is unclear how much of the Capitanian is represented by the Zechstein, but it probably represents the upper part, so 263.8–260.4 MYA ± 0.7 Myr.

The most ancient lepidosauromorph is debated–Benton (1993, p. 688) indicated that *Saurosternon bainii*, sole representative of the Saurosternidae, may be the oldest, but he was uncertain. Other authors (Gauthier et al. 1988; Clark and Hernandez 1994; Reynoso 1998) were more convinced that this is a true lepidosauromorph. The doubt arises because the taxon is based on a single partial skeleton lacking the skull. *Saurosternon* is from the *Cistecephalus* or *Dicynodon* Assemblage zone of South Africa (Hancox and Rubidge 1997) equivalent to the uppermost Wuchiapingian or Changhsingian, respectively, perhaps some 257–251 MYA. If *Saurosternon* is not a lepidosauromorph, the next possibility would be a sauropterygian. The uncertainty here is whether sauropterygians are lepidosauromorphs—the group was unplaced phylogenetically for some time, but deBraga and Rieppel (1997) and others have made a strong case that these marine reptiles are unequivocal lepidosauromorphs. Benton (1993, p. 70) listed 2 Lower Triassic (Scythian) sauropterygians, *Corosaurus* and *Placodus*, but the dating of both is uncertain. *Corosaurus* is from the Alcova Limestone Member of the Chugwater Formation in Wyoming, formerly assigned to the Middle or Upper Triassic, but noted as Lower Triassic by Storrs (1991). The precise age is hard to pin down. The Lower Triassic *Placodus* is from the Obere Buntsandstein of Pfalz, Germany, a unit dated as spanning the Olenekian–Anisian boundary, and ranging in age from 246 to 244 MYA ± 1.5 Myr.

Based on the oldest neodiapsid, *Protorosaurus*, the minimum constraint on the divergence of crocodilians and lizards is 259.7 MYA.

In order to establish the soft maximum constraint on this divergence, outgroups to Neodiapsida are considered. Ichthyosauria are known first in the Early Triassic, younger than the minimum age constraint. Younginiformes and *Claudiosaurus* are of similar age to *Protorosaurus*, or younger. Next oldest is *Apsisaurus* from the Archer City Formation of Texas, dated as Asselian (299–294.6 MYA ± 0.8 Myr) (Benton 1993), and so 299.8 MYA. This is a long way below the minimum age constraint, but there is a well-known "gap" in suitable fossiliferous formations through the Mid Permian.

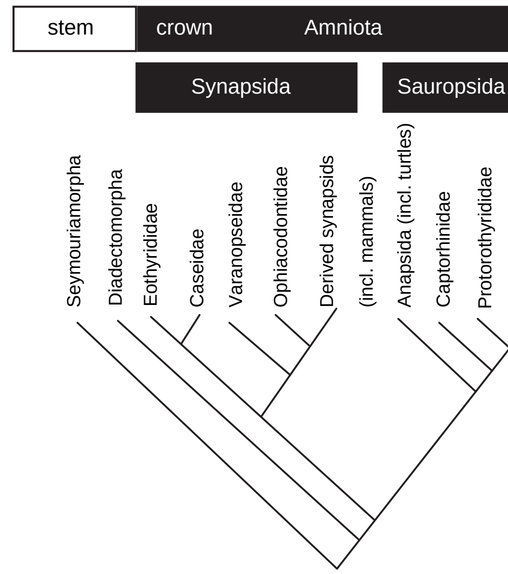

FIG. 5.—Outline relationships of the major clades of Amniota.

Basal amniotes and tetrapods

Bird–Mammal

The ultimate divergence date between birds and mammals has been quoted many times as 310 MYA, generally tracing back to Benton (1990), who in fact gave the age as 305 MYA. van Tuinen and Hadly (2004) trace the history of estimates of this date in molecular analyses, and they quote a range of estimates from 338 to 247 MYA, with a preference for the 310 MYA date on the basis of reassessment of the Late Carboniferous timescale.

This estimate has been criticized for being used without error bars (Graur and Martin 2004; van Tuinen and Hadly 2004), for being based on uncertain fossils and hence too old (Lee 1999), for being misdated (Reisz and Muller 2004; van Tuinen and Hadly 2004), and for being poorly bracketed by outgroups above and below (Reisz and Muller 2004) and Müller and Reisz (2005) indeed argue that this calibration point should no longer be used because it is so problematic, but others (Hedges and Kumar 2004; van Tuinen and Hadly 2004) reasonably point out that there is a demand to use this date because of the volume of sequence data for mammals and birds, and the need to use a member of one or other clade as an outgroup in many studies.

The ultimate ancestor of birds and mammals has to be tracked back to the base of the Synapsida and Sauropsida, the larger clades that include mammals and birds, respectively (fig. 5). These 2 clades together make up Amniota, the clade containing all tetrapods other than amphibians, and the relationship of major groups is agreed by most (e.g., deBraga and Rieppel 1997; Reynoso 1998; van Tuinen and Hadly 2004; Benton 2005). The question of the ultimate bird–mammal split becomes synonymous then with dating the origin of the clade Amniota.

The oldest identified synapsid is *Protoclepsydrops* from the Joggins Formation of Joggins, Nova Scotia. The age of the Joggins Formation has been much debated, and figures in the range from 320 to 305 MYA have been cited recently. Reisz and Müller (2004) indicate an age of 316–313 MYA, whereas van Tuinen and Hadly (2004) settle for 310.7 MYA ± 8.5 Myr. Detailed field logging and biostratigraphy (Dolby 1991; Calder 1994; Falcon-Lang et al. 2006) confirm that the Joggins Formation falls entirely within the Langsettian European time unit, equivalent to the Westphalian A, and roughly matching the Russian Cheremshanian, in the later part of the Bashkirian stage. Earlier dates for these units were equivocal (Menning et al. 2000), but Gradstein et al. (2004) date the Langsettian as 314.5–313.4 MYA ± 1.1 Myr.

Protoclepsydrops has been classed as an ophiacodontid, not a member of the basalmost synapsid families—Eothyrididae, Caseidae, or Varanopseidae—whose basal members, if ever found, might be of the same age or older. *Protoclepsydrops haplous* is known from one incomplete partial skeleton and skull (Reisz 1972), but the remains are fragmentary; even the identification of these remains as a synapsid has been questioned (Reisz 1986; Reisz and Modesto 1996). Lee (1999) used this uncertainty to reject *Protoclepsydrops* as informative in this discussion, and to look at the next oldest synapsids, such as *Echinerpeton* and *Archaeothyris* from the Morien Group of Florence, Nova Scotia (Myachkovian, upper Moscovian, 307.2–306.5 MYA). Because each retained only one synapomorphy of Synapsida, Lee (1999) rejected them, and moved up to more complete material of basal synapsids from some 288 MYA. van Tuinen and Hadly (2004) rejected *Protoclepsydrops* as a useful marker of the bird–mammal split, but accepted *Archeothyris* as reasonable, with a date of 306.1 MYA ± 8.5 Myr.

The earliest member of the other branch, the Sauropsida (sometimes called Eureptilia, or Reptilia) is less contentious. *Hylonomus*, also from the Joggins Formation at Joggins, Nova Scotia, is a member of Protorothyrididae (Carroll 1964; Gauthier et al. 1988; Laurin and Reisz 1995), part of the stem to Diapsida, and the oldest known member of the clade. The clade Captorhinidae is more basal than Protorothyrididae, but the oldest captorhinid is younger—*Romeria primus* from the Moran Formation of Texas (Early Permian, Sakmarian, c. 294–284 MYA; Benton 1993). Lee (1999) cast doubt on the assignment on *Hylonomus* to the sauropsid clade, and preferred to redate that branch also to some 288 MYA.

Lee's (1999) proposal would move the mammal–bird split date from somewhere around 310 MYA to 290 MYA, whereas van Tuinen and Hadly (2004) settled for 305 MYA as a minimal date. However, Reisz and Müller (2004) and van Tuinen and Hadly (2004) suggested that Lee was wrong to cast doubt on nearly all the Carboniferous synapsids and sauropsids—many are diagnostic of one or other group. More importantly though, Reisz and Müller (2004) pointed out that the question of dating the ultimate bird–mammal split is synonymous with dating the origin of Amniota. So, it may be uncertain whether *Protoclepsydrops* is a synapsid, and *Hylonomus* is not a diapsid, and one could debate the phylogenetic position of Protorothyrididae, but all these taxa are diagnostically members of Amniota, so the origin of Amniota happened before the age of the Joggins Formation of Nova Scotia.

The minimum constraint on the mammal–bird split, equivalent to the minimum age of the origin of clade Amniota corresponds to the age of the Joggins Formation. This is 314.5–313.4 MYA ± 1.1 Myr, a date based on biostratigraphy (palynology) and exact dating from elsewhere, conferring a minimum constraint of 312.3 MYA.

The soft maximum constraint on the bird–mammal split is based on the next richly fossiliferous units lying below these horizons. The first is the East Kirkton locality, source of a diverse fauna of batrachomorphs and reptiliomorphs (see human–toad split below), but that has hitherto not yielded anything that could be called either a diapsid or a synapsid. Further, fossiliferous sites of similar facies lie below the East Kirkton level, and they have not yielded reptile remains. We take the age of the fossiliferous Little Cliff Shale of the East Kirkton locality (Brigantian; 328.8–326.4 MYA ± 1.6 Myr) as the basis for the soft maximum age constraint of 330.4 MYA.

Toad–Bird, Mammal

The African clawed toad (*Xenopus laevis*) is a representative of modern Amphibia (the clade Lissamphibia, including frogs and toads, salamanders, and caecilians), and the human–toad split is equivalent to the deep branching point between Amphibia and Amniota. Within crown Tetrapoda, this is the split of Batrachomorpha (extant lissamphibians and extinct relatives) and Reptiliomorpha (extant amniotes and their extinct relatives) (fig. 6).

The oldest batrachomorph is *Balanerpeton woodi*, a basal temnospondyl from the East Kirkton locality in Scotland. Another putative basal batrachomorph is *Eucritta melanolimnetes*, from the same location, described as a possible baphetid (Clack 1998), but possibly a batrachomorph (Ruta et al. 2003). The fossils come from the Little Cliff Shale, a unit within the East Kirkton Limestone, a subdivision of the Upper Oilshale Group of the Midland Valley of Scotland. The fossil beds are ascribed to the Brigantian (D2; lower portion) of the Viséan stage, based on biostratigraphic comparisons of the fossil plants, pollen, and bivalves with the rich records of Lower Carboniferous sites throughout Europe (Rolfe et al. 1993). The Brigantian regional stage is dated from 328.8 to 326.4 MYA ± 1.6 Myr.

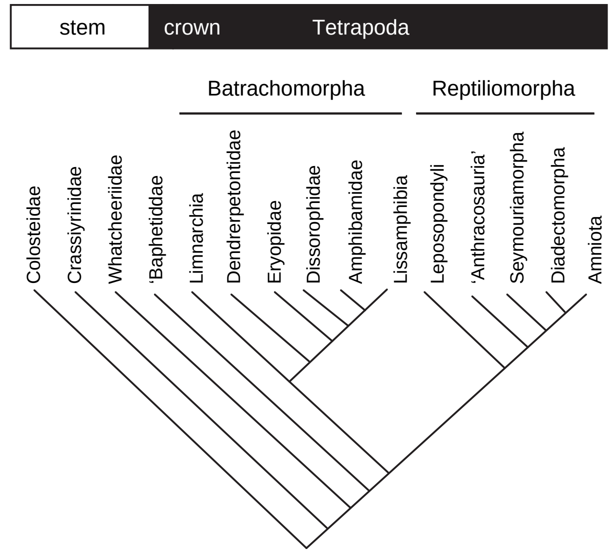

FIG. 6.—Outline relationships of the major clades of Tetrapoda.

The oldest reptiliomorphs are the basal lepospondyl *Westlothiana lizziae*, and the aïstopod *Lethiscus stocki* (Ruta et al. 2003). *Westlothiana* and *Lethiscus* are both from the Viséan. *Westlothiana* comes from the East Kirkton locality, and is dated at 327.6 MYA ± 2.8 Myr (see above). *L. stocki* is from the Wardie Shales, part of the lower Oil Shale Group, near Edinburgh, and dated as older than the East Kirkton locality (Rolfe et al. 1993). The Wardie Shales are assigned to the Holkerian regional stage on the basis of fossil fishes and palynomorphs (Paton et al. 1999), dated as 339.2–332.4 MYA ± 2.0 Myr.

van Tuinen and Hadly (2004) reviewed the amphibian–amniote divergence date in detail, but assigned the Wardie Shales to the Asbian, the stage above the Holkerian, and so came to an age of 332.3 MYA. Further, they used radiometric dates from Menning et al. (2000) that have been revised in Gradstein et al. (2004). Our minimum constraint on the human–toad divergence is 330.4 MYA, based on *Lethiscus*, and biostratigraphic placement of the Wardie Shales Formation, with radiometric dating of the Holkerian from elsewhere.

The soft maximum constraint is harder to determine because most of the close outgroups to the batrachomorph–reptiliomorph clade are known only from younger deposits: the oldest baphetids and crassigyrinids are from the Brigantian (Benton 1993), the oldest colosteids from the Asbian (Benton 1993). The whatcheeriids *Whatcheeria* and *Pederpes*, from North America and Europe, respectively, are older, however, and dated to the Ivorean regional North American stage, and so 348–345.3 MYA ± 2.1 Myr. These horizons are underlain by further units of Famennian age, dated as 374.5 MYA ± 2.6 Myr to 359.2 MYA ± 2.5 Myr, with basal tetrapods known from several continents, but no batrachomorphs or reptiliomorphs. We choose the whatcheeriids as marking the soft maximum constraint, even though they are phylogenetically more distant from crown Tetrapoda than baphetids and colosteids—but the latter 2 are younger than *Lethiscus*. Thus, we propose a date of 350.1 MYA as a soft maximum constraint.

Dating Divergences among Basal Vertebrates and Other Metazoans

Takifugu–Tetraodon

Following the phylogenetic scheme of Holcroft (2005), this divergence event represents the origin of crown-group Tetraodontidae. *Archaeotetraodon winterbottomi* has been identified as a member of this clade on the presence of numerous tetraodontid synapomorphies, including the presence of 11 caudal fin rays, 18 vertebrae, broadened neural and haemal spines and an absence of ribs (Santini and Tyler 2003). It has been recorded from the Pshekhsky Horizon, in the lower part of the Maikop Formation of the north Caucasus, Russia (Tyler and Bannikov 1994), making it the earliest known member of Tetraodontidae (Santini and Tyler 2003). The lower part of the Maikop Formation has been widely quoted as Lower Oligocene (Tyler and Bannikov 1994; Gürgey 2003), although evidence is rarely presented in support of this.

Leonov et al. (1998) provide evidence on the age of the Pshekhsky Horizon on the basis of planktic and benthic foram, nannoplankton and dinocyst biostratigraphy. The base of the Pshekhsky Horizon coincides with the base of range of the *Globigerina tapuriensis* that belongs to the Zone P18 of the Paleogene planktic foram zonation scheme (Spezzaferri and Silva 1991). The base of P18 equates to the base of the Oligocene that has been dated at 33.90 MYA ± 0.1 Myr (Luterbacher et al. 2004). The top of the Pshekhsky Horizon coincides approximately with the first appearance of the nannoplanton species *Sphenolithus predistentus*, and the base of NP23, a Paleogene Nannoplankton zone (Leonov et al. 1998). The latter has been dated at 32.25 MYA (Luterbacher et al. 2004), the errors on which are negligible, though there will be an inherent uncalculated error on the biostratigraphic correlation to the Caucasus.

Thus, paleontological evidence on the divergence of the lineages leading to *Takifugu rubripes* and *Tetraodon nigroviridis* provides a minimum constraint of 32.25 MYA. Relationships within Tetraodontiformes have been approached from anatomy and molecular phylogenetics, but remain poorly constrained. Nonetheless, the oldest records for the potential sister clades are all of Eocene age and among them, the oldest record is provided by the balistid *Moclaybalistes danekrus*, known from the Lower Eocene Mo-Clay (Fur/Ølst) Formation, that has been dated using magnetostratigraphy and biostratigraphy using nannoplankton, dinoflagellate, and pollen zones (Willumsen 2004). The base of the Ølst Formation coincides with the base of dinoflagellate Zone 6 and the base of the *Apectodinium augustum* zone that coincides with the base of the Eocene. A soft maximum constraint on the split of *T. rubripes* and *T. nigroviridus* can thus be obtained from the age of the base of the Eocene that has been dated at 55.8 MYA ± 0.2 Myr (Luterbacher et al. 2004), thus 56.0 MYA.

Stickleback–Takifugu, Tetraoodon

This divergence event represents the split between Gasterosteiformes and Tetraodontiformes within Percomorpha. The oldest member of Gasterosteiformes is *Gasterorhamphosus zuppichinii* from Calcare di Mellissano, near Nardò, Lecce, Apulia southeastern Italy (Sorbini 1981), that is believed to be Campanian (Late Cretaceous) in age (Patterson 1993). This is younger than the oldest known member of the tetraodontiform lineage, *Plectocretacicus clarae*, the earliest stem-tetraodontiform, from the Cenomanian (Upper Cretaceous) of Hakel, Lebanon (Sorbini 1979; Tyler and Sorbini 1996). The age of the lithographic limestones at Hakel is derived from the occurrence of *Mantelliceras mantelli* and the benthic foraminifer *Orbitulina concava* (Hückel 1970). The stratigraphic range of *O. concava* ranges from Late Albian to Early Cenomanian (Cherchi and Schroeder 2004), whereas *M. mantelli* is more restricted temporally, and falls fully within the range of *M. mantelli*, defining the basal ammonite zone of the Cenomanian. The base of the *M. mantelli* zone is well dated on the basis of Ar–Ar and cycle stratigraphy at 99.1 ± 0.4 MYA (Obradovich et al. 2002). Ogg et al. (2004) provide a date of 97.8 MYA for the top of the *M. mantelli* zone; errors on the timescale on surrounding zonal boundaries are 0.9 Myr. Thus, the minimum age of the divergence of Atherinomorpha and Percomorpha can be based on the age on the minimum age of the Lithographic Limestones of Hakel that would be 96.9 MYA.

Given that *P. clarae* is also the oldest known percomorph (Patterson 1993), the most appropriate soft maximum bound on the divergence of Gasterosteiformes and Tetraodontiformes would be the earliest euteleost record, provided by taxa such as *Tischlingerichthys viohli* and associated crown-euteleosts from the Tithonian of Solnholfen (Arratia 1997). Acanthopterygians (as are convincing members of any elopocephalan superorders or orders) are entirely absent. The maximum age of the Solnholfen Lithographic limestones (justified below in connection with the Ostariophysean–Euteleost split) is 150.8 MYA ± 0.1 Myr. Thus, a soft maximum constraint for divergence of the gasterosteiform and tetraodontiform lineages is 150.9 MYA.

Medaka–stickleback, Takifugu, Tetraodon

This divergence event represents the split between Atherinomorpha and Percomorpha within Acanthopterygii. The oldest member of Atherinomorpha, based on otoliths of "*Atherinidarum*", from Argile de Gan, Gan, Pyrénées-Atlantiques, France, and has been assigned a Lower Eocene (Ypresian) age (Nolf 1988). The earliest skeletal records are Upper Eocene (Priabonian) (Patterson 1993). The oldest percomorph is the stem-Tetraodontoform *P. clarae* (see above). Thus, the minimum constraint on the divergence of Atheriniomorpha and Percomorpha is the same as for Gasterosteiformes and Tetraodontiformes, 96.9 MYA. Similarly, the soft maximum constraint is 150.9 MYA.

Zebrafish–Medaka, stickleback, Takifugu, Tetraodon

This divergence event represents the splitting of the Ostariophysean and Euteleost lineages.

The earliest ostariophysean is *T. viohli* from the Tithonian of Solnholfen (Arratia 1997). It is recognized on the basis of synapomorphies including the absence of a basisphenoid, and dorsomedial portions of the anterior neural arches expanding and abutting against each other and the posterior margin of the exoccipital.

From the same deposit, Arratia (1997) also described a number of additional taxa (*Leptolepides, Orthogonikleithrus*) that qualify as the earliest record of the euteleost lineage. These were assigned to Salmoniformes. The security of their assignments to these higher level clades within Euteleostei is questionable, although their assignment to the euteleost total group is not, based not least on the presence of enlarged neural arches/spines.

Thus, earliest representatives of both lineages are in precise agreement. However, this should come as no surprise given that they were recovered from the same deposit. Therefore, the fossil date is likely to be a considerable underestimate, subject to lagerstätten effect. There are no earlier records.

The dating of the Solnhofen has been based on ammonite zonation and the Formation is assigned to the ti_2 division of the Middle Tithonian, Late Jurassic. The Tithonian is dated as 150.8 MYA $\pm$ 4.0 Myr to 145.5 MYA $\pm$4.0 Myr (Gradstein et al. 2004), but the Solnhofen Formation represents just the middle biohorizon of the lowest ammonite zone of the Tithonian (Zeiss 1977), its base intercalated by the first (local) appearances of the ammonites *H. hybonotum* (and *Gravesia*) and *Glochiceras lithographicum* (Barthels et al. 1990). In proposed stratotype sections, the base of the Tithonian is represented by the marked by the simultaneous first appearance of these 2 taxa plus the immediately subsequent appearance of *Gravesia* sp. (Ogg 2005). The base of *H. hybonotum* zone coincides with the base of the normal-polarity Chron M22An that is dated at 150.8 MYA $\pm$ 0.1 Myr (Ogg 2005). Given that the Solnhofen Formation falls fully within the *H. hybonotum* zone, it is possible to derive a lower bound on its age from the base of the succeeding, *S. darwini* ammonite zone that coincides approximately with the M22n Chronozone, dated at 149.9 MYA $\pm$ 0.05 Myr (Ogg 2005).

Thus, the earliest paleontological evidence and, therefore, a lower bound on the split of *Danio rerio*–*T. rubripes*, *Tetraodon nigris* can be considered to be 150.8 MYA $\pm$0.1 Myr to 149.9 MYA $\pm$0.05 Myr, giving a minimum date of 149.85 MYA. However, note should be taken of the fact that the co-occurrence of the earliest records of these 2 lineages is an artefact of their presence in a Konservat-lagerstätte. A soft maximum constraint on the divergence of the Ostariophysean and Euteleost lineages is provided by the census of Teleost–total group diversity provided by the assemblages recovered from the many Oxfordian localities in the Cordillera de Domeyko (Arratia and Schultze 1999). Many species are known in conditions of exceptional preservation and these are stem-teleosts; no otophysans or euteleosts are known from here or from older deposits. The base of the Oxfordian (161.2 MYA $\pm$ 4.0 Myr; Ogg 2005) can be taken as the soft maximum constraint: 165.2 MYA.

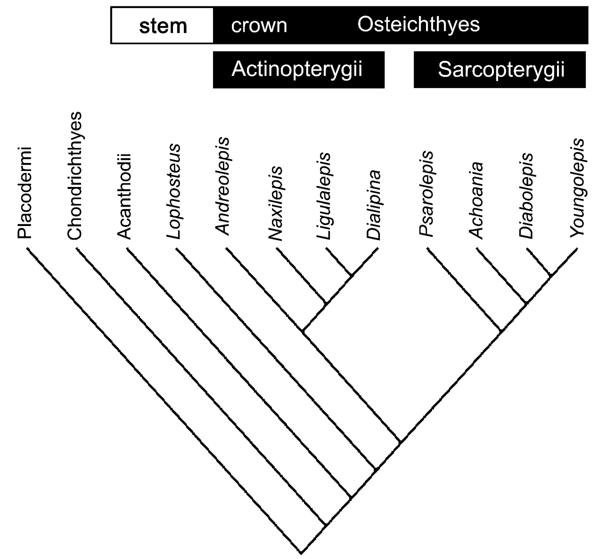

FIG. 7.—Outline relationships of basal members of Osteichthyes.

Zebrafish, Medaka, stickleback, Takifugu, Tetraodon–toad, bird, mammal

This divergence event represents the splitting of Actinopterygii and Sarcopterygii (fig. 7), and so the minimum constraint depends on determining the oldest member of either clade.

The earliest representative of total-group Actinopterygii may be *Andreolepis hedei*, known from microfragments from Gotland, Sweden (Gross 1968; Märss 1986; Fredholm 1988a, 1988b) and elsewhere (Märss 2001). It can be assigned to total-group Actinopterygii on the following synapomorphies: rhomboid scale shape, ganoine-covered scales. The oldest occurrence that is readily constrained is from the lower part of division C of the Hemse Marl at Västlaus, Gotland, Sweden (Fredholm 1988a). Although there are no direct radiometric dates from the Ludlow of Gotland, these sections have been incorporated into a graphic correlation composite standard that incorporates radiometric dates (Kleffner 1995; Fordham 1998). Thus, a date for this occurrence can be established from the composite standard through the line of correlation that equates to 421.75 MYA.

The certainty with which *A. hedei* is assigned to Actinopterygii is obviously less than it might be were it known from articulated remains. However, it is known from a number of skeletal elements (Gross 1968; Janvier 1971, 1978), rather than mere scales, as are the other, slightly younger, early records of Actinopterygii (Schultze 1968; (Wang and Dong 1989).

Naxilepis, although known only from scales (Wang and Dong 1989), possesses a further synapomorphy of total-group Actinopterygii, in addition to those exhibited by *A. hedei*, in the form of a narrow-based dorsal peg and discrete rows of ganoine. The earliest occurrence is from the Miaogao Formation of the Cuifengshan Formation of Quijing District, Yunnan, China, and has been reported to co-occur with the conodont *Ozarkodina crispa* (Wang and Dong 1989; Zhu and Wang 2000) although this has not

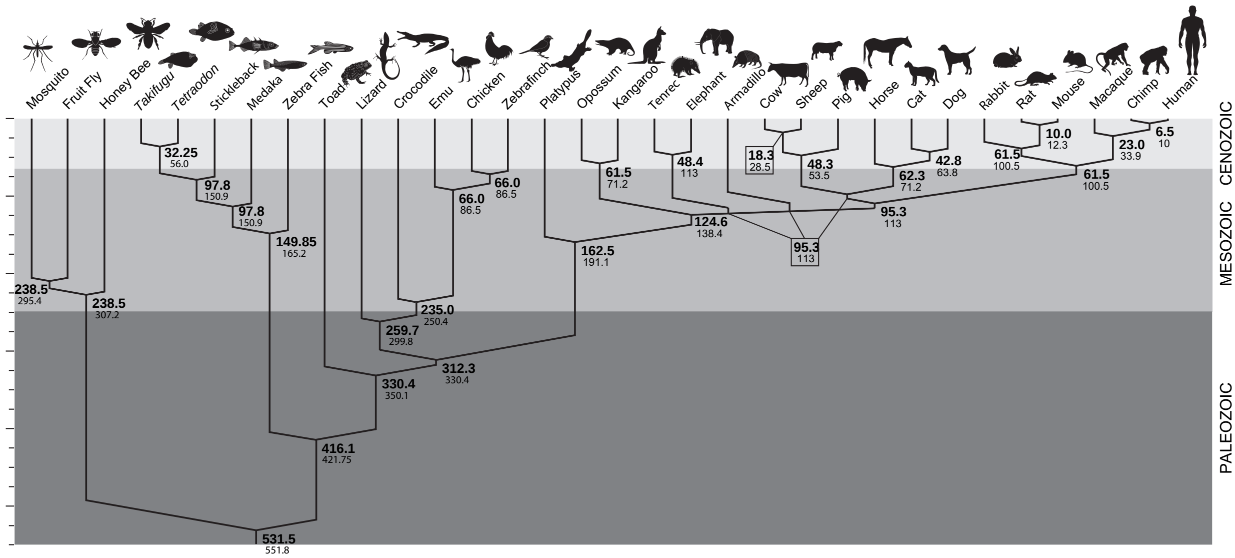

FIG. 8.—Tree of relationships of the key genome model organisms showing minimum (bold) and maximum (roman) fossil-based dates for each branching point. The pattern of relationships is based on a consensus of current views. The minimum age constraints are based on the oldest fossil confidently assigned to either of the 2 sister groups that arise from each branching point. The maximum age constraint is based on bracketing (maximum ages of sister groups) and bounding (age of an underlying suitable fossiliferous formation that lacks a fossil of the clade). Full justification for each minimum and maximum fossil-based age constraint is given in the text, and in tree-based form at http://www.fossilrecord.net.

been substantiated. As below, this constrains the age of the first occurrence of *Naxilepis* between the middle Ludlow and the Ludlow–Pridoli boundary (418.7 MYA).

The earliest macroremains assignable to total-group Actinopterygii are of *Dialipina markae* from the Lochkovian of Siberia (Schultze 1992) that is also know in fully articulated remains from the lower Devonian (Emsian) of the Canadian Arctic (Schultze and Cumbaa 2001). Justification for the Lochkovian age assignment is not clear (Cherkesova 1988).

The earliest record of the sarcopterygian total group is *Psarolepis romeri*, known (in stratigraphic order) from the Yulongsi (Zhu and Schultze 1997), Xishancun (Zhu and Schultze 1997), and Xitun (Yu 1998) members of the Cuifengshan Formation, Quijing District, eastern Yunnan, China (the recently described *Meemania eos* is apparently a more basal member of the sarcopterygian stem but it is known only from the Xitun Member, Zhu et al. 2006). The dating of these occurrences relies primarily upon biostratigraphic dating of a lithostratigraphic correlation of the Yulongsi Member in neighboring Guangxi where the conodont *O. crispa* has been recovered from the middle of the Yulongsi Member (Wang 1981). The lower limit of the stratigraphic range of *O. crispa* is constrained by the Ludlow–Pridoli Boundary (Miller 1995) that has been dated as 418.7 MYA ± 2.7 Myr (Gradstein et al. 2004). In the type Ludlow Series, the upper range limit on *O. crispa* is just a few meters below its lower limit (Miller 1995) (the latest Ludlow and earliest Pridoli are probably unrepresented in the Ludlow type area, Miller et al. 1997). Although it is difficult to provide a direct date on this horizon, zircons from a bentonite 12 m deeper in the type Ludlow section has provided a U-Pb Zircon age of 420.2 MYA ± 3.9 Myr (Tucker and McKerrow 1995). There is a report of *O. crispa* as low as "middle Ludlow" (Viira and Aldridge 1998) although this is just one of a number of possible interpretations of the conflicting biostratigraphic data. Attempts to directly date the Quijing succession biostratigraphically have yielded the conodont *Oulodus elegans detorta* from the upper part of the Yulongsi Member (Fang et al. 1994). The stratigraphic range of *O. elegans detorta* is confined to its zone which is the ultimate conodont zone of the Silurian (Jeppsson 1988). Thus, direct and indirect biostratigraphic dating is in agreement concerning the age of the middle and upper parts of the Yulongsi Member, indicating that the earliest record of *Psarolepis* is no younger than latest Ludlow (418.7 MYA ± 2.7 Myr) and possibly older than 420.2 MYA ± 3.9 Myr.

Although originally described as a sarcopterygian (Zhu and Schultze 1997; Yu 1998), *Psarolepis* has also been interpreted as stem-Osteichthyes (Zhu et al. 1999; Zhu and Schultze 2001). However, more recent and universal analyses have confirmed its assignment to the sarcopterygian stem lineage (Zhu et al. 2001, 2006).

After *Psarolepis*, the next oldest representatives of total-group Sarcopterygii, *Diabolepis*, *Youngolepis*, and *Achoania* are approximately coeval. They are derived from the Xishancun Member of the Cuifengshan Formation of Qujing District. The Xishancun Member is clearly younger that the underlying Yulongsi Formation, the upper part of which is dated as latest Silurian in age on the occurrence of *O. elegans detorta* (see above), and it has been directly dated as Lochkovian on the basis of ostracode biostratigraphy (Wang and McKenzie 2000).

Outgroups of the Actinopterygii + Sarcopterygii clade may provide evidence for a maximum age constraint. *Lophosteus superbus*, described on the basis of a wide variety of microremains (Gross 1969, 1971) has been considered stem-Osteichthyes (Schultze 1977), although this is poorly substantiated (Janvier 1996; Märss 2001). The earliest occurrence of *L. superbus* is from the Pridoli of Gotland (Gross 1969, 1971), Estonia (Märss 1986), and Latvia (Märss 1986), is later than the first record of *A. hedei* which, despite concerns over assignment to Actinopterygii (Janvier 1996), and has not been disputed membership of total-group Osteichthyes. Indeed, some of the evidence on which *Andreolepis* has been assigned to Actinopterygii can be called into question on the basis of the discovery and phylogenetic position of *Meemania*, in which a ganoine-like tissue appears to be present (Zhu et al. 2006). Thus, it is possible that *Andreolepis* presents only osteichthyan symplesiomorphies and that on the basis of the available evidence, it is better assigned to stem-Osteichthyes.

Dating the earliest record of successive sister taxa is complicated by long-standing debate over the relative phylogenetic position and monophyly of the various groups. Acanthodii is generally considered the sister group of Osteichthyes and its earliest record is from the Ashgill of Siberia (Karatajuté-Talimaa and Predtechenskyj 1995). Chondrichthyes is generally accepted as the succeeding sister taxon, the oldest record for which is Caradoc (Sansom et al. 1996), although precious few characters bind these remains to the stem of Chondrichthyes (Donoghue et al. 2003). The oldest placoderms are undescribed forms from the Wenlock of China (Janvier 1996) and Vietnam (Thanh et al. 1997).

Conservative assessments of the age of the earliest remains readily assignable to the actinopterygian and sarcopterygian total groups are in close approximation (421.75 MYA ± 0 Myr vs. 418.7 MYA ± 2.6 Myr, respectively). However, phylogenetic assignment of these microremains rests on 1 or 2 equivocal synapomorphies, and this is insufficient evidence on which to justify constraining molecular clock analyses. Thus, we argue that it is best to rely on the evidence of better-known and better phylogenetically constrained *Psarolepis* to provide a minimum constraint on the divergence of sarcopterygian and actinopterygian lineages. The firmest age dating on the earliest record of *Psarolepis* (based on biostratigraphic correlation) is 418.7 MYA ± 2.7 Myr. Thus, a minimum constraint on the divergence of crown-Osteichthyes should be quoted as 416.0 MYA. A soft maximum constraint could be provided by the age of the earliest record of *A. hedei*, dated at 421.75 MYA.

Fruit fly–Mosquito

This divergence event represents the splitting of Brachycera and Culicomorpha lineages.

The oldest representative of Culicomorpha is *Aenne triassica* from the Late Triassic (Rhaetic) Cotham Member of the Lilstock Formation, Penarth Group at Aust Cliff, near Bristol England (Krzeminski and Jarzembowski 1999). Although this displays chironomid synapomorphies, only the distal half of a wing is preserved. The base of the Cotham Member coincides with the base of SA5n.3r that equates to the E23r reverse polarity magnetozone of the Newark Supergroup (Hounslow et al. 2004), the base of which is estimated at 202 MYA ± 1 Myr on the basis of volcanics in the upper part of the underlying E23 normal-polarity magnetozone (Gradstein et al. 2004). Hounslow et al. (2004) argue that the whole of the Cotham Member equates to the E23r magnetozone, the duration of which is beyond stratigraphic resolution in the current timescale (Gradstein et al. 2004). Thus, we conclude the age of the first possible representative of Culicomorpha to be 202 MYA ± 1 Myr.

The next oldest record is *Aenne liasina* from the Lower Toarcian (Lower Jurassic) of Grimmen, NE Germany (Ansorge 1994), followed by an abundance of other Culicomorpha records in the Lower and Middle Jurassic (Grimaldi and Engel 2005).

The oldest documented representatives of Brachycera are from the Upper Triassic Dan River Group of Virginia (Krzeminski 1992; Krzeminski W and Krzeminski E 2003), although their assignment rests upon precious few and largely inconsistent venation characters (Grimaldi and Engel 2005). There remains an older record of Brachycera, *Gallia alsatica*, from the Grès-à-Voltzia Formation of Arzviller, northeast France (recognized on the basis of the following apomorphies: cell *m3* narrowed distally and Cu and A_1 terminating in one point at the wing margin) (Krzeminski and Evenhuis 2000; Krzeminski W and Krzeminski E 2003). The Grès à Meules facies of the Grès-a-Voltzia Formation, from which these remains are derived, has been dated as Lower Anisian (Papier and Grauvogel-Stamm 1995; Papier et al. 2005), although the evidence on which this is based was not presented. The top of the Lower Anisian is dated as 240.5 MYA, based on proportional scaling of major conodont zones (Ogg 2004) from a graphic correlation global composite standard (Sweet and Bergström 1986), from which an error of ±2.0 Myr is derived. Otherwise, there are convincing records from the Early Jurassic, including the Black Ven Marls (Sinemurian) at the cliff of Stonebarrow Hill near Charmouth, Dorest, England (*turneri-obtusum* zone), 194.1–192.0 MYA (Ansorge and Krzeminski 1994), and the Lower Toarcian (*Harpoceras falciferum* zone) of Dobbertin, Mecklenburg, Germany, 182.7–181.2 MYA (Krzeminski and Ansorge 2000).

The oldest representatives of the clade comprising Culicomorpha and Brachycera are members of grauvogeliid Psychodomorpha, specifically, *Grauvogelia arzvilleriana* from the middle Triassic Grès-a-Voltzia Formation of France (Krzeminski et al. 1994). Crucially, this is neither the most primitive crown-dipteran nor the oldest known total-group dipteran, but the oldest record that falls within the clade circumscribed by *Anopheles* and *Drosophila*, following the phylogenetic scheme presented in Grimaldi and Engel (2005).

Thus, on the record of *G. arzvilleriana* (Krzeminski et al. 1994), its coincidence with the earliest (albeit undocumented) record of Brachycera (Krzeminski and Evenhuis 2000; Krzeminski W and Krzeminski E 2003), and the phylogenetic hypothesis of Grimaldi and Engel (2005), the minimum date for the divergence of the lineages leading to *Drosophila melanogaster* and *Anopheles gambiae*, is 238.5 MYA.

A soft maximum constraint is provided by the insect fauna of Boskovice Furrow, Oboro, Moravia, Czech Republic. A huge diversity of insects has been described from this deposit which is the single most important Paleozoic insect locality in the World (Grimaldi and Engel 2005). No members of the clade circumscribed by Brachycera and Culicomorpha have been described from here or from older deposits. The Oboro fauna has been dated at Early Artinskian (Kukalová-Peck and Willmann 1990) and Sakmarian (Zajic 2000), although only the latter has been substantiated. The base of the Sakmarian has been dated at

294.6 MYA ± 0.8 Myr (Gradstein et al. 2004). Thus, the soft maximum constraint on the divergence of Brachycera and Culicomorpha can be taken as 295.4 MYA.

Honeybee–Fruit fly, Mosquito

This divergence event represents the splitting of the Hymenoptera and Panorpoidea lineages.

The earliest recognized Panorpoidea are the mecopteroids that are interpreted as stem Panorpoidea (or panorpoideans) and are known from records as early as the Permian, the very oldest of which are members of Kaltanidae, interpreted as stem panorpoideans (Willmann 1989).

The earliest recognized Hymenoptera are from the Middle Triassic of Central Asia (Rasnitsyn 1964, 1969), and the Upper Triassic of Australia (Riek 1955), and Africa (Schlüter 2000), all of which are referred to the Archexyelinae within Xyelidae. This difference in first records of Hymenoptera and Panorpoidea has led to the suggestion that putative stem-panorpoideans from the Permian are unified on symplesiomorphies of Panorpoidea + Hymenoptera (Grimaldi and Engel 2005). Thus, the minimum date for the divergence of Hymenoptera and Panorpoidea would be based on the earliest records from the Middle Triassic Madygen Formation of Central Asia (Rasnitsyn 1964, 1969) that is dated as Ladinian and/or Carnian on the basis of palynological data (Dobruskina 1980, 1982). In the absence of greater biostratigraphic control, it is possible only to derive a minimum date from the base of the Norian (base Norian 216.5 MYA ± 2.0 Myr; Ogg 2004) in the absence of better stratigraphic constraint. Thus, a minimum constraining date would be 214.5 MYA.

However, this inconsistency is predicated upon the assumption that Hymenoptera and Panorpoidea are sister taxa, a view that is not universally accepted. Rasnitsyn (2002a), for instance, maintains that Hymenoptera and Panorpoidea are more remotely related, the closest relatives of Panorpoidea being Neuropteroidea and Coleopteroidea (united on modified ovipositor gonapophyses 9 [=dorsal valvula] lost, and the intromittant function transferred to gonocoxa 9 + gonostylus 9 [=Valvula 3]). In this view, Panorpoidea + Neuropteroidea + Coleopteroidea diverged from the lineage leading to Hymenoptera within the paraphyletic order Palaeomanteida, at a time approximating to the Carboniferous/Permian boundary. Unfortunately, the systematics of this group are poorly resolved and it is unclear which represent the earliest members of the either lineages ultimately leading to Panorpiodea and Hymenoptera. The best estimate must be provided by the earliest member of the clade Panorpoidea + Neuropteroidea + Coleopteroidea, but note should be taken of the fact that this date is likely to be extended in light of systematic revision of Palaeomanteida. The oldest known member of Coleoptera is *Pseudomerope gallei*, from the Asselian (299–294.6 MYA ± 0.8 Myr) (Lower Permian) of Rícany, Czech Republic (Kukalová-Peck and Willmann 1990), though the basis of this age assignment is not clear.

The oldest recorded member of this clade appears to be an undescribed member of Coleopteroidea from the Middle Carboniferous Mazon Creek fauna of Illinois, USA (Rasnitsyn 2002b). The Mazon Creek fauna is derived from the Francis Creek Member of the Carbondale Formation in NE Illinois. The Francis Creek Shale Member has been dated as middle Desmoinesian and middle Westphalian D age on the basis of both palynological and paleobotanical data (Pfefferkorn 1979; Wagner 1984; Peppers 1996). This equates to the upper part of the Moscovian stage, the top of which has been dated at 306.5 MYA ± 1.0 Myr on the basis of a graphically correlated composite standard calibrated using radiometric dates (Davydov et al. 2004). The top of the Westphalian D is slightly older at 307.2 MYA (Davydov et al. 2004). Thus, within the phylogenetic milieu that posits that Hymenoptera are not immediate sister taxa (Rasnitsyn 2002a), the minimum date on the divergence of these 2 clades is 307.2 MYA.

In conclusion, however, it must be emphasized that Hymenoptera and Panorpoidea are conventionally viewed as sister taxa. Nevertheless, a minimum date for divergence of 214.5 MYA, post dates the minimum date of is 238.5 MYA for the divergence of the lineages leading to *D. melanogaster* and *A. gambiae*. *Apis mellifera* falls outside this clade and so in the absence of better constraint over the interrelationships of Diptera and Hymenoptera, a minimum date for their divergence can be taken as 238.5 MYA. A soft maximum constraint can be provided by the less likely hypothesis that Panorpoidea are more closely related to Neuropteroidea and Coleopteroidea, using the oldest record of this clade, described above as 307.2 MYA.

Bird, Mammal, Toad, Fish–Fruit Fly, Mosquito, Honeybee

This divergence event represents the splitting of crown-Bilateria and the divergence of deuterostome and protostome lineages.

The oldest possible record of chordates dates from the Lower Cambrian Yu'anshan Member of the Heilinpu Formation (Chengjiang Biota) of Yunnan Province, South China, from which the remains of putative tunicates (Shu et al. 2001a; Chen et al. 2003), cephalochordates (Chen et al. 1995; Shu et al. 1996), and even vertebrates (Shu et al. 1999; Holland and Chen 2001; Hou et al. 2002; Mallatt and Chen 2003; Shu 2003; Shu et al. 2003a) have been described. The problem with many of these records is that the characters defining clades at this deep level within phylogeny are largely cytological or embryological—not the kinds of characters that are preserved under even the most exceptional circumstances (Donoghue and Purnell 2005). Furthermore, both the living and fossil organisms are entirely soft-bodied and so precious few characters are preserved. And of these, many have been resolved to be deuterostome symplesiomorphies, rather than chordate or vertebrate synapomorphies, with the recognition that echinoderms and hemichordates are sister taxa (Gee 2001; Donoghue and Purnell 2005). Thus, *Yunnanozoon* and *Haikouella*, thought by some to represent early craniates (Holland and Chen 2001; Mallatt and Chen 2003), are interpreted by others as basal (perhaps even stem-) deuterostomes (Budd and Jensen 2000; Shu et al. 2001b; Donoghue et al. 2003; Shu 2003; Shu and Conway Morris 2003; Shu et al. 2003b, 2004). Records of early tunicates (Shu et al. 2001a; Chen et al. 2003) have been questioned and the earliest unequivocal remains are Triassic in age (Varol and Houghton 1996). The putative vertebrates *Zhongjianichthys*, *Myllokunmingia*, and *Haikouichthys*

(Shu et al. 1999, 2003a; Hou et al. 2002; Shu 2003) exhibit convincing vertebrate apomorphies, and these provide the best constraint on the minimum date of divergence of vertebrates and chordates. There are contemporaneous records of more primitive deuterostomes, with the identification of vetulicystids as stem-echinoderms (Shu et al. 2004) and vetulicolians as stem-deuterostomes (Shu et al. 2001b, 2004; Shu 2003), although the veracity of the phylogenetic assignments of these taxa is a matter of some controversy (Lacalli 2002; Smith 2004; Briggs et al. 2005). Earlier records of possible deuterostomes include *Arkarua* from among the enigmatic ediaracan biota (Gehling 1987). Although support for the identification of *Arkarua* as an echinoderm has found support from embryological homologies (Mooi 2001), all rests ultimately upon the presence of pentameral symmetry that is not enough to rest an extension of tens of millions of years to a minimum date for divergence of deuterostomes and Bilateria upon. Thus, the vertebrates *Zhongjianichthys*, *Myllokunmingia*, and *Haikouichthys* (Shu et al. 1999, 2003a; Hou et al. 2002; Shu 2003) provide the best evidence for the minimum date of divergence of deuterostomes.

The earliest evidence for the origin of arthropods is *Rusophycus*-like trace fossils from the Upper Nemakit-Daldynian (early Tommotian) of Mongolia (Crimes 1987; Budd and Jensen 2003). However, there are still older representatives of the protostome lineage, further constraining the time of divergence of the Human and fruit fly genomes, as well as the genomes of all integral taxa. The oldest of these is probably the mollusc *Latouchella* from the middle *Purella* Biozone, Nemakit-Daldynian, of Siberia (Khomentovsky et al. 1990; Budd and Jensen 2003). There are a number of candidate crown-bilaterians among the ediacaran biota, among which a molluscan affinity for *Kimberella* has been most cogently argued (Fedonkin and Waggoner 1997). However, the evidence has not withstood scrutiny (Budd and Jensen 2000) and it is certainly insufficient to justify its use as a constraint on molecular clock analyses of metazoan evolution.

Thus, the minimum constraint on the divergence of crown-Bilateria is provided by the vertebrates *Zhongjianichthys*, *Myllokunmingia*, and *Haikouichthys*—the minimum age of the Yu'anshan Member of the Heilinpu Formation, and the age of the first appearance of *Latouchella*—which can be best constrained by the age of the top of the Nemakit-Daldynian.

The age of the Chengjiang biota remains equivocal because, although its local stratigraphic assignment to the *Eoredlichia wutingaspis* Biozone is well constrained and long established (Hou et al. 2004), how this correlates to better dated sections is not clear, not least because the fauna is largely endemic. The Heilinpu Formation belongs to the Qiongzhu stage that is considered to be Atdabanian in age. Thus, a minimum constraint may be provided by the age of the top of the Atdabanian, for which a 518.5 MYA is provided in the latest timescale (Shergold and Cooper 2004). It should be noted, however, that this estimate is stratigraphically, relatively remote from the nearest geochronological-derived date, and contingent upon the questionable conclusion that the Qiongzhu and Atdabanian are time equivalent.

The boundary between the Nemakit-Daldynian and the succeeding Tommotian stage remains equivocal and so a more reliable minimum constraint might be provided by the current best estimate for the base of the Tommotian that is 531.5 MYA (Shergold and Cooper 2004). Thus, on the basis of the available paleontological, stratigraphic, and chronological data, the best minimum constraint for the divergence of crown-Bilateria is 531.5 MYA.

Providing soft maximum bounds on the timing of crown-bilaterian divergence is extremely contentious. Nevertheless, following the same criteria used to provide constraints on other divergence events, it is possible to constrain the timing of crown-bilaterian divergence on the occurrence of older lagerstätten that preserve only records of earlier branching lineages. Inevitably, these records are represented by the Ediacaran faunas, the interpretation of which is extremely contentious, though there is increasing agreement that crown-bilaterians are not represented among them (Budd and Jensen 2000; Shu et al. 2006). Thus, the youngest, most completely sampled Ediacaran assemblage may be used to provide the maximum constraint on the divergence of crown-Bilateria. This is the Doushantuo Formation that provides a sampling of Ediacaran diversity in a number of facies and through a number of modes of exceptional preservation (Yuan et al. 2002; Xiao et al. 2005); although a number of candidate bilaterians have been described from this deposit (Chen et al. 2000, 2002, 2004a, 2004b), these have not withstood scrutiny (Xiao et al. 2000; Bengtson 2003; Bengtson and Budd 2004; Raff et al. 2006; Donoghue et al. 2006; Hagadorn et al. 2006). The top of the Doushantuo Formation has been dated as 551.1 MYA $\pm$ 0.7 Myr (Condon et al. 2005). Thus, a soft maximum constraint on the divergence of crown-Bilateria may be taken as 551.8 MYA.

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The Earliest Known Reptiles

by Robert L. Carroll

Fossils 300,000,000 years old, found in stumps of giant lycopods are very similar to living reptiles in their anatomy.

Today, reptiles are a minor constituent of the terrestrial vertebrate fauna. Particularly in the temperate zones, lizards, snakes and turtles are inconspicuous in comparison with mammals.

In the Mesozoic Era, in contrast, reptiles were the dominant terrestrial vertebrates, filling nearly all the major adaptive zones occupied today by mammals. Living reptiles are but relicts of a very numerous and diverse assemblage which included dinosaurs, the flying pterosaurs and marine ichthyosaurs and plesiosaurs.

Fossil reptiles are of significance to biologists not only as progenitors of the living members of that class, but also as the ancestors of mammals and birds (Figure 1). The origin of these higher vertebrate classes resulted from a fundamental change in reproductive habits. Amphibians, although they are able to a variable degree to live their adult lives on land, typically return to the water to reproduce. Although some amphibians lay their eggs on land, none has the extra-embryonic membranes, characteristic of reptiles, birds and mammals, which enable the embryo to grow to substantial size in the egg or the body of the mother. In most amphibians, the small size of the egg makes it necessary for the young to complete their development in an aquatic medium. Typically this results in a distinct larval stage.

The extra-embryonic membranes may be considered as three distinctive structures: the amnion, which envelops the embryo, enclosing it in a fluid medium for support; the allantois, an outgrowth from the lower intestinal tract which forms a receptacle for urine; and an external

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covering, the chorion. The yolk sac, which may be considered as a fourth extra-embryonic membrane, is a discrete structure which extends out from the tissue of the gut. It is also present in some amphibians and fish. The allantois is particularly important in reptiles in providing a water supply for the embryo. The urea, accumulated as a biproduct of protein metabolism, forms a hypertonic solution which draws in water from the substrate by osmotic pressure. In primitive reptiles, the egg is laid in damp places. The shell is flexible and porous, enabling the egg to absorb water and so increase its volume substantially. The surface of the allantois and yolk sac are well supplied with blood vessels which serve to absorb atmospheric oxygen and discharge carbon dioxide. Despite the necessity for the eggs of many reptiles to be laid in damp places, the method of gas exchange requires that they not be submerged in water. External to these membranes is deposited a membranous shell, which in advanced forms becomes calcified. The evolution of these extra-embryonic membranes and elimination of the aquatic larval stage occurred initially in the evolution of reptiles from amphibians in the late Paleozoic.

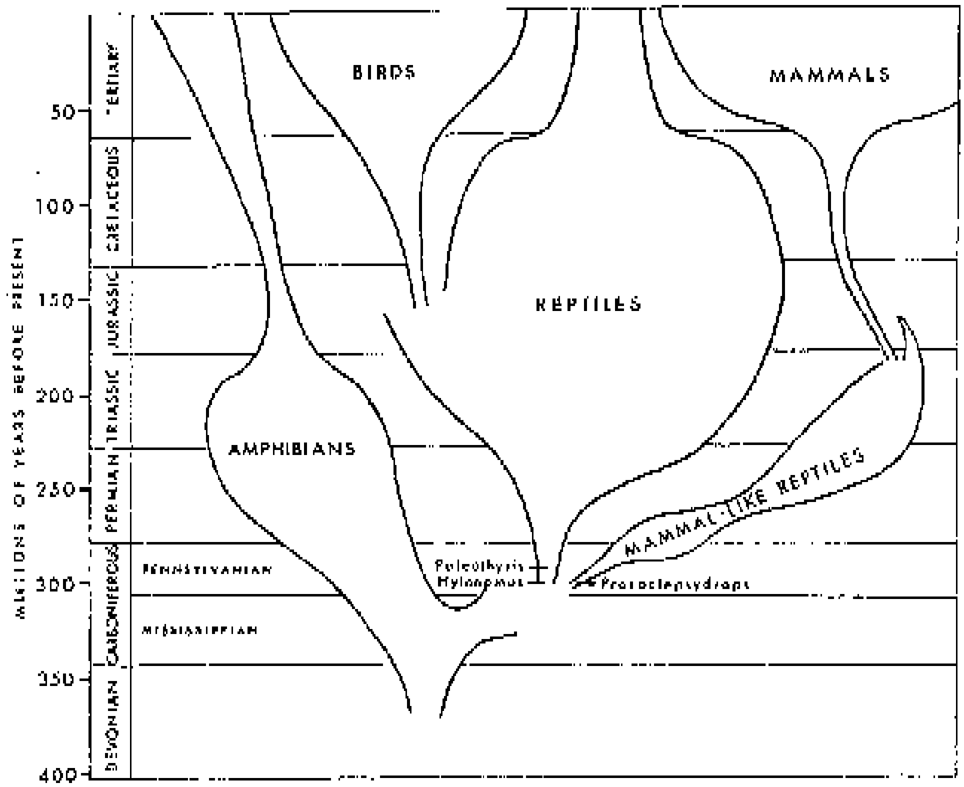

Figure 1

The distinctive reproductive pattern of reptiles is related to their basically terrestrial way of life. Although several groups of reptiles, both living and fossil, have become adapted to an aquatic existence, this is clearly secondary, since even such highly specialized forms as sea turtles and many marine snakes are obliged to return to land to lay their eggs. The basically terrestrial habits of reptiles, as a group, suggests that their origin was specifically related to a new way of life for the adult as well as the young.

The probability that reptiles and their immediate ancestors showed a preference for dry ground, away from the swamps and lakes, typically the habitat of Paleozoic as well as recent amphibians, is unfortunate from a geological standpoint. In general, fossils need to be buried, typically underwater, in order to be preserved. Moreover, only those fossils buried in large deposits, such as those in lakes, swamps, deltas and floodplains are likely to survive subsequent periods of erosion. Animals living in higher terrain, even if buried in local ponds, are likely to be destroyed as the uplands are worn down. Throughout geological history, the fossil record has always shown a bias toward animals living in aquatic environments and the record of truly terrestrial forms becomes increasingly scanty as we reach older and older deposits. This situatiton is particularly distressing in relationship to the origin of reptiles since this transition is inherently associated with the assumption of terrestrial habits. Fortunately, through a combination of curious biological and geological circumstances, two deposits are known from Nova Scotia which reflect a terrestrial environment and include very early reptiles.

The older of the deposits, from the Lower Pennsylvanian, occurs near the coal mining community of Joggins, on the Bay of Fundy. Vertebrate fossils were first discovered there in 1852 by Charles Lyell, one of the greatest early contributors to the science of geology, and J. W. Dawson, one of the pioneers of Canadian geology. These fossils were discovered within the stump of a giant lycopod which had been preserved in an upright position in the vertical sea cliff. Thirty or more such vertebrate bearing trees were subsequently collected at this locality, yielding a rich fauna, including hundreds of specimens of amphibians, and a dozen or so reptiles. The explanation given by Dawson for the occurrence of animals in the stumps still appears valid (Figure 2).

Throughout the Carboniferous, Nova Scotia was an area of tectonic activity. A series of freshwater basins were repeatedly raised and lowered so as to be alternately a few feet above or below the level of the local water table. The climate was apparently mild and wet throughout the year, resulting in luxuriant growth of vegetation (subsequently contributing to the many coal deposits in the region). The dominant forest trees were lycopods, giant relatives of the living club mosses. Unlike most modern trees, the woody tissue in these forms was restricted to a narrow band, just beneath the bark. The center of the tree was either hollow, or filled with a very soft, readily decayed material. Despite their apparent weakness, these lycopods achieved a diameter of three to four feet, and a height approaching 100 feet. The periodic flooding at Joggins and other localities led to repeated burial of the lycopod forests. Fine-grained sediments, up to 20 feet in depth, now surround the bases of the trees. Forty or fifty such buried forests are visible at Joggins, standing one on top of another, within 5,000 feet of sediments. It is obvious that burial was very rapid, since the nature of the trees would lead to decay and collapse within a short period of time after death. In at least four of the buried forests at Joggins, the level of the water fell rapidly while the tops of the trees were still stand-

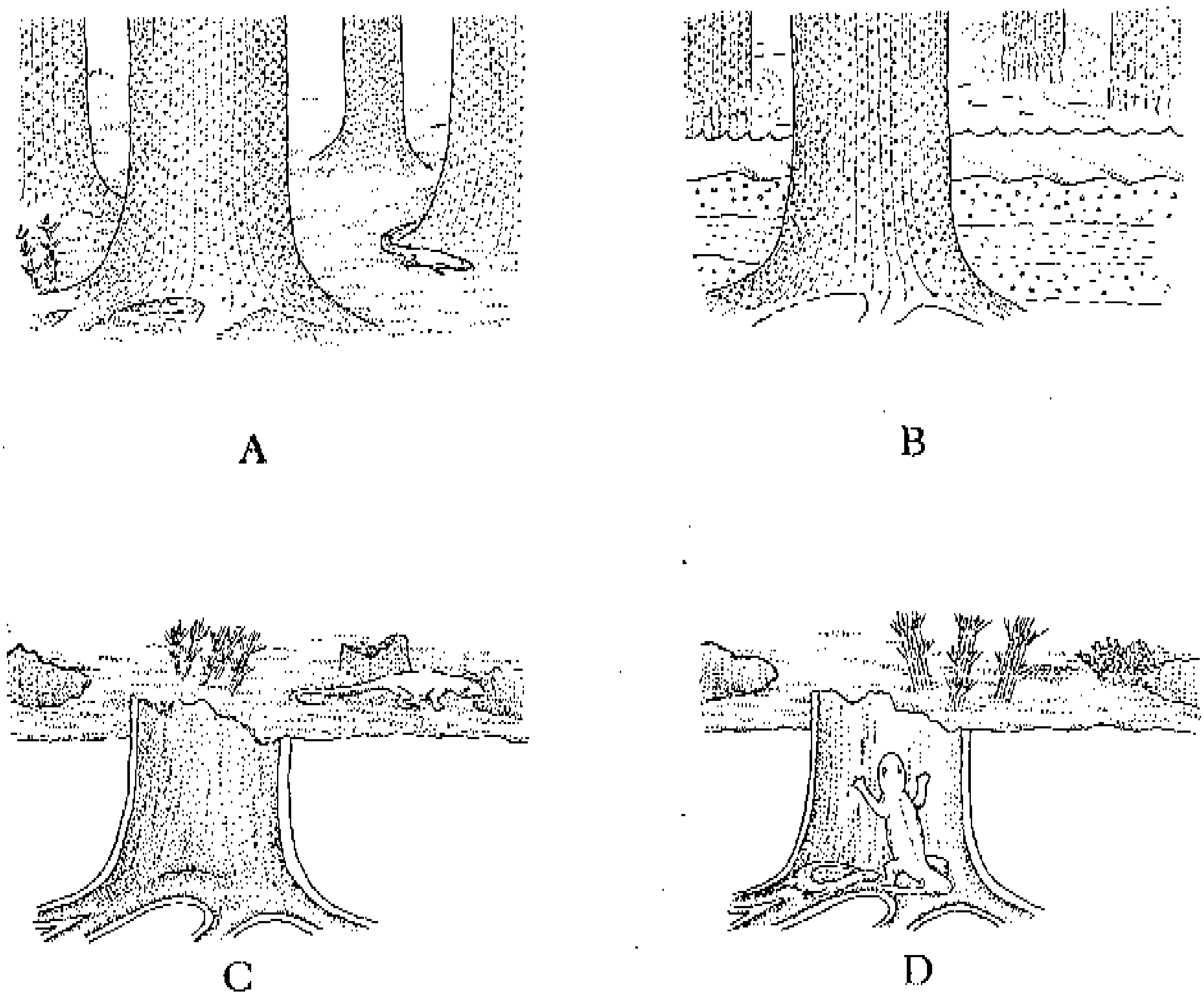

Fig. 2: Sketches of the events leading to the entrapment of terrestrial animals in lycopod stumps. A, Growth of forest of Sigillaria trees. B, Trees are buried and killed by sediments as land subsides. C, Land rises; centers of trees rot out, forming deep pits in new land surface. D, Amphibians and reptiles fall into pits and become trapped. Additional sediments cover animals.

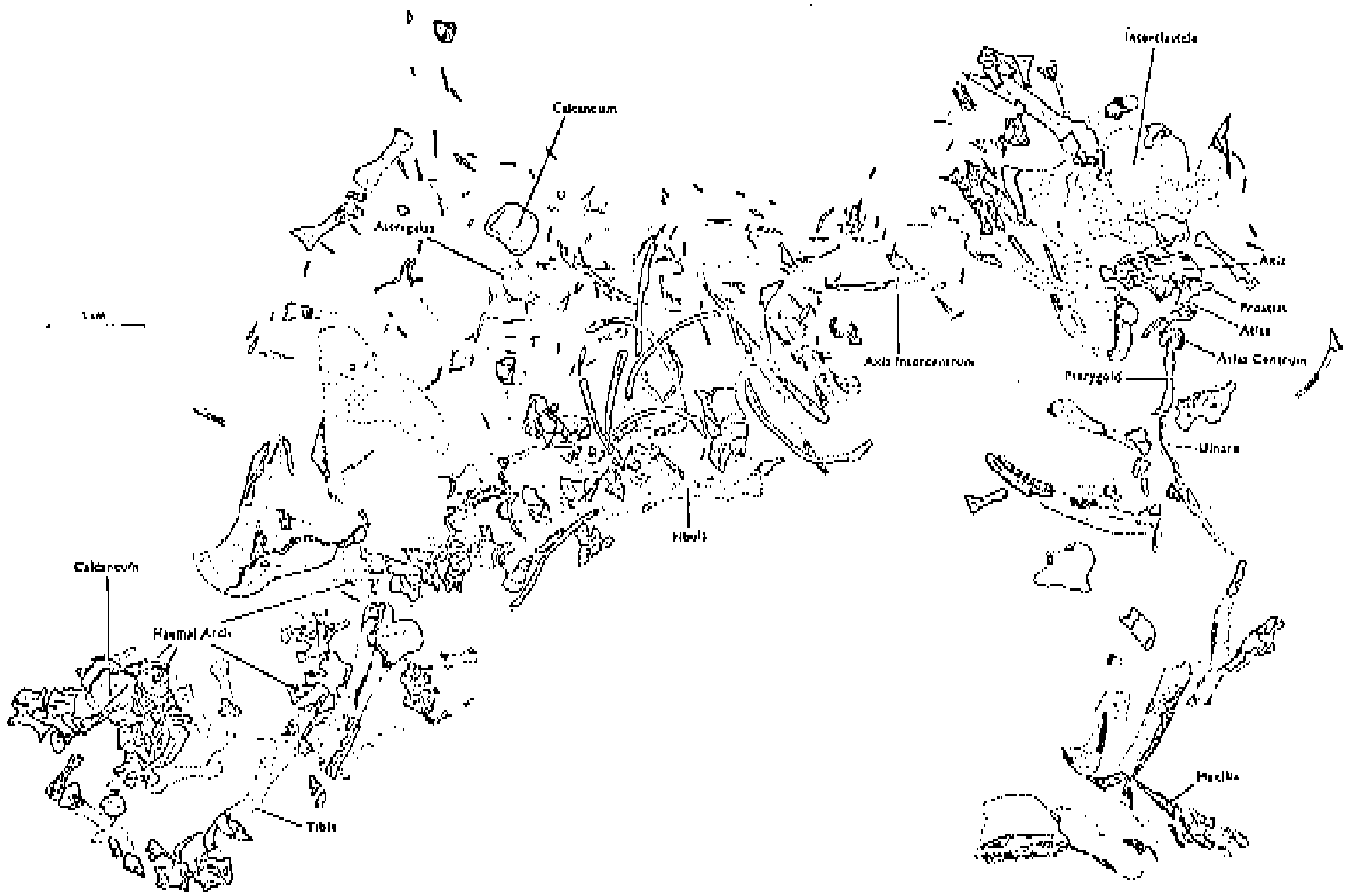

Fig. 3: The first described specimen of Hylonomus lyelli, the most completely known of the earliest reptiles from Joggins. Scale is one centimeter in length.

ing and a new land surface was formed ten feet or more above the old forest floor. A new forest began to grow and animals moved back into the area. The tops of the buried lycopods rotted and collapsed. The stumps remained supported by the strong husk of vascular tissue. The middle portion decayed, however, leaving tall, hollow cylinders, like uncovered manholes. Animals falling into these holes would find it almost impossible to escape. This might seem an isolated tragedy, if it had not occurred in hundreds of instances in this locality alone. It is evident that the animals fell, rather than being washed into the trees since they survived long enough to leave considerable coprolitic material. Since remains of dozens of animals are found close together in each tree, the animals probably fed on each other, as well as on the millipedes and land snails also found in the stumps.

As can be seen in Figure 3, the fossils from Joggins tend to be disarticulated, although the individual bones are well preserved. By use of all the available specimens, a composite restoration of the skeleton of the most common species, *Hylonomus lyelli*, is possible (Figure 4). In size and general form it resembles a medium sized lizard (Figure 5). It may have had similar habits as well. It differs from living lizards principally in having a solidly roofed skull, with no temporal openings.

Hylonomus lyelli is an almost ideal ancestor for the vast majority of higher reptiles; lizards, snakes, crocodiles, turtles and the variety of extinct Mesozoic forms. A second type of reptile is also present at Joggins, although it is represented by much less complete material.

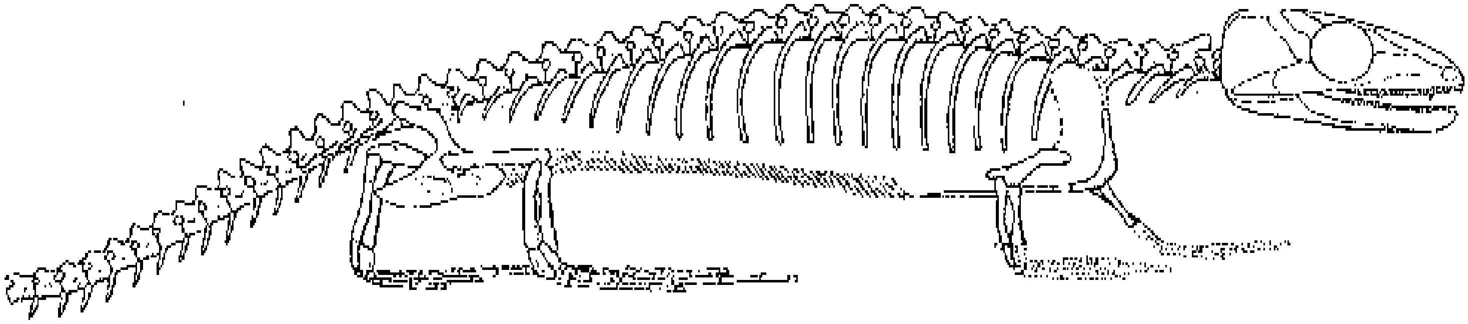

Fig. 4: Reconstruction of Hylonomus lyelli, based on all the available material from Joggins, Nova Scotia. Scale is one centimeter in length.

The genus *Protoclepsydrops* is a synapsid, the group which gave rise to mammals in the late Triassic. Within the very limited reptilian fauna at Joggins we have the ancestors of all major amniote groups.

Although the genera at Joggins can be recognized as reptiles, their remains are generally incomplete and many important features of their anatomy cannot be studied. Considerably better preserved specimens are known from a second locality, somewhat younger in age, which was discovered by a field party from Harvard University under the direction of Dr. Alfred S. Romer, in 1956, near Sydney, Nova Scotia. Here a series of upright trees were found at the edge of a strip mine. Although only five trees have been collected from this locality, three show a rich accumulation of tetrapods, primarily reptiles. In one, at least 15 reptile skeletons are preserved, belonging to three major groups. The smallest are the best preserved, with almost every bone in articulation. The only part missing is the tail (Figure 6). From these specimens, belonging to the genus *Paleothyris*, the skeleton may be reconstructed with little chance of serious error. There seems little to differentiate this form from its antecedents at Joggins, but it is considerably better preserved and so provides a better basis for comparison with other reptiles.

It is very interesting to note the general similarity between these Paleozoic forms, approximately 300,000,000 years in age, and their living counterparts. The more primitive of living reptiles - unspecialized lizards and *Sphenodon* (the New Zealand tuatara) - differ primarily in the anatomy of the skull, particularly in the presence of temporal openings. The vertebrae, limbs and girdles are fundamentally similar. In fact, there would be little difficulty in recognizing the Paleozoic forms as reptiles, even in the absence of any fossil intermediates.

On the basis of their skeletal similarities to later genera and even living forms, there is no doubt that these fossils from Joggins and Sydney should be classified as reptiles. A serious question then arises as to whether these forms had also developed a typically reptilian reproductive pattern. Did they lay amniotic eggs on land and have direct development of the young without an aquatic larval stage? Reasoning by analogy with living amphibians and reptiles indicates that this was almost certainly the case.

Because they lack specialized membranes for support and respiration, amphibian eggs are limited in size to less than 10 millimeters in diameter. The hatchlings are correspondingly limited, even in the largest living forms, to a body length of 30 or 40 millimeters. In large genera, the young emerge as very immature larval stages which must live in the water for support and for intake of readily assimilated water borne food. External gills are necessary for respiration. Such extensive growth stages are known in a large number of Paleozoic amphibians. This is totally different from the developmental pattern observed in reptiles, in which the hatchlings resemble the adults in most features.

A reptilian developmental pattern may be approached by forms laying non-amniotic eggs if the adult body size is small. The eggs can remain within the limits imposed by the absence of extra-embryonic membranes and still give rise to hatchlings which are one half or one quarter the length of the adults. If a great amount of growth is not necessary, the young can resemble the adult in morphology and habits. Since the extra-embryonic membranes in reptiles provide for respiration and water control outside an aquatic medium, it must be assumed that they could only have evolved in a group which initially laid their eggs on land. A developmental pattern of this type is observed in the living salamander family Plethodontidae. Although they have no extra-embryonic membranes, many genera in this group lay their eggs in damp places on land and they hatch as miniature versions of the adults. Among the genera living in temperate regions the forms which reproduce in this manner are limited in size to no more than about 80 millimeters in snout-vent length. Eggs in these genera reach 6 or 7 millimeters in diameter. Because of the inherent restrictions of non-amniotic eggs, it is probable that body size was similarly restricted among the immediate ancestors of reptiles.

A similar relationship between adult body size and egg diameter to that seen in plethodontids is encountered among increase well beyond the limits seen in

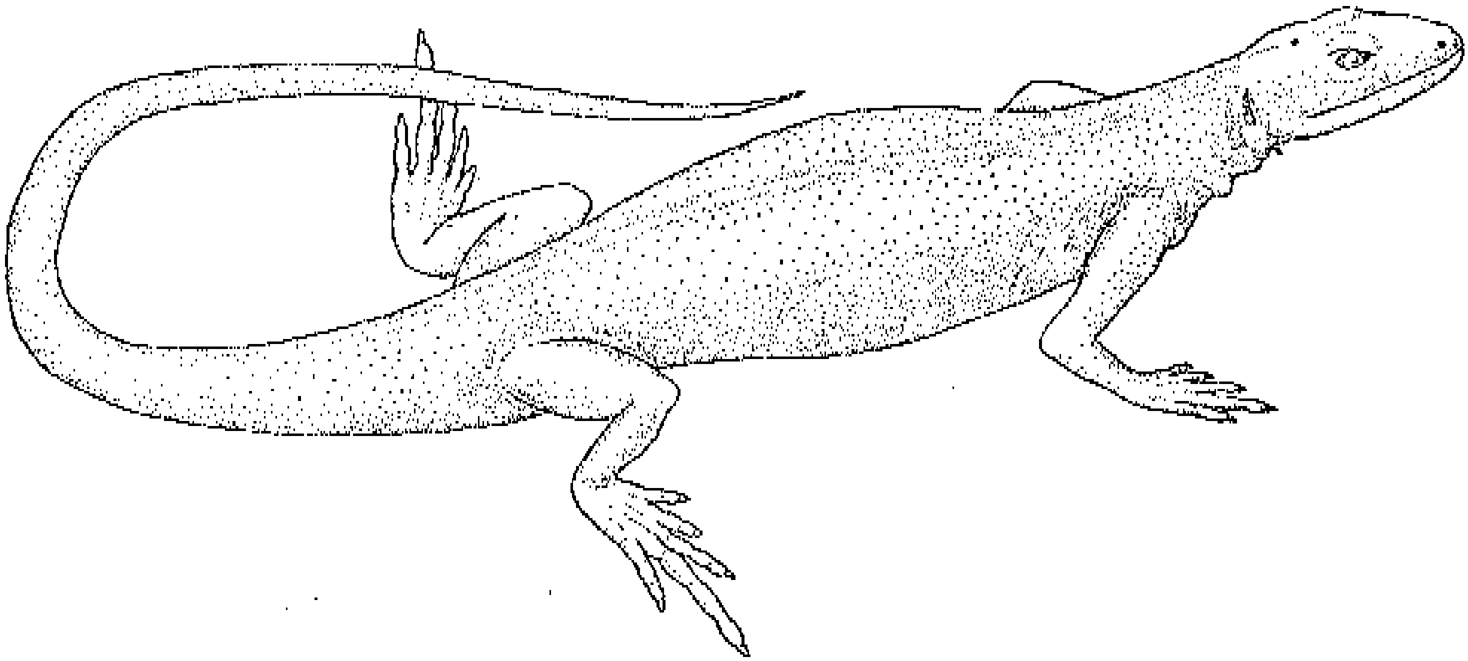

Fig. 5: Restoration of Hylonomus lyelli, one of the earliest known reptiles. Its anatomy indicates that it is close to the ancestry of most groups of higher reptiles. Scale is one centimeter in length.

living reptiles, but only among the smallest members of the class. Only reptiles with a snout-vent length less than about 40 millimeters lay eggs as small as those laid by terrestrial salamanders. Living reptiles of comparable size lay somewhat larger eggs, on the average, than do plethodontids, but some reptiles hatch from smaller eggs than do their amphibian counterparts. The information from living salamanders and reptiles indicates that the reptilian reproductive pattern could have developed from one like that seen in living plethodontid salamanders, but that such a transition is restricted to forms less than about 80 millimeters in body length.

Once extra-embryonic membranes are developed, the size of the eggs can increase, limited ultimately only by the mechanics of the shell. Dinosaur eggs up to several inches in length are reported, although the largest known eggs are those laid by certain extinct birds. Correspondingly, the size of the young and adult can the largest aquatically reproducing amphibians. Although the immediate ancestors of reptiles must have been small in order to reproduce via non-amniotic eggs, laid on land, we can expect a dramatic increase in size once extra-embryonic membranes were developed. The specimens known from the Pennsylvanian accord well with this hypothesis.

The largest of the Joggins reptiles had a snout-vent length of only a little more than 200 millimeters, and other well ossified and evidently adult specimens are much smaller, down to less than 60 millimeters in snout-vent length. The size of these specimens indicates that extra-embryonic membranes had been developed by this time, but that these forms may have only recently evolved from animals laying terrestrial, but non-amniotic eggs. A progressive increase in body size is seen throughout the Pennsylvanian, with Lower Permian forms reaching lengths up to 3 meters and weights in the order of 300 kilograms. The very limited number and diversity of the Joggins reptiles also indicates that this group had only very recently evolved above the amphibian stage.

Although it is the terrestrial habit of the young that is crucial to the achievement of reptilian status, the nature of the fossils at Joggins and Sydney also permits certain speculations as to the habits of the adults. A striking feature in association with the small size of the earliest reptiles is their high degree of ossification. In known aquatic forms, such as the extinct ichthyosaurs and plesiosaurs, the articulating surfaces of the limb bones are not ossified, but formed from extensive areas of cartilage. Strong joints were not necessary in these forms since their body was supported by the buoyancy of the water. Amphibians, particularly strictly aquatic genera, also form much of the skeleton in cartilage rather than bone. The high degree of ossification, even in the smallest bones of the smallest of the early reptiles indicates that support was critical, even at an early age. The terrestrial habits of these early reptiles is also attested to by their manner of preservation. Almost all of the fossils in the tree stumps at Joggins and Sydney are of animals with well developed limbs. They had to be able to walk about on dry land to be trapped in this manner. The land surface must have been ten or more feet above the water table for the bases of the buried stumps to remain dry. Aside from a few fish scales (which may have been someone's dinner) no strictly aquatic animals are preserved.

If the earliest reptiles were primarily adapted to life on land, this implies an abundant source of terrestrial food, possibly one which had recently evolved. From our knowledge of living amphibians and reptiles, the food of early reptiles was almost certainly other animals, rather than plants. Judging from the size of the early reptiles, it is probable that, if they were active predators, the food supply consisted of invertebrates, since only the smallest of the amphibians could be conveniently attacked. In this connection, it is important to note the type of jaw structure in the earliest reptiles in contrast with that of their nearest relatives among Paleozoic amphibians. Broadly speaking, the jaw mechanics in primitive amphibians can be described by the term kinetic-inertial. The structure of the palate shows that there is relatively little space for jaw musculature. Much of the force is supplied by the inertia of the jaw, as it is rapidly jerked shut. The prey is quickly impaled on the long teeth in the *jaws* and palate. This type of jaw structure appears best adapted to feeding on large, rather sluggish prey, and does not enable the predator to manipulate its food to any extent once it is in the mouth. It seems ideally suited to feeding on stranded fish and other carrion. The palate in the earliest reptiles, in contrast, resembles closely that of primitive living lizards, and *Sphenodon*. The area for jaw muscles is roughly twice that in amphibians of similar size and the angle of jaw musculature indicates that the greatest force would be applied when the jaw is shut, or nearly so, enabling the animal to catch and manipulate small, agile prey. The nature of the jaw musculature in the early reptiles, like their small size, implies a diet of terrestrial invertebrates.

The fossil record indicates the presence of some groups of terrestrial invertebrates by the Lower Pennsylvanian; spiders, millipedes and land snails. The latter two groups are, in fact, found in abundance in the same trees as the earliest reptiles. A much larger and more varied diet might be provided by insects. In this case, the fossil record is still very incomplete. The earliest documented insects occur in the Middle Carboniferous, but the group is very poorly represented. This is, however, the case throughout the history of the class. The absence of a good record of insects implies little more than their rarity of preservation. The number of insect groups known from the latter part of the Carboniferous implies a prior period of great evolutionary activity, structural modification and diversification. It is quite probable that this occurred at approximately the same time as the initial divergence of the reptilian stock from among the primitive amphibians.

On the basis of the anatomy of the earliest known reptiles and the preceding speculation as to their feeding and reproductive habits, the events leading to the origin of this class can be reconstructed.

It should first be pointed out that Paleozoic amphibians differ in many important respects from the living members of their class, and in terms of the skeletal anatomy, resemble primitive reptiles more than they do frogs or salamanders. The presence of a continuous covering of bony scales indicates that they did not practice cutaneous respiration, but had a reasonably impervious skin. This would have enabled them to live out of water without rapid desiccation. The size and structure of the ribs indicates that they respired in the same manner as do most living reptiles, by alternately expanding and contracting the thoracic cavity.

It is probable that there existed among primitive amphibians several groups which had attained a fairly terrestrial way of life. Unfortunately, we have little record of such forms prior to the appearance of true reptiles, due to the absence of terrestrial deposits of the appropriate age. These animals may have fed on primitive terrestrial invertebrates, including the wingless predecessors of insects. Small size would have been a premium in these forms, due to the nature of the prey, and in relationship to problems of terrestrial support and locomotion.

One of the first advances which would have been required in the lineage leading to reptiles was the change from external to internal fertilization. In vertebrates in general, the sperm requires a fluid medium to approach and penetrate the egg. In forms laying eggs in the water, the sperm needs only to be discharged in the general vicinity of the egg. If eggs are laid on land, fertilization is ensured only if the sperm is placed within the body of the female. Internal fertilization also assures a much higher level of fertility among forms which lay their eggs in the water, as is the case in many modern salamanders. It is probable that the ancestors of reptiles also began this practice while still retaining a typically amphibian developmental pattern. Special copulatory organs were probably not developed at this time however, since they seem to have evolved separately within each of the higher reptilian lineages. The greater efficiency of internal fertilization would have made it possible to reduce the number of eggs produced, while the size of each was increased. This would enable the eggs to include more nutrients, so that the larvae could hatch at a more mature stage. If growth within the egg were sufficiently prolonged, the hatchling could survive outside an aquatic medium. This would make is possible for the eggs to be laid on land. Laying of eggs on land would have had great selective value since it would have protected both the eggs and the young from being eaten by the great host of aquatic predators. A damp terrestrial site for deposition of eggs would also have been safer from changes in water level or seasonal desiccation. The more reliable developmental pattern would have allowed the number of eggs to be further reduced, and their individual size again increased.

Once this stage was reached, extra-embryonic membranes might begin to develop. According to Szarski, the first to evolve would have been the allantois, since the increase in yolk supply would have prolonged development to the point that water control became crucial. Blood vessels ramifying over the surface of the allantois and yolk sac would serve as an improved method of gas exchange, necessitated by the increase in size and the increased separation of the embryo from the surface of the egg. The membrane overlying the allantois could then spread up over the embryo, to form the amnion. Following the evolution of the extra-embryonic membranes, a membranous shell would develop to protect and support the enlarged egg. With this, all the features whereby amniotes can be distinguished from more primitive tetrapods would have evolved.

Figure 3 is reprinted from the Journal of the Linnean Society, Vol. 45, 1964, pp. 61-83.

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THE ORIGIN AND EARLY RADIATION OF TERRESTRIAL VERTEBRATES

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ABSTRACT—The origin of tetrapods from sarcopterygian fish in the Late Devonian is one of the best known major transitions in the history of vertebrates. Unfortunately, extensive gaps in the fossil record of the Lower Carboniferous and Triassic make it very difficult to establish the nature of relationships among Paleozoic tetrapods, or their specific affinities with modern amphibians. The major lineages of Paleozoic labyrinthodonts and lepospondyls are not adequately known until after a 20–30 m.y. gap in the Early Carboniferous fossil record, by which time they were highly divergent in anatomy, ways of life, and patterns of development. An even wider temporal and morphological gap separates modern amphibians from any plausible Permo-Carboniferous ancestors. The oldest known caecilian shows numerous synapomorphies with the lepospondyl microsaur *Rhynchonkos.* Adult anatomy and patterns of development in frogs and salamanders support their origin from different families of dissorophoid labyrinthodonts. The ancestry of amniotes apparently lies among very early anthracosaurs.

INTRODUCTION

THE EMERGENCE of terrestrial vertebrates from fish in the Late Devonian was one of the most significant events in the history of life. By the mid- to Late Carboniferous, the lineages leading to modern amphibians and the ancestors of reptiles, birds, and mammals had differentiated. These events serve as informative models for the study of other major transitions and large scale radiations, but they also point to the problems of the incomplete nature of the fossil record and the difficulties of establishing relationships.

It is especially difficult to classify early tetrapods because their origin and early radiation occurred within several distinct environments, having different likelihoods of preservation in the sedimentary record. The immediate ancestors of amphibians were osteolepiform fish, which were common in near shore marine to estuarine environments that left an extensive sedimentary record. The oldest known (latest Devonian) amphibians were also widespread at the margins of marine environments. In contrast, very few fossils are known from the succeeding 20 to 30 m.y. of amphibian evolution, during which time ancestral tetrapods adapted to life in shallow fresh water and radiated into more fully terrestrial environments. This gap in the fossil record can be attributed to the much lower probability of preservation. Freshwater deposits are always much less likely to be preserved in the sedimentary record, both because they occupied much less surface area than marine deposits, but also because lakes, ponds, and rivers persist for much briefer periods of time. The ox-bow lake deposits of the Carboniferous coal-swamps, which have a particularly rich amphibian fauna, are each estimated to have lasted no more than about 10,000 years (DiMichele and Hook, 1992). Animals living away from the main water courses are even less likely to leave an informative fossil record.

THE ORIGIN OF TETRAPODS

We are fortunate in having an exceptionally good fossil record of osteolepiform fish from the Middle and Late Devonian of many parts of the world (Long, 1993; Ahlberg and Johanson, 1998). Although fishlike in general body form (Fig. 1.1, 1.2), members of this group can be allied with Late Devonian and Carboniferous tetrapods on the basis of numerous synapomorphies of the skull, vertebrae, and appendicular skeleton (Clack, 2000). Unlike any other group of fish, they possess internal nostrils, like those of all tetrapods. The pattern of bones of the skull roof are more similar to those of early tetrapods than are those of any other group of lobefinned fish, and the configuration of the proximal limb bones can be directly compared with the humerus, ulna, and radius of the forelimb, and the femur, tibia, and fibula of the hind limb. More distal elements can be compared with the proximal bones of the wrist and ankle.

The most tetrapod-like of the osteolepiforms is *Panderichthys*, which has lost the dorsal and anal fins as well as the dorsal and ventral lobes of the caudal fin, presumably in relationship with adaptation to life in very shallow water. The margins of the orbits are raised above the general surface of the skull. The most important change between *Panderichthys* and early amphibians is the modification of the paired fins into tetrapod limbs (Fig. 1.3). Following Darwin (1859), such changes have long been hypothesized as resulting from selection among naturally occurring genetic variations.

It has only been within the last 15 yr that discoveries in molecular genetics have revealed the nature of master control genes that influence the development of major structural features of metazoans (Gehring, 1998). Based on developmental differences observed in modern species, it is now possible to understand how these difference have evolved and so to explain how major morphological changes have occurred. The origin of fingers and toes in early tetrapods can be associated with changes in the expression of the *Hox* genes that regulate development of the body axis and appendages (Shubin et al., 1997). In modern ray-finned fishes, *Hox* genes *d9* to *d13* are expressed in an overlapping, linear sequence from the proximal to the distal end of the limb, along its posterior surface. Tetrapods differ in the extension of the area of expression of the most distal gene, *Hoxd-13*, so that it occupies a more anterior position along the entire distal end of the limb, in the position where the fingers and toes will form (Fig. 2). This can be associated with the distal extension of the limb and the formation of digits in an posterior to anterior sequence in most land vertebrates.

While it was apparently changes in the timing and position of gene expression that enabled the fins to achieve the form of a primitive tetrapod limb, there must have been a long term selective advantage for the formation of distinct digits rather than a broad fin for the prototetrapod with this genetic pattern to have survived and propagated. The skull of *Panderichthys* is truly intermediate between those of fish and tetrapods in its proportions and degree of integration of originally separate bones (Carroll, 1996). Unfortunately, no fossil is yet known that shows an intermediate structure between that of a fish fin and the tetrapod limb, but disarticulated skeletal elements are known from Late Devonian deposits that indicate the possibility for the discovery of truly intermediate structures during this time interval. Although these animals are not well known, differences in the size and proportions of the skull indicate a modest adaptive radiation during the transition between obligatorily aquatic fish and facultatively terrestrial amphibians, which occupied a period of approximately 15 m.y. (Ahlberg, 1991, 1995).

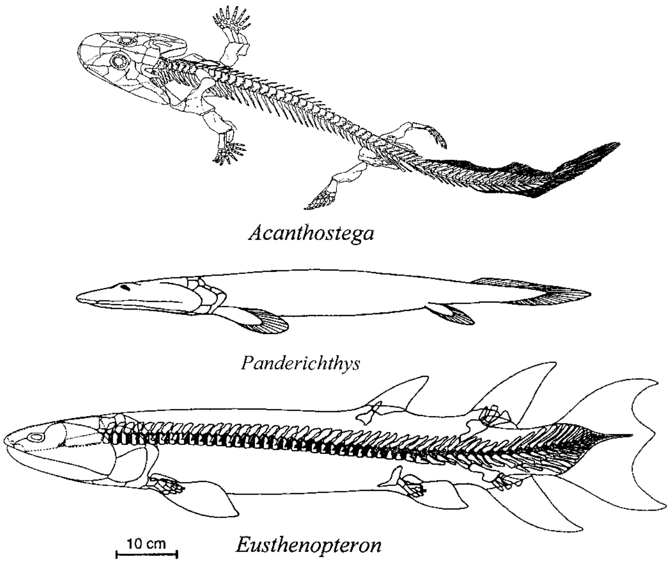

FIGURE *1*—The transition between osteolepiform fish and primitive amphibians represented by *Eusthenopteron* and *Panderichthys* from the Frasnian and *Acanthostega* from the Famennian (Upper Devonian), a period of approximately 15 m.y. *Eusthenopteron* and *Panderichthys* from Carroll (1997), *Acanthostega* from Coates (1996).

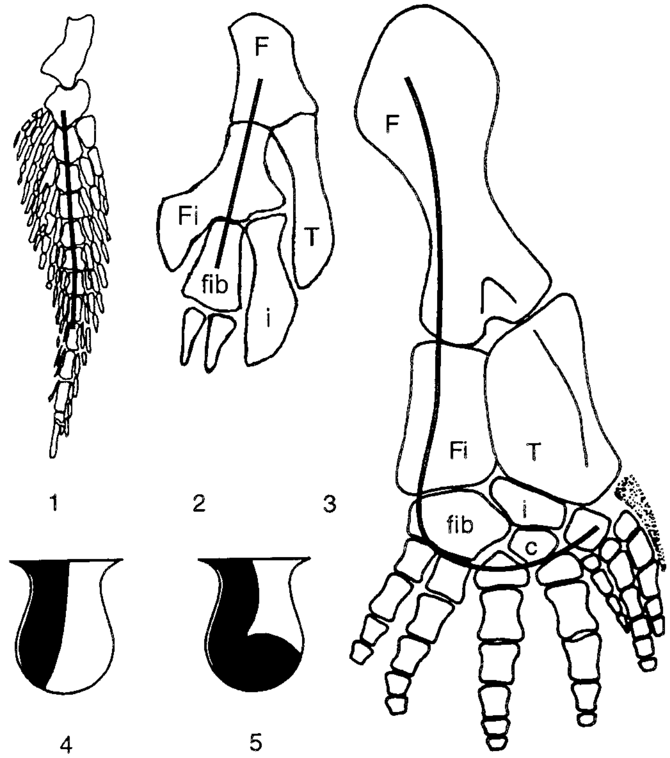

FIGURE *2*—Changes in the axis of development and the expression of *Hox* genes between bony fish and tetrapods. *1,* endochondral bones of the limb of a modern lungfish, showing both preaxial (anterior) and postaxial (posterior) radials, extending from the main axis of development; *2,* limb bones of the osteolepiform fish *Eusthenopteron,* in which all radials are preaxial; *3,* hind limb of the early tetrapod *Ichthyostega,* in which the axis of development angles forward and the distal tarsals and digits develop in a posterior to anterior sequence; *4,* area of expression of *Hoxd 13* in the living zebra fish; *5,* area of expression of *Hoxd 13* in modern tetrapods. From Carroll (1997). Abbreviations: c—centrale; F—femur; Fi—fibula; fib—fibulare; i—intermedium; T—tibia.

Knowledge of the entire skeleton of advanced osteolepiform fish and Upper Devonian tetrapods shows that rates of change vary greatly among the various parts of the body (Clack, 2000). However, even the most rapid changes, seen in the limbs, ribs, and braincase, may have occurred no more rapidly than those that have been measured within well known lineages of Cenozoic mammals. The total amount of morphological change in this transition can be accounted for by rates of evolution, estimated for the time span between generations, that are far slower than those recorded in modern populations (Gingerich, 1993; Lofsvold, 1988). As is the case for other major transitions that are adequately known from the fossil record, it is not necessary to hypothesize especially high rates of change in the fish-amphibian transition, but only that the direction of selection and so the direction of change are relatively constant, rather than rapidly fluctuating, as is usually the case during most of the evolutionary history of individual clades. What distinguish the long-term changes in the origin of tetrapods were the many selective factors associated with the shift in environment from sea to fresh water and onto land. These included locomotion, support, feeding, respiration, the sensory apparatus, and reproduction. All changed in the long run, but the rate and time of change varied greatly from system to system and from lineage to lineage. The structure of the limbs and ribs changed early and rapidly, the pattern of the skull bones changed more slowly and irregularly, and a fully terrestrial mode of reproduction only evolved in one lineage—that leading to amniotes—long after the changes in the skeletal anatomy and way of life of the adults.

DEVONIAN AND PRIMITIVE CARBONIFEROUS AMPHIBIANS

Upper Devonian amphibians were diverse, both structurally and in terms of geographical distribution, being known from Scotland (Ahlberg, 1998), central Russia (Lebedev and Coates, 1995), Latvia (Ahlberg et al., 1994) eastern United States (Daeschler et al., 1994) and Australia (Campbell and Bell, 1977). The best known are *Ichthyostega* and *Acanthostega* from East Greenland (Clack, 2000). These animals, approaching a meter in length, have more digits than any later tetrapods (from 6 to 8 on each limb), but the limbs generally appear like those of most early amphibians. However, Clack and Coates (1995) stressed the presence of a very fish-like tail and the retention of gill supports suggestive of aquatic respiration to argue that these animals may have been largely aquatic in their habits, and suggested that ''tetrapod'' limbs may have evolved in primarily aquatic animals. *Tulerpeton,* from the Upper Devonian of Russia, is found in a deposit with a rich fauna of marine invertebrates. The presence of an Upper Devonian amphibian in Australia may have resulted from their extensive distribution via marine waters, along the coasts of the continents.

Following the very informative fossil record in the Late Devonian, there is a gap of 20 to 30 m.y. before we have evidence of the initiation of the major tetrapod lineages of the mid- and Upper Carboniferous. Coates and Clack (1995) refer to this as ''Romer's gap,'' in reference to Dr. Romer's long search for Early Carboniferous amphibians. This presumably represents a crucial period in the further penetration of vertebrates into a more strictly terrestrial environment.

Within the Lower Carboniferous and Namurian A, most of the known localities preserve a more or less uniform fauna, dominated by obligatorily aquatic amphibians and a diverse assemblage of fish (Carroll, 1994). In common with the Upper Devonian tetrapods, most retained lateral line canal grooves, and some lineages evolved an elongate trunk and diminutive limbs. These animals presumably retained the feeding patterns of their Devonian predecessors, with dependency on large, aquatic vertebrates. This environment was occupied by very similar species in what are now recognized as the continents of Europe, North America, and Australia. The Upper Devonian amphibians and many of their Lower Carboniferous descendants retained the relatively large size of their sarcopterygian predecessors. They may also have retained a mode of development similar to that of their fish ancestors.

No juvenile specimens of *Panderichthys* or any of the Upper Devonian amphibians have yet been discovered, but a long growth series, beginning with specimens 3 cm in length, has been described for the well known Frasnian osteolepiform *Eusthenopteron* (Cote et al., 2001). In contrast with modern amphibians, there is no evidence of a distinct larval stage. The juveniles resemble the adults in body proportions and lack external gills. There is no evidence of metamorphosis. A surprising feature is the direction of ossification of the vertebrae. In contrast with living tetrapods, which ossify the column from anterior to posterior, *Eusthenopteron* ossified from the tail forward, presumably because of the necessity for effective swimming at a very small size to catch prey and avoid predation. External gills would not have been necessary in well-aerated coastal waters. The retention of a long caudal fin in *Ichthyostega* and *Acanthostega* indicates emphasis on the tail for locomotion and suggests that they may have retained the sequence of vertebral ossification seen in *Eusthenopteron.*

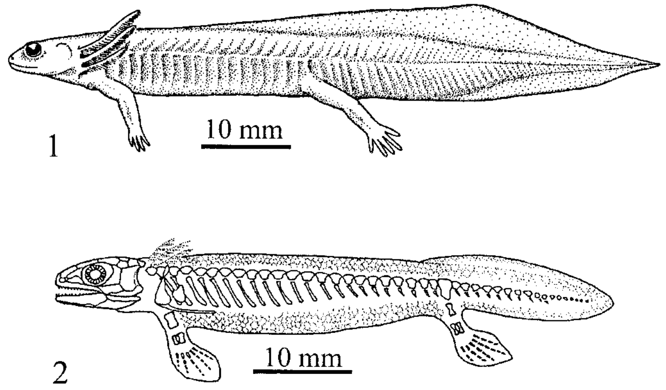

FIGURE 3—Larvae of labyrinthodonts. *1, Apateon,* a temnospondyl larva, found by the thousands from Lower Permian beds in Europe (from Milner, 1982); *2,* larva of the seymouriamorph *Ariekanerpeton* from the Lower Permian of Central Asia. The seymouriamorphs are typically placed within the Anthracosauroidea or Reptiliomorpha, with suggested affinities with amniotes (from Laurin, 2000).

ADVANCED PALEOZOIC AMPHIBIANS

It wasn't until approximately 30 m.y. after the appearance of amphibians in the Upper Devonian that fully terrestrial tetrapods, with well developed limbs and lacking lateral line canals in the adults, are known. In marked contrast with other Early Carboniferous deposits, the late Viséan locality of East Kirkton, near Edinburgh, Scotland, preserves a diverse fauna of primarily terrestrial amphibians (Rolfe et al., 1994). Although fish are common in some horizons, they do not occur in the tetrapod-bearing beds. Most of the amphibians can be assigned to major lineages that dominated the later Paleozoic, and presumably included close relatives of most of the living tetrapod clades. Not only are the adults of most of these animals clearly distinct from earlier taxa, but the immature specimens show evidence of different patterns of ontogenetic development, which distinguish major clades of more advanced tetrapods.

Labyrinthodonts.—By the late Viséan of East Kirkton, three major assemblages, not common in fully aquatic deposits, can be recognized—terrestrially adapted labyrinthodonts, lepospondyls, and a sister taxon of amniotes. All are differentiated by derived structures and/or patterns of development of the vertebrae. The most diverse assemblage are the labyrinthodonts, consisting of temnospondyls and anthracosaurs. They retained the relatively large size of their Late Devonian ancestors and the presence of multipartite vertebrae, which formed developmentally from paired neural arches, pleurocentra, and intercentra. Labyrinthodonts from the Upper Carboniferous and Permian had clearly distinguishable larval stages, termed branchiosaurs, with conspicuous external gills (Fig. 3) (Boy and Sues, 2000). In contrast with *Eusthenopteron,* vertebral ossification proceeded from anterior to posterior, suggesting less emphasis on caudal locomotion than on the limbs. The postcranial skeleton, and especially the vertebrae, carpals and tarsals, were very slow to ossify (Fig. 4.1). A juvenile specimen of the temnospondyl *Balanerpeton* from East Kirkton closely resembles later branchiosaurs (Milner and Sequeira, 1994).

We can only speculate on the sequence and timing of events leading to such a biphasic life history, during the roughly 30 m.y. since the Late Devonian. Clearly, reproduction in the earliest tetrapods occurred along the margins of the continents, in estuarine, brackish water environments, intermediate between the open sea and the marshes, deltas, and river mouths where fresh water was encountered.

East Kirkton, as well as many of the previously known Carboniferous localities, represent primarily quiet, partially isolated bodies of fresh water. These included vegetation-clogged ponds, coal swamps, and ox-bow lakes, which would have been commonly depleted in oxygen. This would have required the evolution of external gills in the relatively large larvae of both temnospondyl and anthracosaurian labyrinthodonts. The East Kirkton fauna lived within and around a moderately large lake, the water chemistry and temperature of which were influenced by local volcanic activity. The ephemeral nature of these bodies of water may have restricted the number of large aquatic predators. Both fish and tetrapods are known from East Kirkton, but they are always found in different horizons (Clarkson et al., 1994). The East Kirkton labyrinthodonts were amphibians in the modern sense, with obligatorily aquatic larvae, a more or less conspicuous metamorphosis, and a terrestrial adult stage.

Lepospondyls.—Two other groups are represented at East Kirkton whose later members lack distinct larval stages, and show no evidence of external gills. Both are characterized by rapid ossification of the vertebrae at a small body size. The lepospondyls are represented by the aïstopods, which were already highly specialized in the fenestration of the skull, the great elongation of the vertebral column, and the complete loss of limbs (A. C. Milner, 1994). The distinctive nature of the lepospondyls was initially recognized by Zittel (1890), based on the presence of cylindrical centra, fused to the neural arches, in contrast with the multipartite vertebrae of labyrinthodonts.

Adult lepospondyls are most clearly distinguished from labyrinthodonts by their small body size. Labyrinthodonts show a very wide range of skull sizes, from 5 cm to 50 cm, while most lepospondyls had a skull length of 2 cm to 3 cm, with little overlap between the sizes of the two groups (Fig. 5). Small size is most plausibly interpreted as an adaptation to feeding on small prey, such as the burgeoning population of small adult insects and other fresh water and terrestrial arthropods. Many of the anatomical features that distinguish the lepospondyl orders from labyrinthodonts and from one another can be attributed to miniaturization and paedomorphosis—the retention of juvenile traits into the adult. Structures such as labyrinthodont infolding of the dentine, that only appear late in labyrinthodont ontogeny, are seen in only

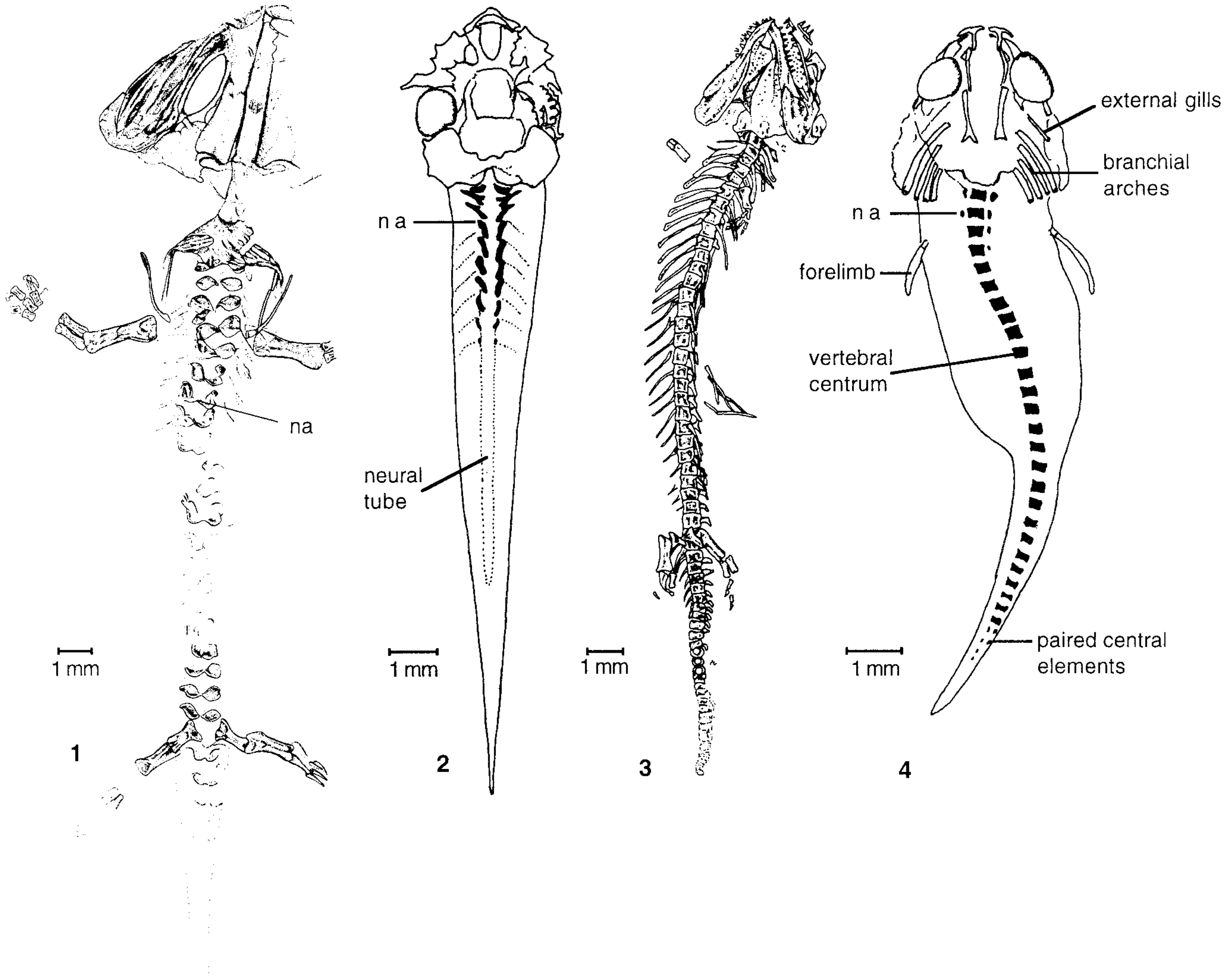

FIGURE 4—Patterns of vertebral development in Paleozoic and modern amphibians. *1,* branchiosaur, in which the neural arches ossify long before the centra, in an anterior to posterior direction, with the caudal vertebrae being the last to develop; *2,* larval frog, *Rana pipiens,* in which the arches are chondrified, but there is no trace of centra. No elements of the vertebrae develop in the tail; *3,* the Carboniferous microsaur *Hyloplesion,* in which cylindrical centra are ossified in the tail of the smallest specimens known; *4,* the primitive living salamander *Salamandrella,* in which cylindrical centra extend into the tail, but only a few neural arches are chondrified at the very front of the column. Abbreviation: na—neural arch. From Carroll et al. (1999).

the very largest lepospondyls. Individual skull bones and other anatomical features that are late to develop in labyrinthodonts are variably lost in lepospondyls. Hanken (1984) showed that miniaturization in salamanders can be attributed to hyperossification at small size, which, by analogy with lepospondyls, also explains the formation of cylindrical centra and their frequent fusion with the neural arches at a very small size.

The lepospondyls were an extremely varied assemblage including the limbless aïstopods and adelogyrinids, the newtlike nectrideans (all of which have long, laterally compressed tails), the lysorophids, with extremely fenestrate skulls and elongate trunks but retaining rudimentary limbs, and the salamander- to lizardlike microsaurs, with solidly roofed skulls and typically retaining well developed limbs (Fig. 6). Although no external gills or obviously larval stages have been recognized among this assemblage, members of several groups had lateral line canal grooves and others retained a ossified hyoid apparatus, indicative of aquatic feeding and respiration. It is assumed that lepospondyls were physiologically amphibians in lacking the extraembryonic membranes of amniotes and laying their eggs in the water. Only a single group of lepospondyls is known from East Kirkton, the aïstopods, but these were the most highly specialized members of the entire assemblage. The adelogyrinids, microsaurs, nectrideans, and lysorophids appear in the fossil record progressively during the middle portion of the Carboniferous.

Amniotes.—Clearly distinct from the labyrinthodonts and lepospondyls of the East Kirkton fauna is the genus *Westlothiana* (Smithson et al., 1994) that appears to be a sister-taxon of the amniotes, which became clearly distinguishable by the mid-Pennsylvanian. In common with lepospondyls, *Westlothiana* shows precocial ossification of the vertebrae at a small size. However, more specific features of the vertebrae, including the retention of large intercentra, as well as the structure of the well ossified tarsus and the pattern of the bones of the skull table,

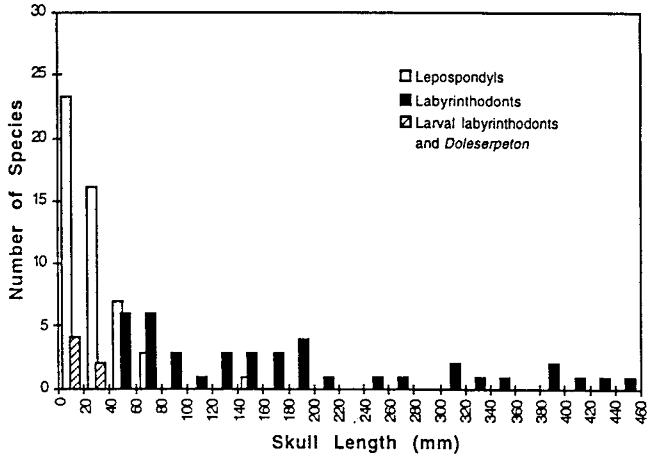

FIGURE 5—Size distribution of cranial length in Paleozoic amphibians. Open bars: lepospondyls. Solid bars: adult labyrinthodonts. Hatched bars: larval, possibly neotenic branchiosaurs and *Doleserpeton*; these are strongly supported candidates for the sister-taxa of frogs and salamanders. From Carroll (1999).

point to amniotes rather than any lepospondyls as close sister-taxa (Carroll, 1991).

Paton, Smithson, and Clack (1999) described an even earlier species, *Casineria kiddi,* from the Cheese Bay Shrimp Bed of Scotland, with highly ossified vertebrae and a five-toed manus resembling those of early amniotes, suggesting a very early divergence of this lineage from other descendants of the Paleozoic tetrapod assemblage. The structure of the manus in *Casianeria,* the foot of *Westlothiana,* and the vertebrae of both genera, suggest affinities with anthracosaurs, although neither is sufficiently complete for an effective cladistic analysis.

In contrast with the modern amphibian orders, which are not recognizable until the Jurassic, ancestors of the modern reptiles, birds, and mammals, are known from the Upper Carboniferous (Carroll, 1982). The ancestral amniotes were small animals, superficially resembling primitive, insectivorous lizards. Most early amniote fossils were preserved under conditions indicative of a fully terrestrial way of life. The oldest of all were found in upright stumps of the lycopod *Sigillaria,* a place of burial that could only be reached by land animals (Carroll, 1964, 1969).

The rarity of older terrestrial deposits has limited our knowledge of their specific relationships among earlier tetrapods. Like the origin of the many lineages of lepospondyls, that of the amniotes was certainly associated with miniaturization and hyperossification. Like lepospondyls, early amniotes ossify fully cylindrical centra at a very small size, but unlike most members of

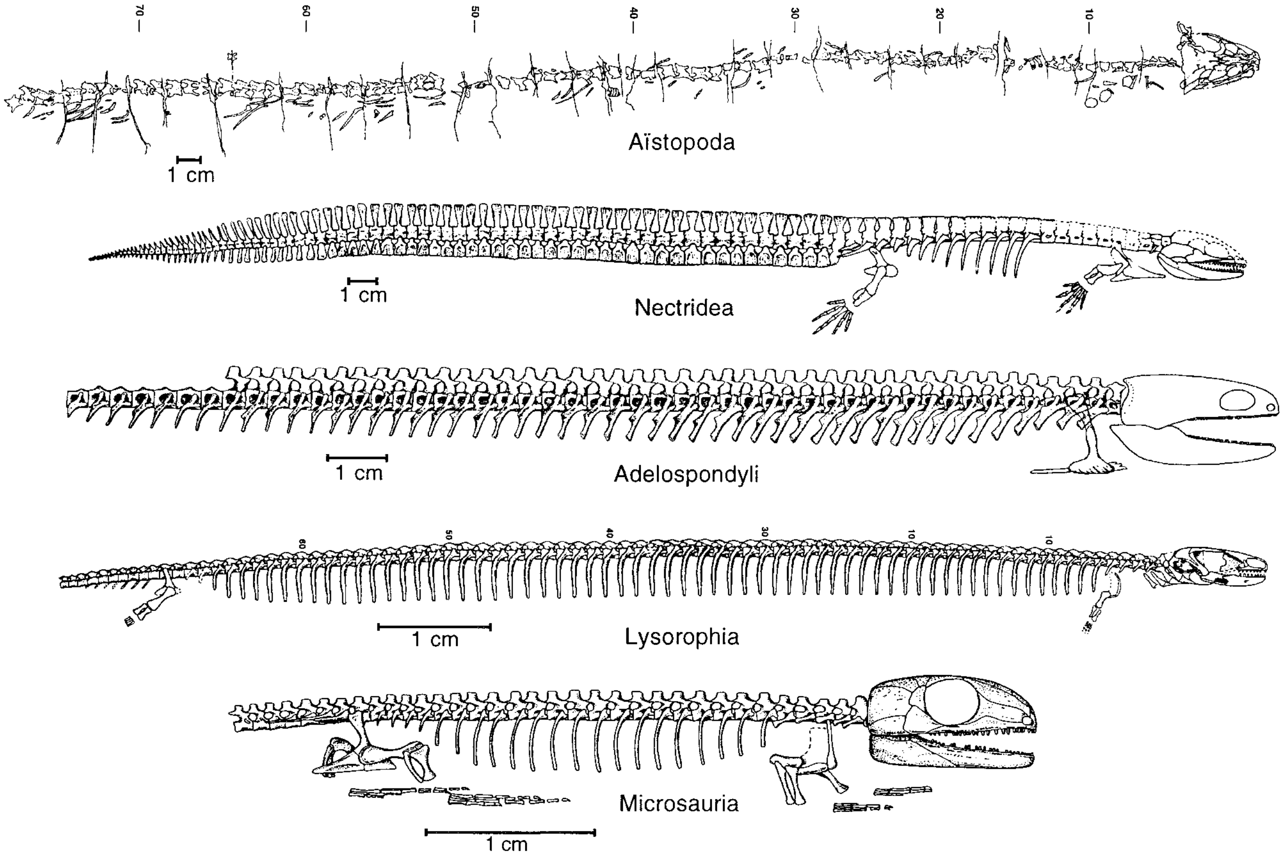

FIGURE 6—Reconstructions of the skeletons of the earliest and most primitive adequately known species of the five major clades of lepospondyls. The Aïstopoda is represented by *Lethiscus stocki* from the Mid-Viséan, Lower Carboniferous, of Scotland. The Nectridea is represented by *Urocordylus wandesfordii,* Westphalian A, Upper Carboniferous, Ireland. The Adelospondyli by *Palaeomolgophis scoticus,* Viséan of Scotland. The lysorophid is *Brachydectes newberryi,* Westphalian D, Upper Carboniferous, Ohio. The microsaur is *Utaherpeton franklini,* lower portion of Upper Carboniferous, Utah. Illustrations modified from Carroll et al. (1998).

that group, the intercentra remain large throughout the trunk region. The most important other feature of the vertebrae is the retention of a multipartite atlas-axis complex, which allowed controlled movement of the head in all planes. No lepospondyl has more than one element of the atlas centrum, and in most orders movement is limited to hinging in the vertical plane.

The problems of classification.—The sudden appearance of several major groups of tetrapods in the late Viséan makes it difficult to establish their interrelationships and thus those of their descendants, which include the ancestors of all modern tetrapods (Fig. 7).

Of all the lineages known from East Kirkton and other mid- to Late Carboniferous deposits, only one, the anthracosaurs or reptiliomorphs, appears to show specific affinities with any of the Upper Devonian tetrapods. Bones attributed to *Tulerpeton* (Lebedev and Coates, 1995) from central Russia retain primitive cranial features, including an intertemporal bone and mobility between the skull table and cheek, that are shared with later anthracosaurs but not with the very diverse temnospondyls. Isolated humeri from the earliest known Carboniferous locality of Horton Bluff are appropriate intermediates between those of *Tulerpeton* and later anthracosaurs (Clack and Carroll, 2000), but both *Acanthostega* (Coates, 1996) and *Ichthyostega* (Jarvik, 1996) have numerous autapomorphies that preclude close comparison with any other Paleozoic tetrapods. Among Paleozoic amphibians, only anthracosaurs share significant similarities with amniotes, but even the earliest known stem amniote, *Casineria,* is too highly derived for detailed comparison.

Most Paleozoic labyrinthodonts belong to the Temnospondyli (Holmes, 2000). They appear to be monophyletic in origin, but their specific relationships to Upper Devonian or other Carboniferous labyrinthodonts remain uncertain. Many Carboniferous temnospondyls appear to have been primarily terrestrial in habits, with strong limbs, but no lateral line canals. On the other hand, numerous lineages returned to a more amphibious way of life. This was carried to its extreme within a major secondary radiation, beginning in the Late Permian and continuing into the Early Cretaceous—the stereospondyls (Warren, 2000).

All of the taxa grouped as lepospondyls are highly derived when they first appear in the fossil record, with no plausible intermediates between them and any other groups of Paleozoic tetrapods. Many attempts have been made to classify the lepospondyls, using both cladistic analysis and other means (Carroll, 1995; Carroll and Chorn, 1995; Carroll et al., 1998; Laurin and Reisz, 1997; Anderson, 2001), but the disparity of the resulting cladograms is too great to give any of them credence. Relationships of lepospondyls among one another, and with any of the labyrinthodont groups can only be established on the basis of new discoveries of fossil from the Lower Carboniferous that show intermediate morphologies.

THE ANCESTRY OF THE MODERN AMPHIBIAN ORDERS

Most Carboniferous tetrapods have been classified among the amphibians, yet none is an obvious relative of the modern frogs, salamanders, and caecilians (poorly known, elongate, limbless animals of the wet tropics). The oldest known fossils that are assuredly assigned to these orders are from the Lower and Middle Jurassic, separated by a gap in the fossil record of approximately 100 m.y. from any plausible Paleozoic ancestors. The oldest known frogs are structurally similar to modern genera, with the rear limbs and pelvic girdle already highly specialized for jumping (Jenkins and Shubin, 1998). Middle Jurassic salamanders are more primitive than members of the modern families, but unequivocally belong to the Urodela (Milner, 2000). Upper Jurassic salamanders from China closely resemble living hynobiids and cryptobranchids (Gao and Shubin, 2001). Although still retaining tiny limbs, the Lower Jurassic caecilian *Eocaecilia* is already elongate, and the skull and lower jaws show many of the highly derived characters that contribute to the unique jaw closing apparatus of living genera (Jenkins and Walsh, 1993; Carroll, 2000).

Although it is generally believed that the three orders had a unique common ancestry distinct from that of amniotes, no known fossil can be recognized as an immediate common ancestor, nor a plausible sister-taxon of such a group. Radically different taxa have been proposed as putative sister-groups. Most studies support ancestry among the temnospondyl amphibians, specifically among the families Amphibamidae and Branchiosauridae (e.g., Bolt, 1969, 1991; A. R. Milner, 1993, 2000), but Laurin and Reisz (1997) hypothesized the Lysorophia among the lepospondyls as the closest sister-taxon (Fig. 6). The Lysorophia shares some characters with each of the three groups: greatly elongate body with much reduced limbs in common with the earliest known caecilian, a fenestrate skull, vaguely comparable with those of frogs and salamanders, and loss of many similar skull bones, but the total configuration is that of a chimera that has no unique derived characters in common with any of the individual orders.

Although numerous individual characters, including pedicellate teeth, cutaneous respiration, green glands, and other aspects of the soft anatomy are found in all three orders, most features of their anatomy and way of life are highly divergent, notably their manner of locomotion and the nature of their larvae. Whatever their ultimate common ancestry, each order must have had a long period of independent evolution, going back into the Carboniferous. Rather than trying to find an immediate common ancestor, the approach taken here will be to look for the most plausible ancestry of each order separately. If a similar ancestry is discovered for all three, then this will demonstrate the likelihood of an immediate common origin.

Caecilia.—The recent discovery of numerous, well-preserved caecilians from the Lower Jurassic of Arizona provides a strong basis for establishing their relationships with Paleozoic amphibians (Jenkins and Walsh, 1993; Carroll, 2000; Jenkins, Walsh, and Carroll, MS in prep.). This genus, *Eocaecilia* (Fig. 8.1) closely resembles recent caecilians in the general configuration of the skull, specifically the unique and highly derived configuration of the lower jaw indicative of the use of the interhyoideus posterior as the primary jaw closing muscle. The trunk was already greatly elongated, although much reduced fore and hind limbs were retained. The closest resemblance among Paleozoic amphibians lies with the lepospondyl microsaur *Rhynchonkos,* which has a very similar skull, elongate trunk, and small limbs (Fig. 8.2). If we limit our consideration to caecilians, certainly their most parsimonious origin is from this microsaur. Neither *Eocaecilia* nor *Rhynchonkos* have any features bearing on the origin of either frogs or salamanders. In particular, the skull roof is complete, without an orbitotemporal opening, and there are large postparietal bones, missing in all later lissamphibians. *Eocaecilia* does, however possess pedicellate teeth, long considered a synapomorphy of the modern amphibian orders. They are not present in any microsaur.

Anura.—Frogs and salamanders share more similarities than either does with caecilians, but they are still highly divergent. In addition to differences in limb proportions, manner of locomotion, and the nature of their larvae, are the typical patterns of vertebral development. A late larval stage of the common frog *Rana pipiens* shows a series of paired, cartilaginous neural arches that form in an anterior to posterior sequence from the head to the sacrum (Fig. 4.2). This is followed by the formation of cartilaginous centra and the subsequent ossification of both elements. Representatives of all modern frog families that have been studied show a similar pattern of vertebral development (Carroll et al., 1999). A very similar pattern is seen in the development of vertebrae in Paleozoic branchiosaurs (Fig. 4.1). The slow appearance

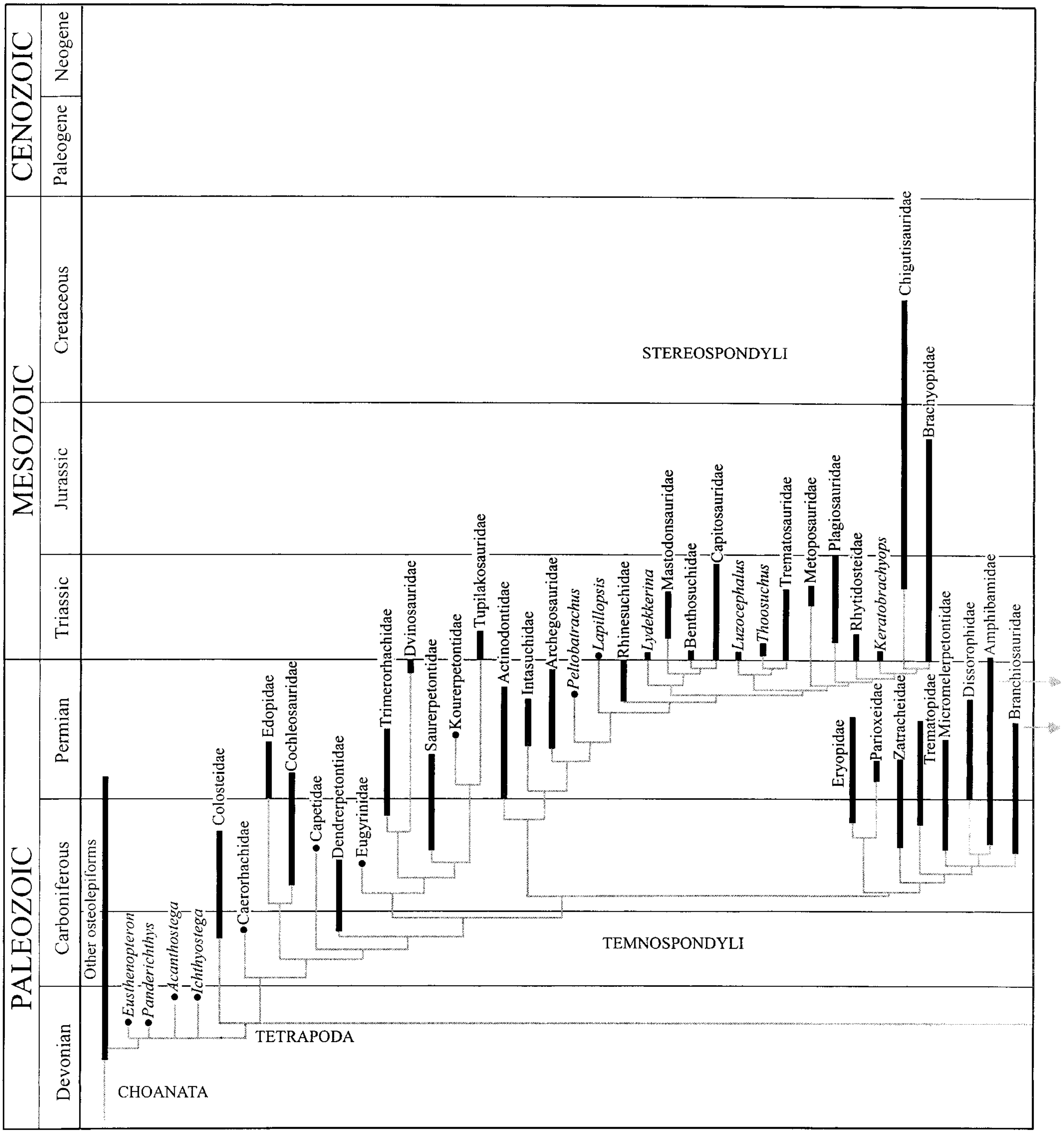

FIGURE 7—Phylogeny of the Amphibia based on data in Heatwole and Carroll (2000). Dark lines represent known fossil record at the family level. Gray lines indicate ghost lineages based on approximate duration of sister-taxa. The fossil record of modern amphibians is too incompletely known to give a reliable estimate of ghost lineages.

of the tail in branchiosaurs provides the mechanism for the absence of caudal vertebrae in tadpoles, which can be attributed simply to the delay and later cessation of chondrification and ossification behind the sacrum.

Close affinities between frogs and temnospondyls have long been assumed on the basis of the cranial similarities between most frogs and members of the temnospondyl families Dissorophidae and Amphibamidae, both of which have well-developed, froglike otic notches, and a stapedial structure strongly suggestive of an impedance matching middle ear. *Doleserpeton*, which Bolt (1969, 1991) hypothesized as ancestral to all three lissamphibian orders, has especially close resemblance to frogs

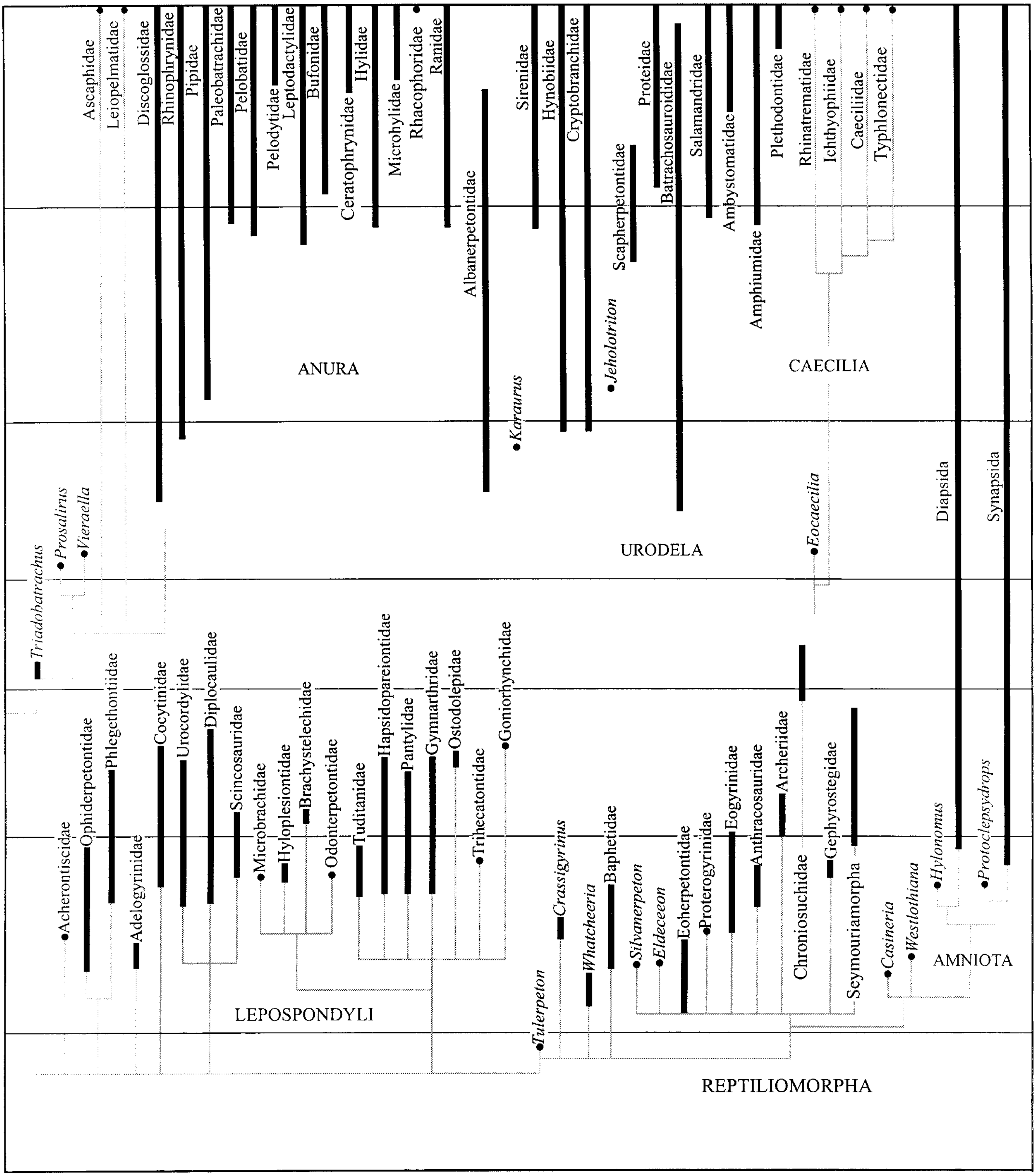

FIGURE 7—Continued.

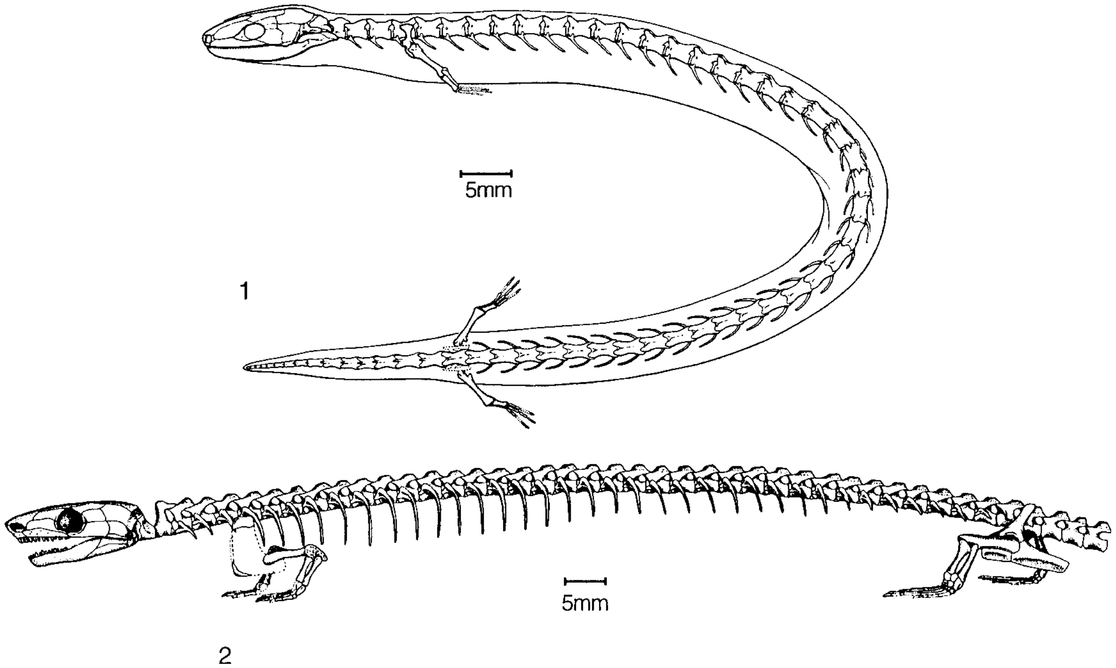

FIGURE 8—Comparison of caecilian and microsaur skeletons. *1,* Reconstruction of the skeleton of the Lower Jurassic caecilian *Eocaecilia,* from Jenkins and Walsh (1993). *2,* Reconstruction of the skeleton of the Lower Permian goniorhynchid microsaur *Rhynchonkos,* from Carroll and Gaskill (1978).

in the bicondylar articulating surface of the atlas, unlike that of any other Paleozoic temnospondyls, and the development of the trunk vertebrae, which pass ontogenetically from multipartite to a strong fusion between a cylindrical centrum and the neural arch.

Further confirmation of a temnospondyl origin for frogs is provided by the roughly intermediate anatomy of the Lower Triassic *Triadobatrachus*, which has a shortened trunk, a very small number of caudal vertebrae, and, most importantly, a forwardly angled iliac blade. The skull resembles that of modern frogs in the presence of conspicuous otic notches, a fused frontoparietal, and orbitotemporal openings. This establishes a protoanuran morphology as early as the Lower Triassic, with no obvious similarities with either salamanders or caecilians (Roček and Rage, 2000).

Caudata.—This leaves the salamanders as the only group without a clearly evident Paleozoic ancestry. After recognizing the very temnospondyl features of vertebral development in frogs, attention was focussed on their ontogeny in salamanders. Many salamanders including *Salamandrella,* a member of the most primitive family, Hynobiidae, show a very different pattern of development from that seen in frogs, with the centra forming well before the neural arches (Fig. 4.4). This is comparable to the pattern seen in lepospondyls, suggesting that salamanders might share a closer common ancestry with that group rather than with labyrinthodonts, indicating a very distinct origin from that of frogs.

Further investigation showed that vertebral development in salamanders was much more varied than that in frogs, with some salamanders, including the hynobiid *Ranodon* and the more derived *Dicamptodon* (Wake and Shubin, 1997) showing a typical anuran sequence. This opens up the possibility of a common ancestry from among temnospondyl labyrinthodonts. In fact, the larvae of modern salamanders show strong similarities with the branchiosaur larvae of labyrinthodonts. Figure 9 shows a branchiosaurid from the Lower Permian of Germany. It combines the presence of salamander-like external gills and well-developed limbs with a frog or labyrinthodont sequence of vertebral development, and a skull retaining an otic notch.

Other specimens show the area of the gill openings and associated "gill rakers," which closely resemble those of the larvae of modern salamanders, specifically *Ambystoma* (Fig. 10). There are six rows of individual denticles in branchiosaurids, interdigitating across the three gill slits like the teeth of a zipper. Research by Lauder and Schaffer (1985) showed that similar shaped "gill rakers" in *Ambystoma* are used to close the gill slits to form a more effective vacuum for drawing in prey when using gape and suck feeding. The pattern of denticles common to salamanders and branchiosaurids is clearly derived relative to that of all other temnospondyl families, in which non-interdigitating "gill rakers" arise from four rows of broad bony platelet associated with the ceratobranchials.

Frog tadpoles, known as early as the Early Cretaceous, have an entirely different feeding appartus than that of salamanders or branchiosaurs, specialized for suspension feeding on microscopic plant material. The proportions and structure of the limbs in branchiosaurids are also more similar to those of salamanders than they are to frogs, with both front and hind limbs present in the larvae, and of comparable size.

A major stumbling block to accepting a labyrinthodont origin for salamanders has been the fact that adult temnospondyls have a conspicuous otic notch, implying an impedance-matching middle ear. If salamanders evolved from branchiosaurids, we must assume that they had lost a prior capacity to detect high frequency, airborne vibrations. Most Lower Permian branchiosaurids are known from large lakes that were permanent on an ecological time scale. This suggests that selection may have acted to elaborate structures associated with aquatic feeding. If one compares the skulls and hyoid apparatus of branchiosaurids and salamanders, one sees a possible conflict between two functions of the cheek region—aquatic feeding and reception of air-borne sound. Most adult frogs have a large, air-filled middle ear chamber medial to the tympanum. The adductor muscles of the cheek region

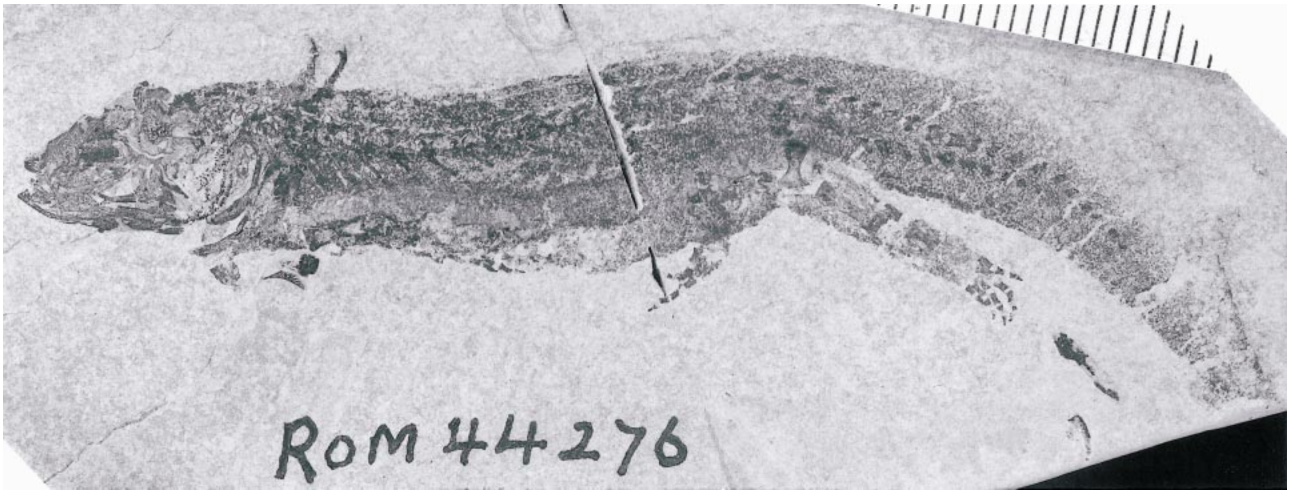

FIGURE 9—Royal Ontario Museum, Toronto, Canada 44276, skeleton of a larval Branchiosauridae, Apateon Lower Permian, Rehborn, Germany. Scale bar in 1 mm intervals.

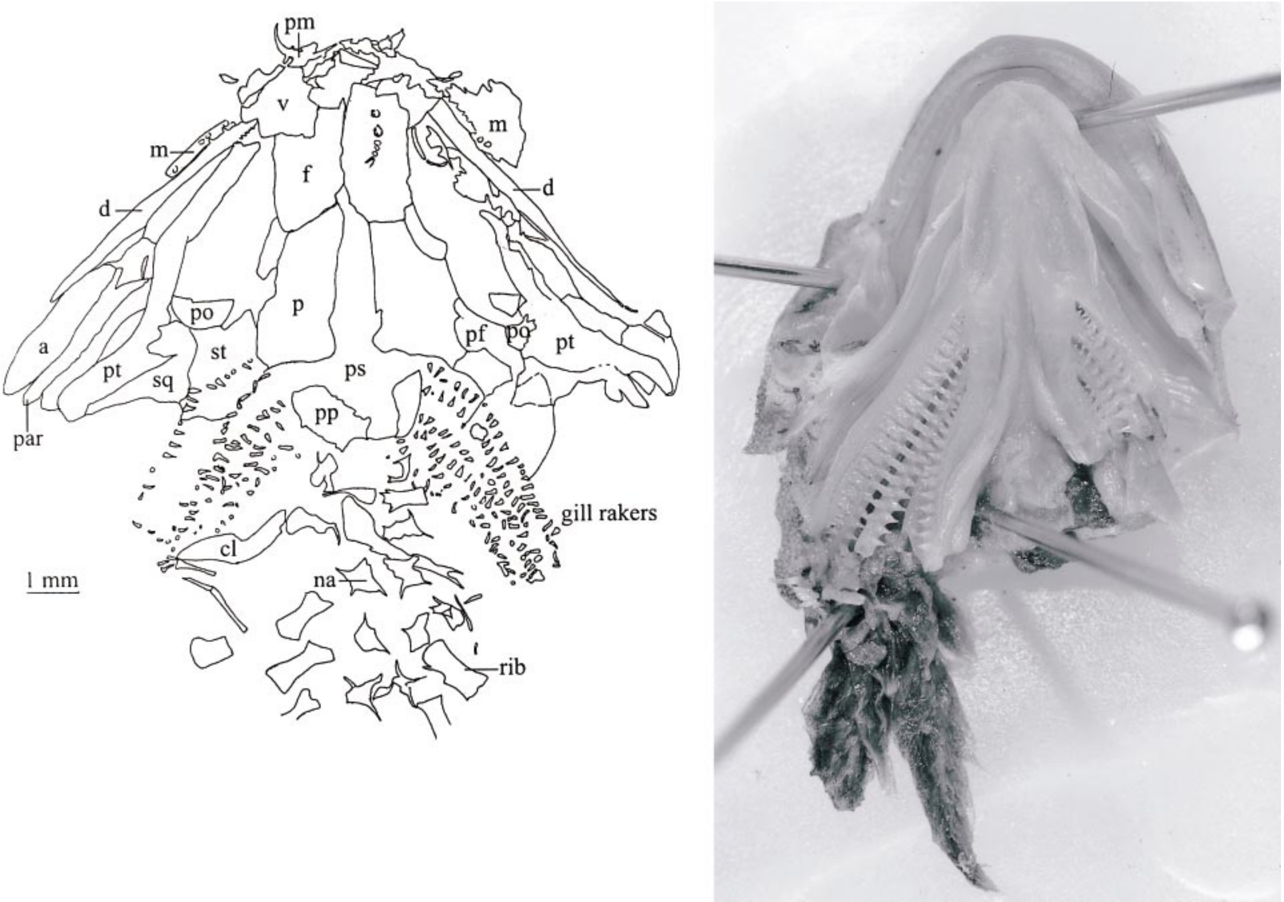

FIGURE 10—Left, Royal Ontario Museum, Toronto, Canada 44276, dorsal view of the skull of a branchiosaurid, Apateon Lower Permian, Rehborn, Germany. Right, dorsal view of the lower jaws and branchial region of *Ambystoma tigrinum*, Canadian Museum of Nature, Ottawa, Canada 7255, from 7.3 mi east of Spruce Grove, Alberta. Abbreviations: a—angular; cla—clavicle; d—dentary; f—frontal; m—maxilla; na—neural arch; p—parietal; par—prearticular; pf—postfrontal; pm—premaxilla; po—postorbital; pp—postparietal; ps—parasphenoid; pt—pterygoid; sq—squamosal; st—supratemporal; v—vomer.

are restricted to a small area, below and anterior to the middle ear. In the advanced larvae and adults of terrestrial salamanders, much of the region behind and somewhat medial to the cheek is occupied by the hyoid apparatus and the area within which the prey would be captured. The adductor jaw muscles completely cover the area lateral to where the tympanum is located in adult frogs. Branchiosaurids seem to show an intermediate condition, in that the squamosal still forms a notchlike posterior recess (although less well defined than in adult temnospondyls), but the stapes does not ossify fully.

Unfortunately, discussion of specific changes between branchiosaurids and primitive salamanders is largely speculative in the absence of any adequately known fossil representatives of the lineage leading to salamanders between the Lower Permian and the Middle Jurassic, a period of roughly 100 m.y. (Fig. 7). Clearly, we have a long way to go before we have adequate knowledge of the evolutionary history of any of the three living amphibian orders. If frogs and salamanders both evolved from temnospondyls, and amniotes from anthracosaurs, then these amphibian orders did have a more recent common ancestry than either had with amniotes. However, this leaves the question of the relationship of caecilians and microsaurs unresolved since there is no substantial evidence as to the specific origin of any of the lepospondyl orders. This can only be established with a more complete knowledge of fossils from the base of the Carboniferous.

CONCLUSIONS

We have a great deal of knowledge of the anatomy of a vast array of Paleozoic tetrapods (Heatwole and Carroll, 2000), but the specific interrelationships of the major taxa and their affinities with the modern orders remain impossible to establish with assurance without much more knowledge of fossils from the Lower Carboniferous and from the period between the Lower Permian and the Jurassic.

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The origin and early evolutionary history of amniotes

Robert R. Reisz

Recent phylogenetic analyses of Paleozoic tetrapods have yielded startling new insights into the origin and early evolutionary history of amniotes. The origin of this successful group involves evolutionary innovations that are associated with the development of the cleidoic egg and related reproductive strategies, and are therefore not represented directly in the fossil record. Despite this obvious difficulty, recent studies have been able to distinguish Paleozoic amniotes from their anamniotic tetrapod relatives to determine major patterns of interrelationships.

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Amniotes are widely perceived as being a paradigm of evolutionary success, as documented by extraordinary taxonomic and ecological diversification. Their present diversity encompasses mammals, birds, crocodiles, squamates and turtles. These vertebrates either have a dominant role, or have a significant presence, in all major environments. The fossil record of amniotes is also very rich, providing extensive anatomical information (Figs 1–4) and a long history that extends through 315 million years, well into the Carboniferous[1,2]. This success has been generally attributed to their diagnostic characteristic, the cleidoic egg. This type of egg contains a large amount of yolk, and four extra-embryonic membranes – yolk sac, allantois, amnion, chorion. It is generally accepted that the evolution of these extra-embryonic membranes and associated reproductive innovations allowed amniotes to sever their dependence on aquatic habitats for reproduction, permitting members of this group to exploit terrestrial environments more effectively than their anamniotic relatives.

Origin of amniotes

Carroll[3] has constructed the most explicit scenario of the origin of amniotes and has proposed a number of evolutionary events that probably led to the amniote condition. These evolutionary innovations included the introduction of internal fertilization, a larger amount of yolk than before, and the elimination of independent larval stages. Using plethodontid salamanders as a model, Carroll also argued that the evolution of the reptilian reproductive pattern proceeded via an intermediate stage in which anamniotic eggs were laid in damp places on land. Apparently, the size of an anamniotic egg is limited by the absence of extra-embryonic membranes and by the absence of a mineralized shell. This, together with the correlation between egg size and adult size found in modern amniotes and plethodontids, led Carroll to suggest that the anamniotic ancestors of amniotes would have been small and that their size would have increased only well after the acquisition of the amniotic egg[4].

Carroll's hypothesis, constructed on the premise that amniotes evolved from anamniotic tetrapods that had direct development and laid their eggs on land (like extant plethodontids) indicated that the amphibian–amniote transition involved a bottleneck of small size. Since small tetrapods have relatively huge sensory organs, according to Carroll such a bottleneck of small size would require modifications of the head that could be recognized in the fossils. Such a reorganization would have allowed vertebrate paleontologists to recognize early amniotes on the basis of their cranial anatomy. One problem with this scenario is that factors other than egg size may constrain plethodontids. The most obvious of these is the absence of lungs. Without lungs, plethodontids are restricted to small adult size because the surface:volume ratio of the animal must remain high enough to allow for the animal's oxygen (O_2) needs to be met. Therefore, the small size of terrestrial plethodontids does not necessarily result from the small egg size or direct development. Another problem with the thesis that plethodontids are small because their eggs are small is that the correlation between egg size and adult size claimed by Carroll for most tetrapods is not strong among living amphibians[5]. In addition, research on reproductive biology has raised serious doubts about this traditional scenario of the origin of amniotes. For example, the amniotic egg, long considered to have been an adaptation to terrestriality, may have evolved to facilitate embryo retention in the mother[6]. Furthermore, the eggs laid by living amphibians, often taken as models of primitive tetrapod eggs, may represent an adaptation to freshwater reproduction[7].

It is possible that the relatively small size of the earliest amniotes may simply be coincidental or the result of taphonomic biases. For instance, most amniotes found at Joggins and Florence, Nova Scotia (Canada), two of the localities with the earliest amniotes, were preserved in hollow tree stumps. Since the largest stumps had a diameter of only about 30 to 60 cm, the vertebrates preserved inside them were relatively small. Some of the amniote remains found at Joggins and Florence[8] were only moderately small, with an estimated snout–vent length of up to 350 mm. In fact, the smallest presumed amniote from Joggins, *Archerpeton* with an estimated snout–vent length of 60 mm, is not an amniote, but a tiny microsaur, a lepospondylous amphibian[2]. A survey of Middle Pennsylvanian amniote-bearing localities indicates that the size of amniotes found in these sites ranges from 130 to 300 mm (snout–vent length). Furthermore, Carroll's scenario was predicated on the assumption that the earliest known amniotes were basal, an assumption not supported by the most recent phylogenies[9–11]. Therefore, there is no evidence that very small size is a primitive character for amniotes, and consequently, early amniotes could not be diagnosed on the basis of their cranial anatomy, especially in the absence of a phylogenetic analysis.

Phylogenetic position of Amniota

The origin and evolutionary relationships of amniotes have always attracted much attention, and early studies

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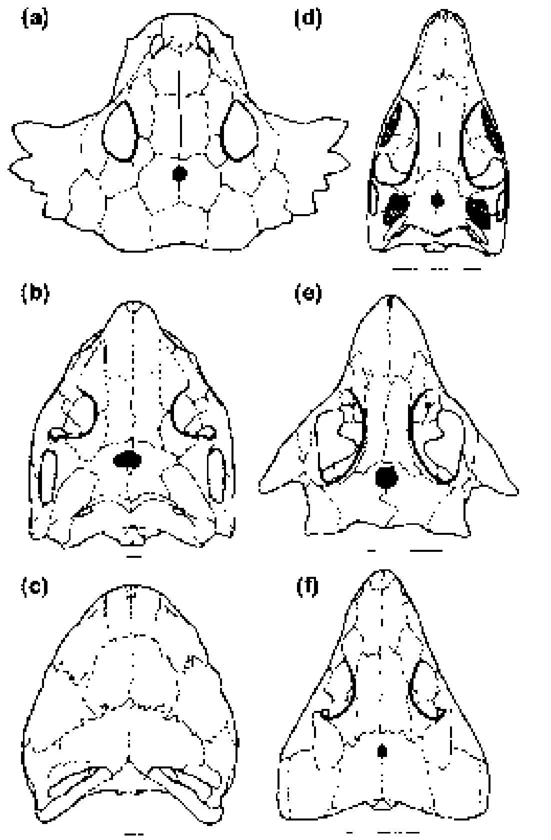

Fig. 1. Skulls of early amniotes in dorsal view. (a) *Scutosaurus*, the best known pareiasaurian parareptile from the Late Permian of Europe. (b) *Cotylorhynchus*, a basal synapsid from the Permian of North America. (c) *Proganochelys*, the oldest known turtle from the Late Triassic of Europe. (d) *Petrolacosaurus*, the oldest known diapsid from the Late Pennsylvanian of North America. (e) *Procolophon*, a procolophonid parareptile from the Early Triassic of South Africa. (f) *Captorhinus*, a captorhinid eureptile from the Early Permian of North America. The thick, curved line represents the edge of the orbit. The black round opening on top of the skull is the pineal foramen, which is absent in turtles. The areas covered with stipples represent temporal fenestrae: there are two pairs of temporal openings in early diapsids, and one pair in early synapsids. In addition, there is an elongate suborbital fenestra in early diapsids, as indicated by cross hatching (top of Fig. 1d). See Fig. 6 for pattern of relationships. *Modified from Ref. 10.*

proposed several potential close relatives. Most notable among these are the articles by Carroll, who proposed that anthracosaurs such as gephyrostegids and *Solenodonsaurus* were the most suitable ancestors, or close relatives, of amniotes[11]. An important change in our perception of amniote relationships was the recognition that diadectomorphs, a group of relatively large reptiliomorph tetrapods, were the closest relatives of amniotes[12]. One of the most important recent developments pertaining to the origin of amniotes was the discovery of *Westlothiana lizziae* from the Visean of Scotland[13]. This small tetrapod, originally referred to as a reptile in the preliminary description, has been re-studied by Smithson *et al.*[14], and reinterpreted as the sister taxon of diadectomorphs and amniotes. Unfortunately, key anatomical features of the skull and postcranial skeleton are insufficiently preserved for making any definitive statements about the precise phylogenetic relationships of this form, beyond the fact that it is not an amniote. Clearly, more specimens must be collected.

The latest and most comprehensive studies on tetrapod phylogeny and amniote relationships were performed by Carroll[15], and Laurin and Reisz[16]. As well as including early amniotes and anthracosaurs, Carroll took a more global approach, and also considered other Paleozoic tetrapods, such as lepospondyls and temnospondyls. This inclusive and judicious choice of taxa yielded some new insights into the origin of amniotes. Of particular significance was the discovery that lepospondyls may be more closely related to amniotes and diadectomorphs than the anthracosaurs. This new hypothesis of relationships is significant to studies on the origin and early evolution of amniotes, because placement of lepospondyls as closer relatives of amniotes than the anthracosaurs will open up new avenues for investigating the anamniote–amniote transition. Osteologically and developmentally, lepospondyls are very different from anthracosaurs[17]. Laurin and Reisz re-studied tetrapod phylogeny using 38 taxa and 157 osteological characters, and found a similar pattern of amniote relationships to that proposed by Carroll. In addition, they found evidence for close relationships between Paleozoic lepospondyls and living amphibians.

Amniote phylogeny and the fossil record

Recent phylogenetic studies of early amniote relationships[7,19] have led to the precise identification of the clade Amniota through the use of a node-based definition[18]: Amniota is therefore recognized as a crown-group, the most recent common ancestor of synapsids (including mammals), testudines (turtles) and diapsids (including squamates, crocodiles and birds), and all its descendants (Fig. 5). All taxa that fall within this clade can be identified as amniotes, both phylogenetically and reproductively, even in the absence of direct fossil evidence of their specific reproductive modes. There is, therefore, clear evidence that entirely extinct problematic taxa, such as mesosaurs and millerettids, are amniotes, and that tokosaurids and nycteroleterids, previously considered to be amphibians, are also amniotes. Even such

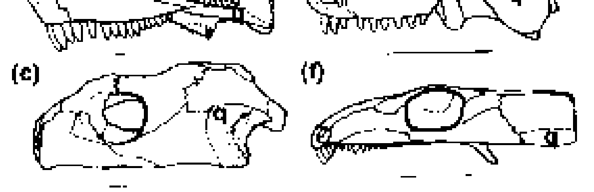

Fig. 2. Skulls of early amniotes in lateral view. (a) *Scutosaurus*. (b) *Cotylorhynchus*. (c) *Proganochelys*. (d) *Petrolacosaurus*. (e) *Procolophon*. (f) *Captorhinus*. The opening surrounded by a thick line represents the orbit. Behind the orbit, the openings covered by large stipples represent temporal fenestrae: one pair for the synapsid *Cotylorhynchus*, two pairs for the diapsid *Petrolacosaurus*. The fine stipples shown in (c) and (e) represent the tympanic notches (for the ear drum) that characterize basal procolophonids and turtles. The quadratojugal (q) is a flat bone in parareptiles that contributes to the edge of the tympanic notch. *Modified from Ref. 10.*

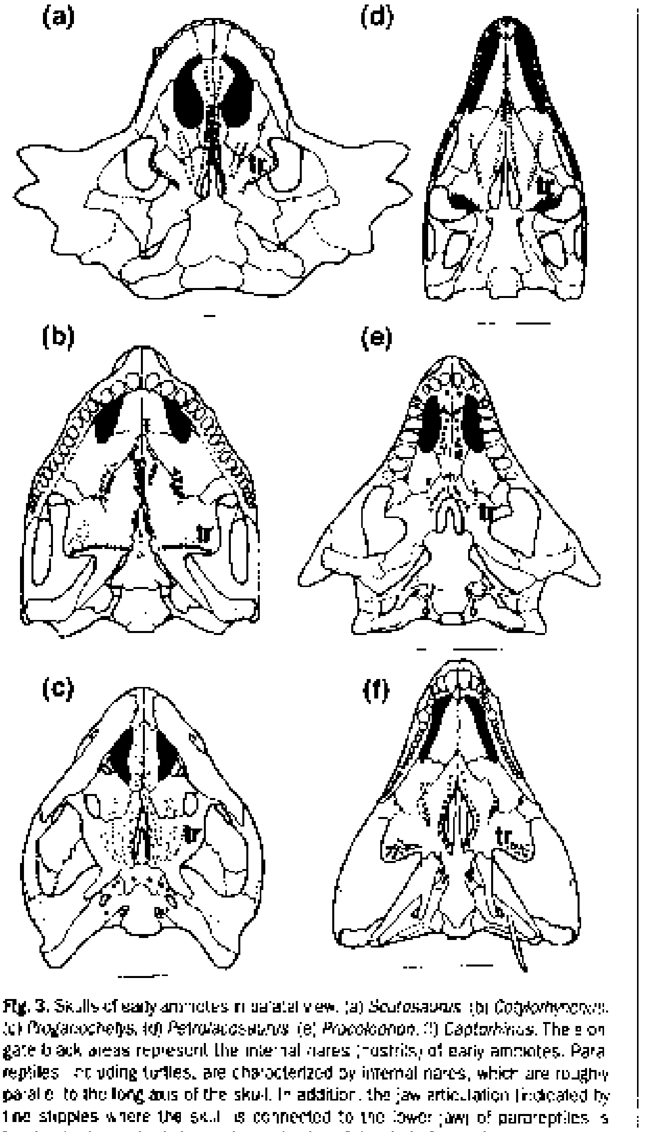

Fig. 3. Skulls of early amniotes in palatal view. (a) *Scutosaurus*, (b) *Cotylorhynchus*, (c) *Proganochelys*, (d) *Petrolacosaurus*, (e) *Procolophon*, (f) *Captorhinus*. The elongate black areas represent the internal nares (nostrils) of early amniotes. Parareptiles, including turtles, are characterized by internal nares, which are roughly parallel to the long axis of the skull. In addition, the jaw articulation (indicated by fine stipples where the skull is connected to the lower jaw) of parareptiles is located far forward relative to the back edge of the skull. All amniotes have a well-developed transverse flange (tr), formed by a bone called the pterygoid. In most early amniotes this flange is covered by teeth, except in procolophonids and turtles. *Modified from Ref. 10.*

an unusual fossil as the aquatic *Lanthanosuchus* from the Late Permian of Russia, which is generally considered to be an aberrant anthracosaurian[1], is actually a parareptilian amniote.

Phylogenetic analyses (Fig. 5) indicate that the first dichotomy in amniote evolution was between synapsids (mammals and their fossil relatives) and sauropsids (reptiles and their extinct relatives). This dichotomy is evident even in the oldest known amniote-bearing localities, in the upright lycopod tree stumps of Joggins and Florence, where representatives of an early synapsid (*Protoclepsydrops*) and an early eureptile (*Hylonomus*) are present[2,8]. Unfortunately, both these taxa are represented by poorly preserved, disarticulated specimens, inadequate for any detailed studies beyond their recognition as members of these two amniote clades. It is really important to recognize that the clades that include mammals and birds have such long separate evolutionary histories, extending to the earliest known evidence of amniotes in the fossil record. This also indicates that two important dichotomies of amniote evolution pre-date the oldest known amniotes in the fossil record. These are the synapsid–sauropsid, and the parareptile–eureptile dichotomies. In addition, there are three major Paleozoic groups of amniotes that have living representatives: synapsids (including extant mammals), parareptiles (including extant turtles) and diapsids (including most extant reptiles and birds) (Fig. 6). Contrary to previous interpretations of amniote evolutionary history, the results of this study indicate that the clades that include turtles (parareptiles) and most other reptiles (eureptiles) have also had long separate evolutionary histories, extending into the Carboniferous.

The evolutionary history of synapsids can be subdivided into several major radiations. The initial evolutionary radiation coincides with the early history of amniotes, extending throughout the Late Paleozoic, from the Early Pennsylvanian to the end of the Permian[19]. The so-called pelycosaurs and early therapsids are Permo–Carboniferous and Late Permian synapsids that rapidly became the most diverse and most common amniotes of their time, dominating the terrestrial scene for over 65 million years. These Paleozoic synapsids record the earliest successful adaptation of amniotes to a broad array of herbivorous and faunivorous modes of life. It is only after the catastrophic extinction event marked by the Permo–Triassic boundary that reptiles (archosaurian diapsids in particular) were able to establish their dominant role, and started the so-called age of reptiles.

Although the origin and early evolutionary history of amniotes is associated with mastery of terrestrial environments, the fossil record indicates that amniotes reinvaded the aquatic medium repeatedly. A spectacular example of this phenomenon in the Paleozoic is represented by Early Permian mesosaurs, the oldest known marine amniotes. The most recent study of these unusual amniotes shows that the high degree of specialization of the mesosaur skeleton supports the hypothesis of an obligatory aquatic lifestyle (S.P. Modesto, PhD thesis, University of Toronto, 1996).

The evolutionary history of parareptiles has attracted a lot of attention recently, partly because of the proposed

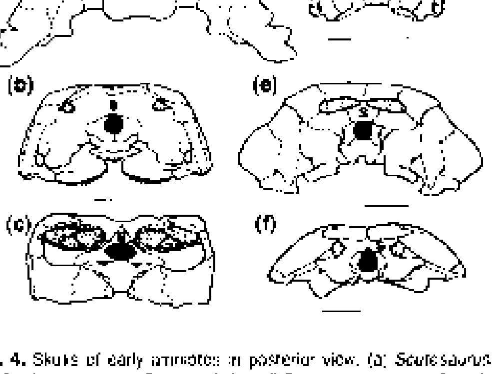

Fig. 4. Skulls of early amniotes in posterior view. (a) *Scutosaurus*, (b) *Cotylorhynchus*, (c) *Proganochelys*, (d) *Petrolacosaurus*, (e) *Procolophon*, (f) *Captorhinus*. The black area represents the foramen magnum, where the spinal cord is connected to the brain. The supraoccipital bone (s), located above the foramen magnum, is a large, plate-like bone in most early amniotes, but is a narrow, pillar-like strut in parareptiles, including turtles. The stippled areas are post-temporal fenestrae. *Modified from Ref. 10*

inclusion of turtles within this clade[20,21]. Previous studies considered that this large group of poorly known amniotes became extinct 200 million years ago. Although the precise phylogenetic position of turtles within parareptiles is still controversial, a general consensus is emerging with regard to their inclusion in this clade[22]. Most non-testudine parareptiles are restricted to the Late Permian and Triassic periods, when the small millerosaurs and procolophonids, and the large, herbivorous pareiasaurians were common members of numerous fossil assemblages. The oldest known parareptile, *Acleistorhinus pteroticus*, comes from Early Permian sediments in Oklahoma (USA)[23], in contrast to paleogeographic distribution of the later members of this clade in Europe and South Africa.

Two groups of Paleozoic reptiles, the Protorothyrididae (represented by *Paleothyris* and *Hylonomus* in Figs 5 and 6), and Captorhinidae (represented by *Captorhinus* in Figs 1–4) have long held a central position in concepts of amniote phylogeny. Mainly through the work of Carroll, these taxa were proposed previously to represent the basal amniote stock[1,3,4]. More recent work has shown that these forms do not represent the ancestral amniote pattern as proposed formerly but protorothyridids still remain the nearest known relatives of diapsid reptiles[9,10,12].

The evolutionary history of the third major clade of amniotes, the diapsids, extends from the Late Carboniferous to the present. *Petrolacosaurus*, a small, delicately constructed reptile from the Late Pennsylvanian (Late Carboniferous) of Kansas (USA)[24], is the oldest known diapsid (Figs 1–4, 6). Despite this extended fossil record, the history of diapsids is quite modest throughout the Paleozoic; only in the Mesozoic do diapsids take on a dominant role among amniotes. Probably the most startling feature of diapsid history during the Paleozoic is the apparent ease with which these amniotes reinvaded the aquatic medium[24,25].

The first crown-amniotes are known from the Upper Carboniferous[1], but the presence of early relatives of diapsids and mammals indicates that amniotes either diversified quickly, or that they originated much earlier, perhaps in the Lower Carboniferous. These findings, while improving our understanding of the origin of amniotes, indicate that the fossil record of stem-amniotes is much less complete than previously realized. Figure 2 shows that the temporal gaps between the minimum divergence time and the actual appearance of amniotes in the fossil record is at least 20 million years. The temporal gap between the minimum divergence time and the actual appearance of parareptiles is even longer, at least 35 million years. The new

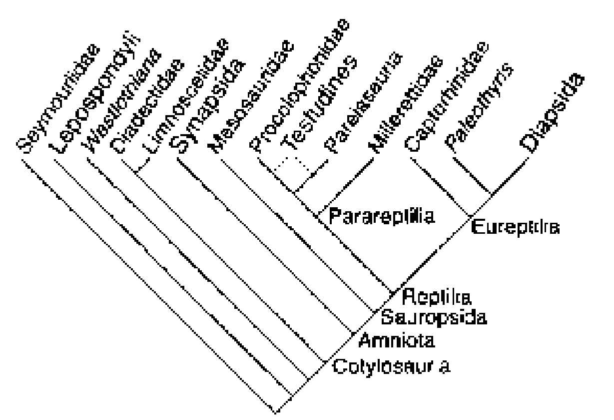

Fig. 5. Amniote phylogeny. The terminal taxa in small print are all extinct, whereas the terminal taxa shown in larger print include extant forms. For example, Lepospondyls include extant amphibians[26,27], Synapsida includes living mammals[18], Testudines are turtles, and Diapsida includes extant crocodiles, lizards, snakes, and birds, in addition to the extinct flying reptiles, dinosaurs and aquatic reptiles. The hypothesis of amniote relationships shown in this figure represents a consensus of several hypotheses. Note that the outgroup Lepospondyli has been added from Ref. 27 and that this taxon includes extant amphibians; the position of Testudines reflects competing hypotheses from Refs 16 and 22; the position of *Westlothiana* as a sister taxon to Cotylosauria has been proposed in Ref. 14. Some of the numerous shared, derived, osteological features used to analyze the patterns of evolutionary relationships of amniotes are mentioned in the previous figure captions. *Redrawn and modified from Refs 10 and 14.*

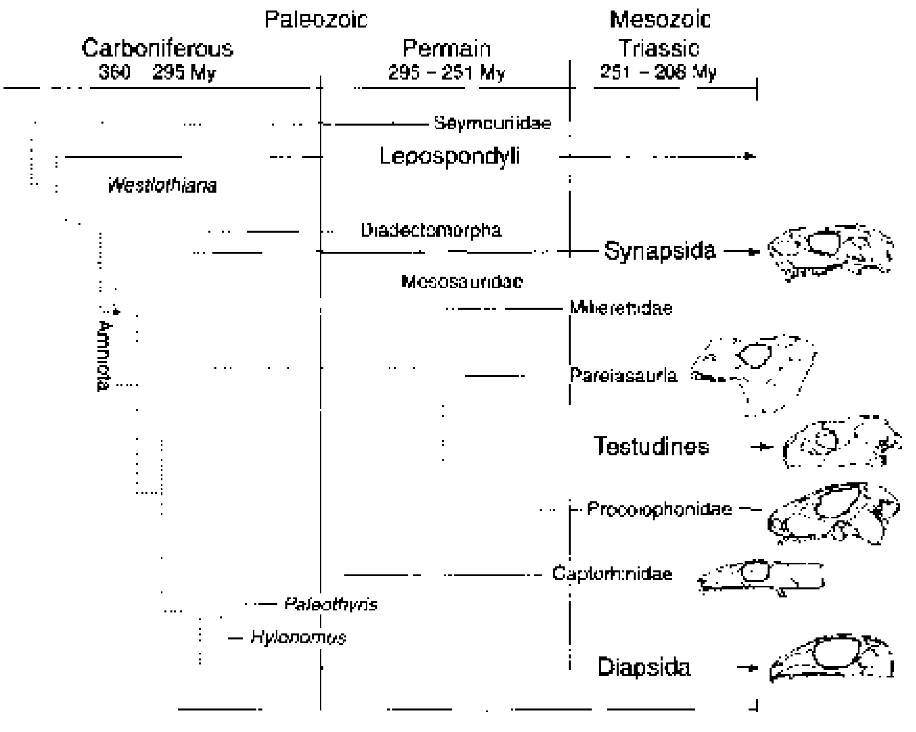

Fig. 6. Amniote phylogeny and the fossil record. Solid lines represent the extent of the known fossil record. Dotted lines represent both the proposed pattern of relationships shown in Fig. 5 and the expected minimum times of divergence. The arrows at the end of four lineages indicate that their fossil record extends beyond the limits of the periods shown in the figure. The numbers beneath each period indicate million years ap (My). The oldest known amniote *Hylonomus* has been added to the cladogram to indicate the correct minimum divergence time, even though the precise pattern of relationships between this eureptile and *Paleothyris* is uncertain. The skulls of the fossil taxa shown in Fig. 2 have been included next to each major clade that they represent. *Redrawn and modified from Refs 10 and 14.*

phylogeny and the ideas on the origin of amniotes associated with a shift in reproductive modes do not provide a clear answer to the question when the amniotic egg appeared. However, according to the new phylogeny, only two nodes may be characterized by the appearance of the amniotic egg: Amniota and Cotylosauria. The correct assignment of the amniotic egg to one of these nodes depends on the type of egg laid by diadectomorphs. Unfortunately, fossil eggs are rare in the Paleozoic (amniote eggs have not been discovered) and only indirect arguments may allow us eventually to solve this question. Arguments associated with the origin of terrestrial herbivory have been used to suggest that diadectids, one of the oldest known herbivores, may have been reproductively amniote[26].

The proposed patterns of amniote relationships, based on studies of early amniotes, affect our understanding of the evolutionary relationships of their living descendants. In addition, the anatomical data provided by the Paleozoic amniotes contribute significantly to the evolutionary biology of extant amniotes. For example, the fossil record shows clearly that the basal members of each of the major clades that have living representatives had massive stapes, and no space for a tympanum. The phylogeny presented in Fig. 5 indicates, therefore, that the slender stapes, the well-developed tympanum, and the impedance-matching ear system seen in living tetrapods such as frogs (lepospondyls), mammals (synapsids), some turtles (parareptiles), lizards and birds (diapsids) evolved independently, at least four times in the history of tetrapods. It is therefore possible to show with the aid of fossils that such soft tissues as the tympanum are not phylogenetically homologous in the living tetrapods.

Directions for future work

The recent proliferation of tetrapod and amniote phylogenies[11–16,20,27] has not only brought to light new patterns of relationships, but also emphasized areas that need to be addressed in future studies. For example, the anatomy of both protorothyridids and captorhinids needs to be reinvestigated thoroughly, and integrated into new phylogenetic analyses. In addition, patterns of relationships between major amniote clades can be investigated using living forms. This is possible because the clades of synapsids, parareptiles and diapsids not only extend well into the Paleozoic (Figs 5 and 6) but also have living representatives.

A recent attempt to combine molecular and anatomical data for a total evidence approach to phylogenetic analysis[28] has shown that the more highly resolved and robust hypothesis of amniote relationships, derived from anatomical data, overwhelms the molecular data available from 18S rRNA, 28S rRNA and protein sequences. However, future studies should integrate anatomical data procured from new studies of Paleozoic amniotes not only with molecular data, but also developmental data derived from extant tetrapods. The use of total evidence for evaluating evolutionary relationships is preferred over any other form of analysis, and eventually may provide a good fit between data provided by fossil and extant taxa.

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Molecular timescales and the fossil record: a paleontological perspective

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The fossil record serves a crucial function as an external calibration for genomic clocks and molecular evolutionary timescales. Although certain portions of the vertebrate fossil record are accurate, there is always uncertainty in establishing a divergence time because the fossils can only provide evidence of the first appearance of the descendants of a split, and by definition they underestimate the date of the true evolutionary event. Nevertheless, recent workers have used fossil data for establishing external calibration dates without taking into account this limitation or the quality of the relevant fossil record. In this article, we present evidence that the fossil record is inadequate for proposing a reliable external calibration date for the mammal–bird split, the most widely used evolutionary event for the study of molecular evolutionary timescales. Instead, we propose the bird–lizard split as an alternative major evolutionary event, one of several potential external calibrations. Finally, we argue for closer, direct collaboration between paleontologists and molecular biologists.

Vertebrate fossils preserve a valuable record of the history of organisms that are most closely related to us. We are fortunate that the primary evidence of the evolutionary history of back-boned animals is based on a rich record of preserved hard skeletons, making it readily available for detailed anatomical, systematic and phylogenetic studies. This fossil record has been of great use in various fields of biology but more recently it has served a crucial function as an external calibration for genomic clocks and molecular evolutionary timescales [1]. This means that at least one selected fossil date was used to establish a model of the mutation rate and the substitution rate of a specific gene, which can then be used to estimate divergence times of other evolutionary events. It is because of this connection between historical and molecular biologists that we feel it is important to present our perspective on the nature of the fossil record, and to explain (in some detail) its usefulness and limitations as the external calibration date of major evolutionary events in molecular phylogenetics and evolutionary timescale studies. In particular, we argue against the use of the fossil record to date the mammal–bird split, as has been presented in a recent review article in this journal [1]. We would also like to present to the molecular biology community our proposals on the proper use of the fossil record and also to emphasize the importance of employing the phylogenetic data that the fossil record provides. Finally, we suggest that the best way to move forward in the field of evolutionary history is through a much closer collaboration and interaction between paleontologists and molecular biologists.

Joggins and the mammal–bird split as an external calibration

Although the fossil record has been used extensively to date several major evolutionary events [2], recently the date of 310 million years ago (MYA) has become one of the most frequently used external calibrations for establishing the mammal–bird divergence; it has also been used for the calibration of the molecular clock for several other vertebrate groups, in addition to metazoans, fungi and plants [3,4]. This date is based on the age of the sediments at Joggins, Nova Scotia where the oldest known amniotes (a reptile and a synapsid) were discovered [5], representatives of the two clades that include birds (reptile) and mammals (synapsids). This is generally considered to be an ideal calibration date because there is a lot of molecular data for birds and mammals, and the split into these two clades represents a widely accepted basal dichotomy of amniotes into two large groups with extensive, separate fossil records that extend from the Carboniferous period to the present, roughly halfway through metazoan evolution. In addition, there is general agreement among vertebrate biologists and paleontologists that this basal dichotomy of amniotes led to mammals and birds [6] (Box 1).

Joggins, Nova Scotia is the locality that contains the oldest known amniotes [7]. Although their skeletal remains are fragmentary, there is no doubt that both taxa present in this locality, *Hylonomus* and *Protoclepsydrops,* fall within the crown-group Amniota, and definitely post-date the mammal–bird split (Figure 1). Even though the current geological evidence indicates that the age of this locality is probably between 313–316 MYA [8], the 310 estimate was selected from the paleontological literature [9] for the age of the mammal–bird divergence [3].

The presence of both taxa provides clear evidence that the geological age of this locality underestimates the time of this evolutionary event. This is contrary to the argument presented by other authors [10], who pressed for a much younger age of the split on the basis of clearly identifiable members of each clade, a diapsid and a synapsid [11,12]. This argument ignores the phylogenetic data provided by the fossil record because the dichotomy of

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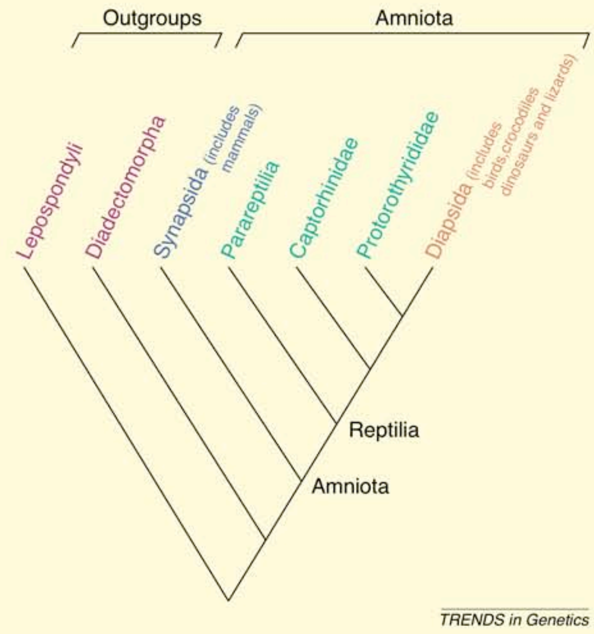
Box 1. Evolutionary relationship among Amniotes

Here we show the overall pattern of evolutionary relationships of amniotes in the form of a cladogram modified from a previous phylogenetic analysis [16]. Amniotes are the so-called 'higher vertebrates' and include modern mammals, turtles, lizards, snakes, *Sphenodon*, crocodiles, birds and their fossil predecessors. There is a general consensus that the nearest outgroups to amniotes are the diadectomorphs and lepospondyls [15], respectively, shown here in purple. Similarly, there is strong evidence for a basal dichotomy of amniotes into synapsids (including mammals) and reptiles (including birds). By definition, this dichotomy is equivalent to the mammal–bird split and it is therefore unimportant if the oldest amniotes belong to some more inclusive clades, such as Diapsida, or not because the presence of any amniote automatically indicates that this basal separation must have already occurred. Although Synapsida are represented by a single line, this group represents the dominant terrestrial vertebrates of the Paleozoic era, during the initial period of amniote evolution and diversification. Next to mammals and their nearest relatives, synapsids also include the so-called 'mammal-like reptiles'. Thus, synapsids represent a largely uninterrupted evolutionary radiation across >300 MY of history. The other branch of the amniote tree is collectively designated as Reptilia, a large clade that includes a large assortment of fossil forms, such as parareptiles, captorhinids and protorothyridids (in green), in addition to the other major branch of amniote radiation, the diapsids (in mustard). Diapsids include numerous fossil groups, for example, flying reptiles, aquatic reptiles and dinosaurs but also birds, crocodiles, lizards, snakes, *Sphenodon* and their extinct relatives. The fossil record of diapsids is also comparatively good and extends from the present into the Carboniferous period. We have not defined the relationships of turtles because of controversies about their phylogenetic position.

The name Amniota is placed at two levels in this cladogram, both the node that defines the basal dichotomy and above to indicate that this clade is a so-called 'crown group'. The bracketing of synapsids, diapsids, and all other forms between these two major branches of the cladogram, represents all extant amniotes and all fossil forms that form part of this impressive evolutionary history. Any forms of life, either currently living or fossilized, that fall within this crown group, are by definition amniotes and are, therefore, younger than the origin and basal split of amniotes.



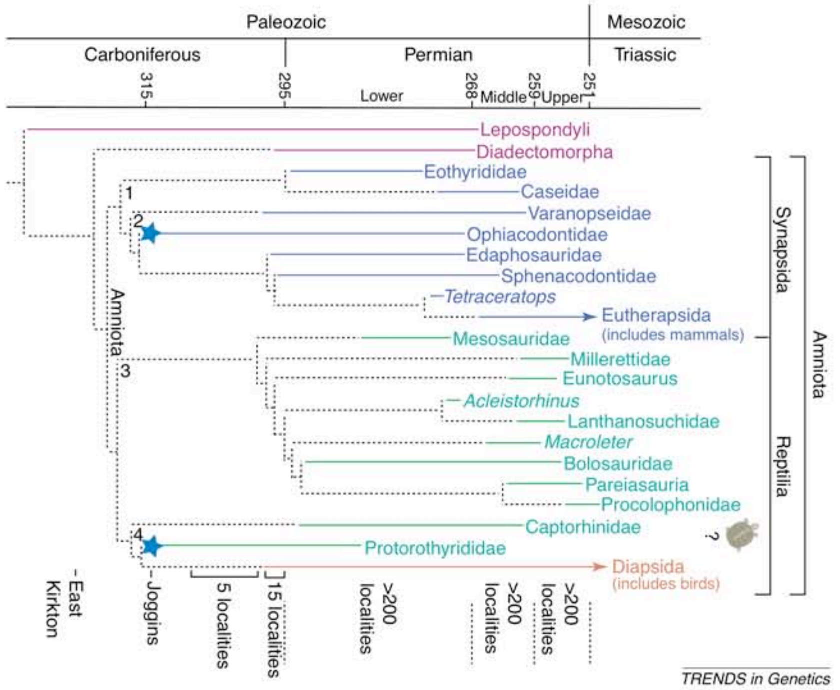


Figure 1. The phylogeny and stratigraphic occurrence of paleozoic amniota and the two nearest outgroups (sister taxa). The fossil record of the outgroups are indicated in purple, the synapsids (includes mammals) in blue, and the reptiles (includes diapsids and birds) in green and mustard. Broken lines represent ghost lineages and the pattern of branching of various lineages. The oldest known lineages of amniotes extend to the level of Joggins [313–316 million years ago (MYA)], and include the fossils *Protoclepsydrops* (Ophiacodontidae), and *Hylonomus* (Protorothyrididae), as indicated by the blue star. 295 and 251 MYA (on the left) represent the boundaries between the Carboniferous, Permian and Triassic periods, and locality numbers are indicated on the right, with the approximate age of Joggins and East Kirkton included. Several long ghost lineages are present during the Carboniferous both within Amniota, and its closest relatives, Diadectomorpha. This lack of data about the time, origin and early history of amniote evolution provides compelling evidence against using this event of calibration of molecular timescales.

amniotes in the two clades that include mammals and birds is synonymous with the node of Amniota. Thus, the generally accepted phylogeny of amniotes (Box 1) indicates that the presence of any amniote in the fossil record, irrespective of whether it is part of the synapsid or diapsid clades (e.g. Parareptiles), automatically post-dates the mammal–bird split. Therefore, there is no need to use the oldest known, clearly identifiable synapsid or diapsid, as previously suggested. The Joggins fossils, although fragmentary, are clearly amniotes and descendants of the original, basal split and definitely members of the reptile (distant, ancient bird relatives) and synapsid (distant, ancient mammal relatives) clades. Nevertheless, molecular biologists have argued that the date of 310 MYA for the mammal–bird split is unlikely to be a major underestimation of the age of the divergence [3]. We strongly disagree with this interpretation for two important reasons detailed in the following sections.

Quality of the fossil record

First, contrary to the opinion expressed in numerous papers on the molecular timescales, the global fossil record for this early period of terrestrial vertebrate evolution is poor and grossly inadequate for the use of either interval-based calibration dates or the single calibration date of 310 MYA that is so widely used in the literature. The origin and basal dichotomy of amniotes are associated with evolutionary events in the terrestrial realm [6,13]. The rich Joggins fauna includes ten tetrapod taxa of which eight are terrestrial amphibians and two are amniotes. There is only one locality that is older than Joggins that preserves a terrestrial vertebrate community: East Kirkton, Scotland, UK (Figure 1). The age of this locality has been estimated to be ~330 MY; its fauna include numerous terrestrial arthropods and at least six terrestrial amphibians that include the enigmatic taxon *Westlothiana*. This small form was incorrectly identified as an amniote but now is tentatively regarded as a lepospondylous amphibian [14,15]. The preservation of terrestrial vertebrate communities improves slightly after Joggins: with only a handful of localities in the Late Carboniferous period (up to ten million years after Joggins), more than a dozen localities near the Carboniferous–Permian boundary and several hundred localities in the Permian period (15–55 MY after Joggins). Thus, the amniote fossil record is poor within much of the Carboniferous period and improves only ~15 MY after the earliest known occurrence of amniotes (Figure 1).

Phylogenetic framework

Second, the difficulties in dating the time of the amniote origin and the basal split become even more apparent when the known taxa are considered within a phylogenetic framework. If we look within Amniota, the combination of the fossil record and the broadly accepted patterns of relationships yield significant ghost lineages (Figure 1). Each ghost lineage indicates that representatives of a particular clade must have been present in the terrestrial vertebrate communities of that time but are not preserved in the fossil record. The placement of a detailed amniote phylogeny within a temporal framework yields numerous ghost lineages within the Late Carboniferous period; at least four ghost lineages of amniotes extend to an age that is older than Joggins. The ghost lineages provide compelling evidence not only that the fossil record is poor during the Carboniferous period but also that the origin of amniotes and the associated basal dichotomy into synapsids and reptiles must have occurred well before the appearance of the oldest amniote fossils. Thus, the age of Joggins (313–316 MYA) represents a significant underestimate of the time of mammal–bird divergence. If we look outside Amniota, we can see that the quality of the fossil record of Diadectomorpha, the closest relatives of amniotes [16], is even poorer than that of amniotes within the Carboniferous period, the earliest known occurrence being near the Carboniferous–Permian boundary [17]. We can only conclude, on the basis of the early record of amniotes and their sister taxa, that this crucial event in the history of terrestrial vertebrates is poorly bracketed.

Interestingly, lepospondyls, diadectomorphs and amniotes all appear to have been adapted originally to a terrestrial lifestyle and, consequently, have been found in substantial numbers only in fossil localities yielding the remains of terrestrial communities. Most Carboniferous localities, however, bear only aquatic representatives, and the poor fossil record of amniotes during that period might be related to biases in preservation rather than evolutionary events. Therefore, even if we appear to be well informed about the phylogenetic relationships of early amniotes and their closest relatives, we are not informed with regard to their fossil record. This is best exemplified by the recent discovery of an isolated, small reptile-like form, *Casineria* [18]. Although lacking a skull, its postcranial skeleton indicates that it is a possible sister taxon to other amniotes. The locality that produced this enigmatic form (Cheese Bay, Scotland) is even older than East Kirkton, emphasizing the possibility that amniotes might have extended to the Lower Carboniferous period. Thus, any possible range in age for the date of the mammal–bird split is by necessity a rough guess, rather than an estimate or a confidence interval, and should be treated as such.

The factors that determine the possible temporal distance between the recovered fossil remains of a particular taxon relative to the evolutionary event (in this case the speciation event associated with the mammal–bird split) that it post-dates include: (i) the rates of evolution of these extinct taxa; (ii) the preservation artifacts that are associated with the process of formation of the fossils; (iii) the recent erosional events that lead to the exposure of the right sediments for potential recovery of the fossil remains; and (iv) the collection biases of the vertebrate paleontologists or the amateur and professional fossil collectors. Because these factors can not be quantified, there appears to be no reliable statistical method to determine the lower limits for the age of any divergence from the fossil record, although there were previous attempts, for example, using error bars on stratigraphic ranges [19]. In addition, to confuse the issue, the actual age of reasonably well-dated localities are presented in the geological literature in the form of confidence intervals. Thus, we have to be careful when we assign a date or, preferably, a possible range of dates to an evolutionary event. We have to recognize that two types of dates are involved, the geologic age of the fossiliferous sediments and the rough guess that is associated with estimating the time of an evolutionary event. As indicated previously [20], fossils can only underestimate the actual date of a particular evolutionary event because the oldest fossil must be younger than the origin of its group. This does not mean that we disagree with the use of the fossil record but we do propose that both phylogenetic and temporal bracketing of an evolutionary event is required for any possible calibration date.

Alternative calibration dates

Our knowledge of the fossil record and patterns of evolutionary relationships enables us to evaluate the quality of various groups of extinct vertebrates as potential calibration dates. It is clear that the fossil record of a particular group, even if it is rich for much of its history, is insufficient by itself for either an adequate minimum or maximum limit to the age of an evolutionary event. Well-defined bracketing of a particular evolutionary event can be tested if the fossil record is placed within a phylogenetic framework, and three features of the paleontological evidence are examined: (i) the quality of the fossil record near the time of the first appearance of taxa that post-date a particular evolutionary event; (ii) the temporal distribution of these taxa within a phylogenetic framework for determining the length of ghost lineages; and (iii) the temporal distribution of the nearest relatives (within a phylogenetic framework) to see if the absence of the fossils that mark the evolutionary event is not an artifact.

If we take into account these three features, we find that the calibration dates derived from the following evolutionary events are highly problematic: (i) the bird–mammal split, as indicated previously, is inadequate because of the presence of numerous long ghost lineages and poor bracketing provided by the absence of the sister taxa from the fossil record; (ii) both the Cartilaginous–Bony fish and the Gnathostome–Lamprey splits are inadequately bracketed because of the late appearance in the fossil record of the sister taxa (outgroups); and (iii) the Amphibian–Amniote split is poorly defined because of the ongoing controversy concerning the phylogenetic relationships of living amphibians (frogs, salamanders and apodans). It has been too often neglected that a reasonable calibration date is not only dependant on the quality of the fossil record of the clade under consideration and has to include its oldest known members but that it also needs to be supported by a good, stratigraphically equivalent and older representation of the immediate relatives outside the clade. Only then is it possible to have reasonable assurance that we can bracket the fossil date that is being used for calibration.

There are other major vertebrate evolutionary events that provide calibration dates that are superior to those currently in use because they are well bracketed within the fossil record and are well dated. These include the crocodile–lizard split and the crocodile–bird split. Crocodiles, together with birds and lizards, belong to the two major diapsid clades, Archosauria and Lepidosauria, and the evolution of these sister taxa can be traced back to the Upper Permian age, based on numerous different localities that span the geological timescale well before and after the first appearance of the relevant taxa (Figure 2). We have studied the crocodile–lizard split (Saurian split into Lepidosauromorpha and Archosauromorpha) in some detail and found that the closest neodiapsid relatives, the South African taxon *Youngina* and some other basal neodiapsids, for example, *Palaeagama* or *Saurosternon*, also have a comparatively good fossil record; they are the same age or older than the earliest representatives of Sauria. This evolutionary event is, therefore, well bracketed within the Upper Permian era (252–257 MYA). This also appears to be the case for the somewhat more recent crocodile–bird split, which is supposed to have occurred in the Middle Triassic period, with many sister taxa of both crocodiles and birds being known from the beginning of the Mesozoic era [21]. This evolutionary event needs to be studied in detail and tested using the methods listed previously. Given that, in the case of the mammal–bird split, the fossil record of both the amniote and outgroup taxa is inadequate, we propose that either the crocodile–lizard split and/or the crocodile–bird split be used as external calibrations for molecular time scales.

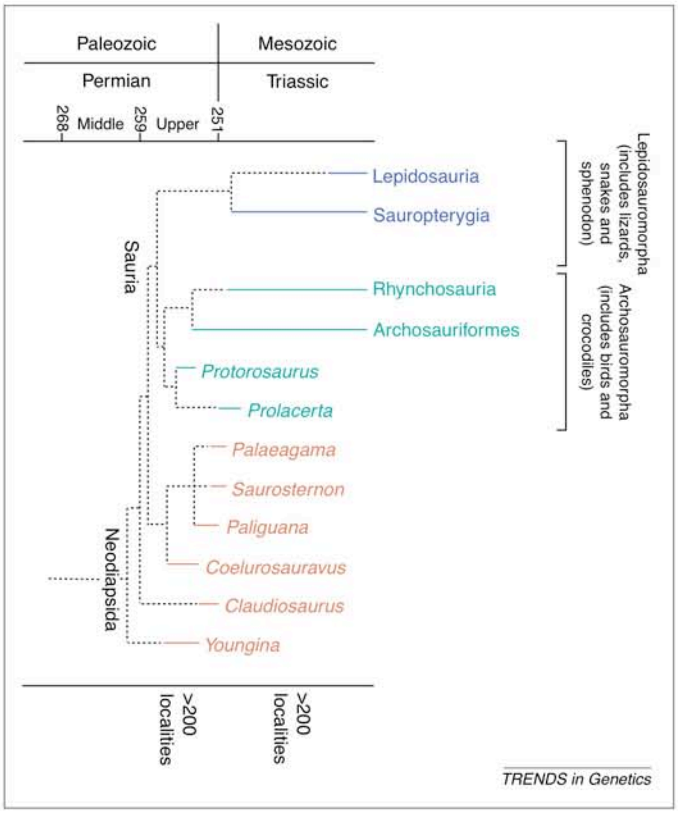


Figure 2. The phylogeny and stratigraphic occurrence of early saurian diapsid reptiles and their closest neodiapsid sister taxa. Sauria includes the lineages leading to lizards, snakes, *Sphenodon* (Lepidosauromorpha) and birds and crocodiles (Archosauromorpha) [25–28]. Turtles have been omitted. The outgroup taxa are either equal in age or older than the oldest saurians. Together with the fact that there are a high number of Upper Permian localities yielding terrestrial vertebrates, the presence of well documented outgroups indicates that the evolutionary event that separated the ancestors of modern diapsid reptiles from each other occurred sometime during very Late Permian period, approximately between 252 and 257 MYA. Thus, this well bracketed evolutionary event can be used as a calibration date.

Multiple calibration date estimates

As vertebrate paleontologists, we consider it problematic to use only a single fossil date for the calibration of many different genomic clocks. It has recently been criticized, correctly, that the usage of just a single or only a few genes is less reliable for a divergence estimate [1] but this also applies to the number of fossil dates being included for calibration. Until now, only a few attempts have been made in which several different fossil dates were taken into consideration [2,22–24]; however, in our opinion, such a methodology appears much more promising and is highly desirable if estimates of time ranges rather than single dates are employed. Thus, we would like to suggest that the above-mentioned splits are well-documented evolutionary events in the fossil record, and are worthy of detailed investigation. Another potentially useful calibration date that merits further study is that of the lungfish–mammal (or the equivalent lungfish–bird) split.

Future collaboration

Our familiarity with the fossil record and patterns of evolutionary relationships enables us to offer a different but important perspective to the studies of genomic clocks and evolutionary timescales. For example, the mammal–bird, mammal–squamate, mammal–crocodile and mammal–turtle splits are all variants of the same basal amniote dichotomy and should, therefore, yield similar values; although the fossil record for this basal dichotomy is inadequate for external calibration, the well-documented pattern of amniote phylogeny leads us to suggest that comparative molecular studies between these taxa would represent an elegant test of the current molecular methodology. Most of the work in this research area has been concentrated on mammals and birds but we are arguing for widening the field of investigation to include the above-named reptilian groups. We are certainly aware that for some of these taxa, such as lizards or crocodiles, there might be comparatively little molecular data, making detailed investigations difficult, at least initially. However, this should not lead us to ignore these groups but, rather, give us new ideas and point to future directions of research in which molecular and paleontological approaches are used in close collaboration.

Alternatively, there are some difficult evolutionary problems in vertebrate paleontology that can be addressed with molecular methods. For example, there are three competing hypotheses of relationships involving living amphibians (lissamphibians). According to these hypotheses, amphibians are: (i) monophyletic, part of a clade of ancient amphibians called temnospondyls and only distantly related to amniotes; (ii) monophyletic, part of another clade of amphibians called lepospondyls and closely related to amniotes; and (iii) diphyletic, some are part of both temnospondyls and others are part of lepospondyls [15,16]. Molecular divergence times of the three groups of living amphibians might help resolve this controversy and further enhance collaborations between paleontologists and molecular biologists.

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The Pennsylvanian tropical biome reconstructed from the Joggins Formation of Nova Scotia, Canada

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Abstract: The Pennsylvanian (Langsettian) Joggins Formation contains a diverse fossil assemblage, first made famous by Lyell and Dawson in the mid-19th century. Collector curves based on *c*. 150 years of observation suggest that the Joggins fossil record is relatively complete. A key feature of the site is that fossils occur in (par)autochthonous assemblages within a narrow time interval (<1 Ma). Analysis of co-occurring taxa within a precise facies context permits ecosystem reconstruction, and three main communities are recognized in this study. Brackish seas, the distal extension of European marine bands, were populated by Foraminifera, molluscs, annelids, arthropods, fishes, and aquatic tetrapods. Poorly drained coastal plains were covered by rainforests of lycopsids, calamiteans, ferns, pteridosperms, and cordaitaleans, inhabited by a terrestrial fauna of molluscs, annelids, arthropods, and tetrapods, including the earliest known reptiles. Well-drained alluvial plains were covered by fire-prone cordaitalean scrub containing a low-diversity fauna of molluscs, arthropods, and tetrapods, locally preserved in waterholes. These three environments repeatedly interchanged with one another in response to base-level fluctuations forced by tectonism and glacioeustasy. Located further inland than other well-studied Pennsylvanian tropical sites, the Joggins Formation is significant because it contains a record of intra-continental terrestrial ecosystems.

During Pennsylvanian times, Europe and North America were located close to the equator, and were characterized by a great variety of tropical forest and coastal environments, now preserved as coal-bearing strata (Murchison & Westoll 1968). Analysis of richly fossiliferous assemblages, collected over two centuries, has elucidated the nature of this ancient tropical biome in detail (Scott 1977, 1998). Pennsylvanian ecosystems are among the best understood in Phanerozoic history, depicted as humid tropical rainforests in many museum dioramas (DiMichele & Hook 1992; DiMichele & Phillips 1994; DiMichele *et al*. 2001).

One of the most important Pennsylvanian fossil sites is Mazon Creek in Illinois, USA (Nitecki 1979), where some 338 species of vertebrates, invertebrates, and plants, have been documented since the mid-19th century (Shabica & Hay 1997). Although Mazon Creek contributes significantly to our knowledge of Pennsylvanian diversity, these fossils are dominantly preserved within an estuarine succession, transported from a variety of terrestrial and aquatic habitats, and therefore are of limited usefulness in ecosystem reconstruction.

Another fossil site with a long history of research is Joggins in Nova Scotia, Canada (Fig. 1a–c; Logan 1845; Dawson 1868), acclaimed as the world's finest Pennsylvanian exposure by Sir Charles Lyell (1871), and first studied in detail, for over 40 years, by Sir William Dawson (Falcon-Lang & Calder 2005). The Joggins fossil assemblages are not as diverse as those at Mazon Creek, but are typically preserved in the environmental context in which they lived (parautochthonous). Analysis of fossils in a facies context permits communities of coexisting organisms to be reconstructed, and inferences to be made about community ecology.

There have been various attempts to synthesize knowledge of the Joggins section (Dawson 1854, 1865; Carroll *et al*. 1972; Duff & Walton 1973; Ferguson 1975; Gibling 1987), but none focuses on ecosystem reconstruction. In this paper, we present a new synthesis of Joggins palaeoecosystems, drawing together *c*. 150 years of palaeontological observation into a modern sedimentological framework. Results clarify the nature of a distinct intra-continental province of the Pennsylvanian tropical biome, and improve understanding of this historic fossil site (Falcon-Lang & Calder 2004).

Geological setting

The Pennsylvanian Joggins Formation (Cumberland Group) is exposed in spectacular sea-cliffs along Chignecto Bay, Nova Scotia, and is traceable eastwards inland for ⩽35 km (Fig. 2; Copeland 1958). The 915.5 m thick type section (Davies *et al*. 2005) located between Lower Cove and the old Joggins Wharf (45°42′N;64°26′W) has recently been relogged at the bed scale for the first time since 1843 (Rygel & Shipley 2005), and the stratigraphy of the Joggins Formation revised (Calder *et al*. 2005*a*). Palynological analyses place the entire revised formation within the Langsettian stage (Dolby 1991, 2003), a unit with a probable duration of *c*. 313.4–314.5 Ma (Fig. 1c; Gradstein *et al*. 2004).

The Joggins Formation was deposited close to the centre of the Cumberland sub-basin, part of the Late Palaeozoic Maritimes Basin complex of SE Laurasia (Gibling 1995). The Maritimes Basin lay close to the equator during Pennsylvanian times (Scotese & McKerrow 1990), and was connected to the open ocean in NW Europe during sea-level highstand, as indicated by brackish incursions (Duff & Walton 1973; Archer *et al*. 1995; Falcon-Lang 2005*a*), and drainage patterns (Gibling *et al*. 1992; Calder 1998). Compared with the Appalachian, Illinois, and North Variscan paralic basins, which contain common marine bands (Opluštil 2004), the geological context of the Maritimes Basin was more restricted and intra-continental, at times of sea-level lowstand, probably becoming intermontane.

Three sedimentary facies associations are recognized in the

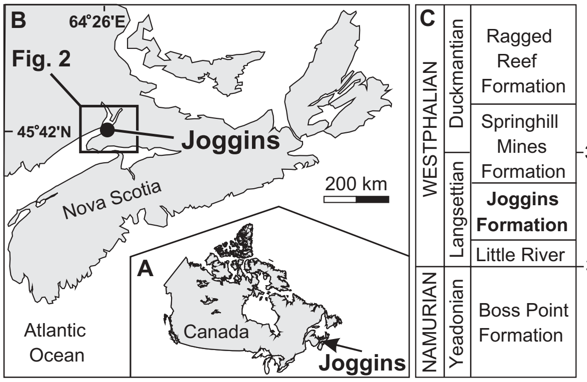

Fig. 1. Location and stratigraphy. (**a**) Location of Joggins in Canada; (**b**) location in Nova Scotia; (**c**) stratigraphy of the Lower Pennsylvanian Cumberland Group (after Gradstein *et al*. 2004; Calder *et al*. 2005*a*).

Joggins Formation, organized into 14 rhythms (Davies & Gibling 2003; Davies *et al*. 2005). Each rhythm commences with a retrograding, poorly drained coastal plain association (rPDF), typically overlain by an open water association (OW), together marking progressive basin-wide flooding by a brackish sea, the distal extension of European marine bands. These deposits are succeeded by a poorly drained coastal plain association with a progradational motif (pPDF), recording bay-filling by wetland deltas, and in nine rhythms, by a well-drained alluvial plain association (WDF), deposited following floodplain aggradation above base-level (Davies *et al*. 2005). Rhythms primarily record the superimposed effects of tectonism and glacioeustasy (Davies *et al*. 2005).

Time interval and completeness of fossil record

Sediment accumulation rates in the Cumberland sub-basin were amongst the highest of all Euramerican coal basins, partly as a result of salt withdrawal at depth (Waldron & Rygel 2005). The Lower Pennsylvanian Cumberland Group comprises, from base to top, the Boss Point, Little River, Joggins, Springhill Mines, and Ragged Reef formations (Fig. 1c), and is *c*. 4 km thick along Chignecto Bay (Gibling 1995). Given that the Yeadonian–Langsettian boundary may lie near the base or middle of the Little River Formation and that the Langsettian–Duckmantian boundary is positioned *c*. 380 m above the base of the Springhill Mines Formation (Dolby 1991, 2003; Calder *et al*. 2005*a*; Utting & Wagner 2005; Utting *et al*. 2005), the total thickness of the Langsettian stage in this region is of the order of 1600 m.

The absolute duration of the Langsettian is controversial (Menning *et al*. 2000). The most recent data imply a period of *c*. 1.1 Ma, but radiometric dates of key boundaries are currently missing, and precision is therefore impossible (Gradstein *et al*. 2004). These uncertainties aside, assuming a constant rate of

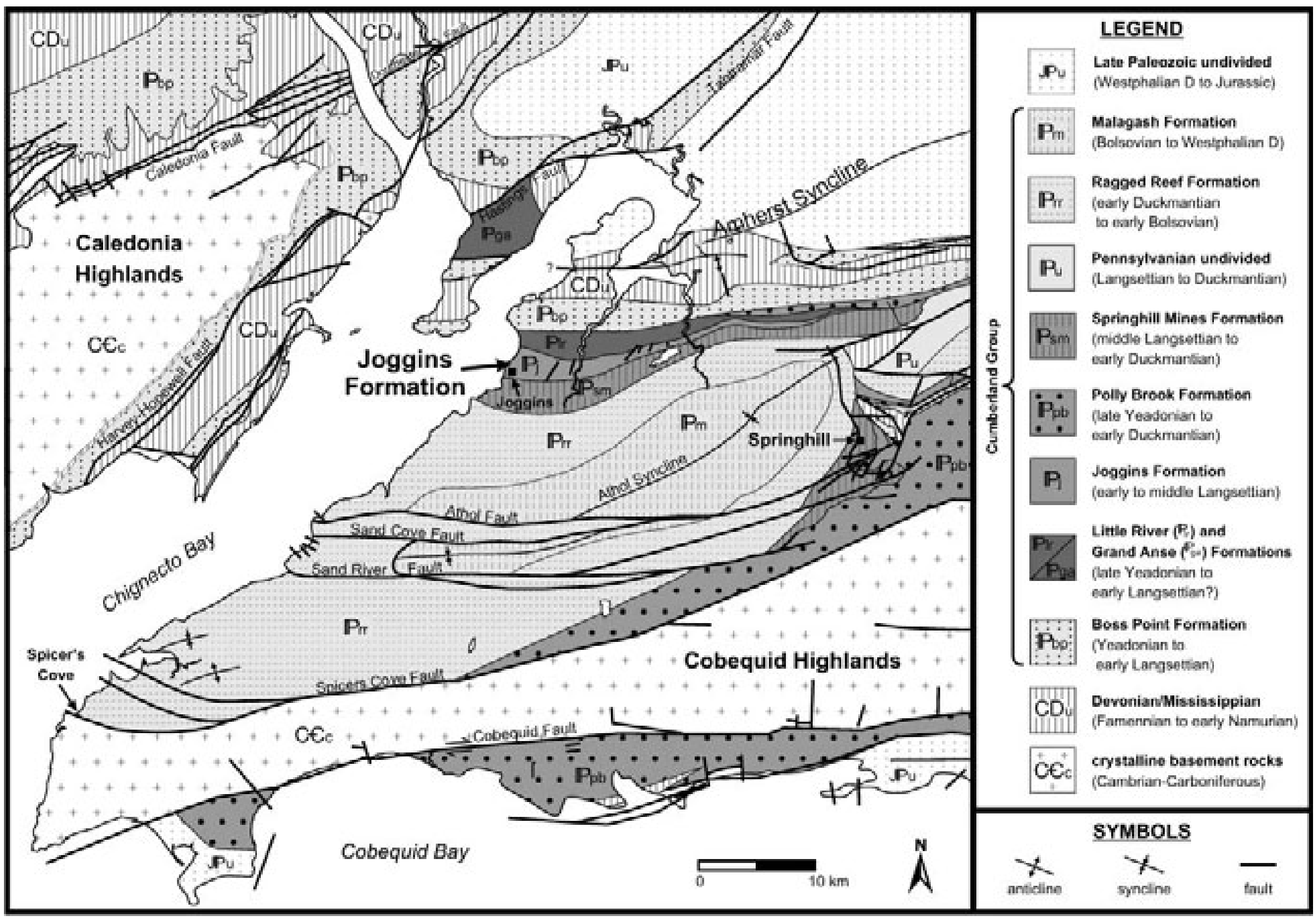

Fig. 2. Geological map of the Cumberland sub-basin showing the distribution of the Joggins Formation (after Calder *et al*. 2005*a*).

deposition for the Langsettian part of the basin-fill, the 915.5 m thick Joggins Formation clearly represents <1 Ma. The Joggins Formation thus comprises an unusually complete mid-Langsettian record, as additionally shown by the apparent absence of major discontinuities (valley-base sequence boundaries and coeval mature palaeosols) and the relative completeness of the preserved drainage network (Davies & Gibling 2003; Rygel 2005).

A rich biota comprising *c*. 96 genera (*c*. 148 species) of protist, animal, and plant body fossils, and an additional *c*. 20 genera of trace fossils, is recorded from this short time interval. As the Joggins Formation has been studied over an extended period, collector curves may be constructed to assess the completeness of the fossil record, and the likelihood of significant new discoveries (Benton 2001). Although earlier fossil reports exist (Brown & Smith 1829; Jackson & Alger 1829; Gesner 1836; Lyell 1843, 1845), the baseline year for our assessment of fossil record completeness was taken as 1850 because, prior to that date, descriptions were generally too imprecise for generic assignment. The publication date at which each genus of body fossil was first recorded from the Joggins Formation was noted, and data were plotted as a cumulative curve. Trace fossils (ichnogenera) were excluded because one producer can create several different ichnotaxa, thus exaggerating the estimated diversity. To gauge the amount of effort exerted over time, the number of publications about the Joggins Formation were also recorded and plotted as a decadal histogram. Raw data used in this analysis are available on request.

Results show that 67% of fossil discoveries were made rapidly during the first two decades of study, the remaining 33% slowly accumulating over the subsequent 125 years (Fig. 3a). Although the rate of discovery has significantly slowed since 1870, there is no indication that the zenith of the collector curve is close to being attained. However, it is possible that the slow, but constant, rate of new fossil discovery seen in the 20th century is only being sustained by a massive increase in effort over time, as indicated by the publication records (Fig. 3b). Plants are, at present, one of the most incompletely known fossil groups (Bell 1944), and several new taxa will be added in the course of current revision (R. H. Wagner, pers. comm.). Although more discoveries are likely in the future, the data imply that the current fossil record is probably a reliable indicator of Joggins Formation diversity in general terms.

In this paper, all known fossil assemblages collected since 1850 are placed in their facies context (rPDF, OW, pPDF, WDF; Davies & Gibling 2003; Falcon-Lang 2003*a*). In his original log of the Joggins Formation, Logan (1845) noted 45 coal seams, numbered from youngest (Coal 1) to oldest (Coal 45). Logan's coal numbering scheme is used to indicate the approximate stratigraphic position of key fossil assemblages in addition to the precise metrage (which relates to the detailed bed-by-bed log published by Davies *et al*. 2005). The position of fossil assemblages and Logan's coals is shown on the type section (Fig. 4). The degree of autochthony of each fossil record is assessed, and inferences about the original habitat are made. Data are then used to reconstruct communities of co-occurring organisms and to build ecosystem models.

Retrograding poorly drained coastal plain (rPDF) fossil assemblages

Each sedimentary cycle begins with an rPDF unit, which includes some of the thickest and most laterally persistent coal

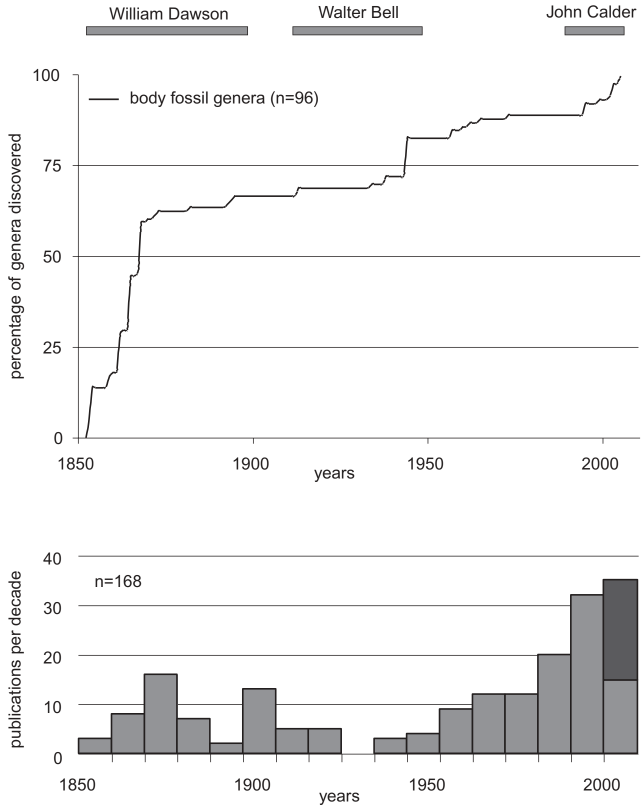

Fig. 3. Assessment of fossil record completeness for the Joggins Formation based on data for the 1850–2003 interval. (**a**) Cumulative curve of body fossil genus discovery over time; (**b**) decadal histograms of publications about the Joggins Formation over time showing estimates projection (dark grey) for 2000–2010. The activity of the three most historically important palaeontologists who have worked on the Joggins Formation is highlighted by the time-lines.

seams in the Joggins Formation (termed here coal zones), and contains a distinctive fossil assemblage (Table 1).

Coal zones (CZ facies)

The CZ facies comprises 0.01–1.5 m thick coals (typically ⩽0.1 m thick) interbedded with rooted, grey mudstone. Coals have high sulphur (⩽13.7% in some bands; locally pyritous) and metal contents (especially Zn, Ni, Ba, V, and Mn; Hower *et al*. 2000; Skilliter 2001), and are underlain by *Stigmaria*-rich seat earths. Adpressed plant assemblages are dominated by the lycopsid *Sigillaria*, including in Coal 15a (621 m), one 9.2 m long unbranched trunk (Dawson 1868). Other adpressions include lycopsids (*Lepidodendron*, *Lepidophloios*, *Cyperites*), sphenopsids (*Calamites*, *Pinnularia*), medullosan pteridosperms (*Alethopteris*, *Neuropteris*) and cordaitaleans (*Cordaites*, *Cordaicarpus*). The richest assemblages are in Coal 8 (780 m). In contrast, palynological assemblages from the same beds, principally Coals 28 (446 m), and 32 (390 m), are dominated by *Lepidophloios*, *Lepidodendron* or *Diaphorodendron* lycopsid spores, with minor contributions from *Sigillaria*, tree-ferns, sphenopsids, and cordaitaleans (Hower *et al*. 2000; Calder *et al*. 2005*b*).

Spirorbis worm tubes encrust plant remains in Coals 1 (915 m), 5 (871 m), 7 (806 m), 12 (669 m), 15a (621 m) and 20 (547 m), being especially common on *Sigillaria* trunks and

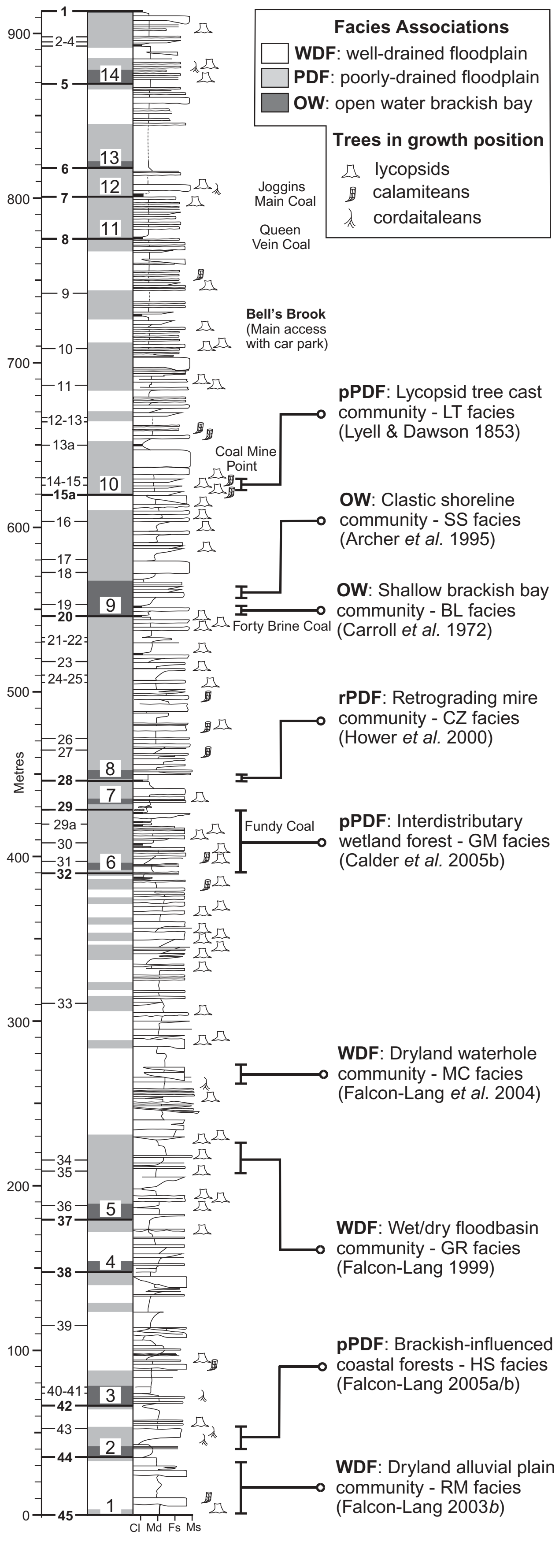

Fig. 4. Summary log of the 915.5 m thick revised Joggins Formation (after Davies *et al*. 2005), showing Logan's coal numbering scheme (left column; Logan 1845; Dawson 1868), facies associations and rhythms (middle column; Davies & Gibling 2003), and the position of representative fossil assemblages of the nine main ecosystems described (this paper).

Cordaites leaves. In Coals 28 (446 m) and 32 (390 m), indeterminate scorpion cuticle occurs (Mösle *et al*. 2002; Calder *et al*. 2005*b*). In Coal 8 (781 m), cuticular fragments of the giant eurypterid *Hastimima* (Clarke & Ruedemann 1912; Bell 1922; Copeland & Bolton 1960; Briggs *et al*. 1979; Waterston *et al*. 1985), and the malacostracan *Pygocephalus*, occur within mudstone partings (Salter 1863) with *Naiadites* bivalves and *Carbonita* ostracodes (Dawson 1868). On the upper surface of Coal 6 (820 m), fish teeth, scales, and bones of *Ctenoptychius*, *Xenacanthus*, *Rhizodopsis*/*Strepsodus*, and palaeoniscids are present (Dawson 1868; Calder 1998). Although the coal is positioned beneath a bituminous limestone, Dawson (1868) specifically noted the unusual occurrence that the fish were embedded within the coal.

Open water (OW) fossil assemblages

The OW association represents deposition in a brackish sea, the distal extension of European marine bands (Davies & Gibling 2003). Sedimentary facies include a lower interval comprising bituminous limestone beds with platy shales, locally interdigitating with underlying coals of the rPDF association, and an upper interval of sharp-based sandstone beds with intervening grey mudstone beds. Each facies contains a distinct fossil assemblage (Table 1).

Bituminous limestone (BL facies)

The BL facies comprises ⩽2 m thick bituminous limestone beds, and associated organic-rich shales. Plant remains are rare in bituminous limestone units. The tops of several beds are rooted by *Stigmaria*, especially at 35 m, 77 m, and 148 m, where they are interbedded with thin coals (Falcon-Lang 2003*a*). Other poorly preserved (*Cordaites*, *Calamites*, decorticated lycopsid trunks), or indeterminate plant fragments are encrusted by *Spirorbis* worm tubes (Dawson 1868). Palynological assemblages are dominated by *Paralycopodites* spores, and medullosan pteridosperm pollen, cuticle, and resin rodlets, whereas *Lepidodendron* and *Lepidophloios* spores are rare (Hower *et al*. 2000). Locally common plant adpressions in organic-rich shales are dominated by pteridosperms (*Alethopteris*, *Karinopteris*, *Paripteris*, *Trigonocarpus*), putative progymnosperms (*Pseudadiantites*, *Rhacopteris*), cordaitaleans (*Cordaites*, *Dadoxylon*), sphenopsids (*Calamites*, *Asterophyllites*) and decorticated lycopsid trunks (Falcon-Lang 2003*a*).

Both bituminous limestone and organic-rich shale contain an invertebrate fauna, the richest assemblages occurring above Coal 20 (555 m; Copeland 1957). Most common are disarticulated bivalves (*Naiadites* 2 sp., *Curvirimula*) crushed together into dense accumulations (Rogers 1965), and ostracodes (*Candona* 2 sp., *Carbonita* 7 sp., *Hilboldtina*, *Velatomorpha*), whose taxonomy is currently being revised (Tibert & Dewey 2005). *Spirorbis* worm tubes locally encrust bivalves. Less common invertebrates include the malacostracan *Pygocephalus* (Salter 1863; Dawson 1877*a*), and the xiphosuran *Bellinurus* (Copeland 1957; spelling after Morris 1980). Although conchostracans are mentioned in

Table 1. *Fossil assemblages in the open water (OW) association*

Protists					
	Phylum Foraminifera				
					Ammobaculites sp. (SS)
					Ammotium sp. (SS)
					Trochammina sp. (SS)
					cf. *Textularia* sp. (SS)
Animals					
	Phylum Annelida				
			Class Polychaeta		
					Spirorbis carbonarius (CZ, BL, SS)
	Phylum Mollusca				
			Class Pelecypoda		
					Curvirimula sp. (BL, SS)
					Naiadites 2 sp. (CZ, BL, SS)
	Phylum Arthropoda				
			Class Ostracoda		
					Carbonita 7 sp. (CZ, BL)
					Candona 2 sp. (BL)
					Hilboldtina rugulosa (BL)
					Velatomorpha sp. (BL)
			Class Malacostraca		
					Pygocephalus dubius (CZ, BL)
			Class Merostomata		
					Bellinurus sp. (BL)
			Class Arthropleurida		
					Hastimima whitei (CZ)
			Class Arachnida		
					Indet. scorpion cuticle
	Phylum Chordata				
		Superclass Pisces			
			Class Acanthodii		
					Gyracanthus sp. (BL)
			Class Chondrichthys		
					Callopristodus pectinatus (BL)
					Ctenacanthus sp. (BL)
					Ctenoptychius cristatus (CZ)
					Xenacanthus sp. (CZ, BL)
			Class Osteichthyes		
					Haplolepis canadensis (BL)
					Megalichthys sp. (BL)
					Rhabdoderma sp. (BL)
					Rhizodopsis/*Strepsodus* (CZ, BL)
					Sagenodus sp. (BL)
					Indet. palaeonisids sp. (CZ)
		Superclass Tetrapoda			
			Class Amphibia		
				Order 'Anthracosauria'	
					Baphetes minor (BL)
Trace fossils					
	Phylum Annelida				
					Arenicolites sp. (SS)
					Cochlichnus anguineus (SS)
					Gordia sp. (SS)
					Haplotichnus (SS)
					Plangtichnus erraticus (SS)
					Treptichnus pollardi (SS)
	Phylum Arthropoda				
			Class Merostomata		
					Kouphichnium sp. (SS)
					cf. *Limulocubichnus* sp. (SS)
				Incertae sedis	
					Siskemia sp. (SS)
Plants					
			Class Lycopsida		
					Cyperites sp. (CZ)
					Lepidodendron sp. (CZ)
					Lepidophloios sp. (CZ)
					Sigillaria sp. (CZ)
					Stigmaria ficoides (CZ, SS)
			Class Sphenopsida		
					Asterophyllites sp. (BL, SS)
					Calamites cisti (CZ, BL, SS)
					Pinnularia sp. (CZ)
			Class Progymnospermopsida		
					Pseudadiantites sp. (BL, SS)
					Rhacopteris sp. (BL)
			Class Cycadopsida		
					Alethopteris sp. (CZ, BL, SS)
					Karinopteris sp. (BL, SS)
					Mariopteris sp. (SS)
					Neuropteris sp. (CZ, SS)
					Paripteris sp. (BL)
					Trigonocarpus sp. (BL)
			Class Coniferopsida		
					Cordaites principalis (CZ, BL, SS)
					Cordaicarpus dawsoni (CZ)
					Dadoxylon 2 sp. (BL, SS)

CZ, coal zone, interpreted as retrograding peat mire deposits; BL, bituminous limestone, interpreted as brackish bay deposits; SS, sharp-based sandstone, interpreted as shallow shoreline deposits. Sources: Dawson 1854, 1865, 1868; Marsh 1862; Romer & Smith 1934; Copeland 1957; Copeland & Bolton 1960; Baird 1962, 1978; Romer 1963; Salter 1863; Rogers 1965; Carroll *et al*. 1972; Duff & Walton 1973; Briggs *et al*. 1979; Archer *et al*. 1995; Calder 1998; Skilliter 2001; Mösle *et al*. 2002; Falcon-Lang 2003*a*, 2005*a*.

one field guide (Carroll *et al*. 1972), we cannot find support for their occurrence in primary literature (Salter 1863; Dawson 1868; Copeland 1957).

Vertebrate remains, including fish and tetrapods, are present in almost every bituminous limestone in small numbers. The most productive fish-bearing units overlie Coals 19 (555 m) and 20 (547 m), and have yielded two complete specimens of *Haplolepis* (Baird 1962, 1978), and numerous fragmentary remains of *Callopristodus*, *Ctenacanthus*, *Megalichthys*, *Rhizodopsis*, *Sagenodus*, and *Xenacanthus* (Romer & Smith 1934; Carroll *et al*. 1972; Baird 1978; Calder 1998), and cf. *Rhabdoderma* (Duff & Walton 1973). A *Gyracanthus* spine occurs in a limestone above Coal 41 (77 m; Dawson 1868; Baird 1978). Above Coal 20 (547 m), rare tetrapod fossils including a large basal tetrapod, cf. *Baphetes minor* are present (Romer 1963).

Sharp-based sandstone sheets (SS facies)

The SS facies comprises sharp-based, sheet-like sandstone beds, <1 m thick, with basal flute casts and tool marks, interbedded at some levels with grey, laminated mudstone showing flaser beds (Skilliter 2001). Generally characterized by planar bedding and present as packages a few metres thick, in a few examples the sharp-based sandstone sheets contain overlapping mounds <100 m in apparent width (Davies & Gibling 2003). Indeterminate roots are abundant in the upper part of some sandstone sheets, and rarely *Stigmaria* occur in intervening mudstone beds. Highly fragmentary plant adpressions within sandstone sheets are rare, but locally include sphenopsids (*Asterophyllites*, *Calamites*), progymnosperms (*Pseudadiantites*), pteridosperms (*Alethopteris*, *Karinopteris*, *Mariopteris*, *Neuropteris*), and cordaitaleans (*Cordaites*, *Dadoxylon*; Falcon-Lang 2003*a*).

Animals are also rare, and include a few *Naiadites* and *Curvirimula* bivalves, *Spirorbis* worm tubes, and indeterminate fish scales. In addition, a putative assemblage of agglutinated Foraminifera occurs in one interval above Coal 19 (569 m). It comprises *Trochammina*, *Ammobaculites*, *Ammotium*, and cf. *Textularia* with a modal test size of 125–250 μm (Archer *et al*. 1995). Invertebrate trace fossils occur at several intervals, but the richest unit overlies Coal 19 (568 m), and includes xiphosurian (*Kouphichnium*), and other arthropod or annelid traces (*Arenico-*

lites, *Cochlichnus*, *Gordia*, *Haplotichnus*, *Plangtichnus*, *Treptichnus*; Archer *et al*. 1995; Davies & Gibling 2003). *Protichnites* also present in this bed is reinterpreted as *Siskemia* in this paper. Another assemblage above Coal 44 (41 m) contains *Kouphichnium*, cf. *Limulocubichnus* and *Cochlichnus* (Falcon-Lang 2005*a*).

Prograding poorly drained coastal plain (pPDF) fossil assemblages

pPDF associations represent poorly drained coastal plain deposits (predominantly terrestrial wetlands). Sedimentary facies include, at the base of two pPDF units, heterolithic sandstone intervals (Falcon-Lang 2005*a*), and more generally, intervals comprising grey mudstone with thin coals, sheet sandstones, and channel sandstone bodies (Davies & Gibling 2003). Each facies contains a distinct fossil assemblage (Table 2).

Table 2. *Fossil assemblages occurring in the poorly drained coastal plain (pPDF) association*

Animals
- Phylum Mollusca
  - Class Pelecypoda
    - *Naiadites* 2 sp. (GM)
  - Class Gastropoda
    - *Dendropupa vestusta* (LT)
    - *Pupa bigsbii* (LT)
    - *Protodiscus priscus* (LT)
- Phylum Annelida
    - *Spirorbis carbonarius* (GM, LT)
- Phylum Arthropoda
  - Class Merostomata
    - cf. *Mycterops* sp. (LT)
  - Class Diplopoda
    - *Archiulus xylobioides* (LT)
    - *Xyloiulus sigillariae* (GM, LT)
  - Class Arthropleurida
    - *Amynilyspes springhillensis* (LT)
  - Class Arachnida
    - *Coryphomartus triangularis* (LT)
    - *Graeophonus carbonarius* (GM, LT)
    - Indet. scorpion cuticle (GM, LT)
  - Class Insecta
    - Order Megasecoptera (GM)
- Phylum Chordata
  - Superclass Tetrapoda
    - Class Amphibia
      - Order Microsauria (69)
        - *Archerpeton anthracos* (LT)
        - *Asaphestera intermedium* (LT)
        - *Hylerpeton dawsoni* (LT)
        - *Leiocepehalikon problematicum* (LT)
        - *Ricnodon* sp. (LT)
      - Order 'Temnospondyli' (106)
        - *Dendrerpeton acadianum* (GM, LT)
        - *Dendrerpeton confusum* (LT)
        - *Dendrepeton helogenes* (LT)
      - Order 'Anthracosauria' (12)
        - *Calligenethlon watsoni* (GM, LT)
  - Series Amniota
    - Class Sauropsida
      - Order 'Captorhinomorpha' (18)
        - *Hylonomus lyelli* (LT)
      - Order 'Pelycosauria' (4)
        - *Protoclepsydrops haplous* (LT)

Table 2. *Continued*

    - Class Synapsida
      - Incertae sedis (1)
        - *Novascoticus multidens* (LT)

Trace fossils
- Phylum Annelida
    - cf. *Asterichnus* sp. (HS)
- Phylum Arthropoda
    - *Diplichnites cuithensis* (GM)
    - *Taenidium barretti* (GM)
- Phylum Chordata
  - Superclass Tetrapoda
    - Class Amphibia
      - Order 'Temnospondyli'
        - *Limnopus vagux* (HS, GM)
        - *Matthewichnus velox* (GM)
      - Order Microsauria
        - *Dromillopus quadifidus* (GM)
        - *Ornithoides trifudus* (GM)
  - Series Amniota
    - Class Sauropsida
      - Order 'Captorhinomorpha'
        - *Notalacerta* sp. (GM)
        - *Pseudobradypus* sp. (GM)

Plants
- Class Lycopsida
  - *Bothrodendron punctatum* (GM)
  - *Cyperites* sp. (GM, LT)
  - *Diaphorodendron* sp. (GM)
  - *Lepidodendron* 4 sp. (GM, LT)
  - *Lepidophloios* sp. (GM)
  - *Lepidostrobus* 2 sp. (GM, LT)
  - *Paralycopodites* sp. (GM, LT)
  - *Sigillaria* 4 sp. (GM)
  - *Stigmaria ficoides* (GM)
- Class Sphenopsida
  - *Annularia* sp. (GM)
  - *Asterophyllites* sp. (HS, GM)
  - *Calamites* 2 sp. (GM, LT)
  - *Eucalamites* sp. (GM)
  - *Palaeostachya* sp. (GM)
  - *Sphenophyllum* sp. (GM)
- Class Filicopsida
  - *Renaultia* 4 sp. (GM)
  - *Sphenopteris* 4 sp. (GM)
  - *Zeilleria* 5 sp. (GM)
- Class Cycadopsida
  - *Alethopteris* 3 sp. (HS, GM)
  - *Karinopteris acuta* (GM)
  - *Mariopteris* sp. (GM)
  - *Neuralethopteris schlehanii* (GM)
  - *Neuropteris* 2 sp. (GM)
  - *Paripteris* sp. (GM)
  - *Senftenbergia dentata* (GM)
  - *Trigonocarpus parkinsoni* (GM, LT)
- Class Coniferopsida
  - *Artisia transvera* (GM)
  - *Cordaites principalis* (HS, GM, LT)
  - *Cordaicladus* sp. (HS)
  - *Cordaicarpus dawsoni* (HS, GM)
  - *Cordaianthus* sp. (HS, GM)
  - *Dadoxylon* 2 sp. (HS, GM)

HS, heterolithic sandstone, interpreted as micro-tidal lagoon deposits; GM, grey mudstone with channel bodies, interpreted as coastal plain deposits; LT, interior of lycopsid trees within GM. Sources: Lyell & Dawson 1853; Dawson 1854, 1860, 1861, 1863, 1865, 1868, 1876, 1877*b*, 1882, 1891*a*,*b*, 1892, 1896; Scudder 1873, 1895; Petrunkevitch 1913; Steen 1934; Copeland 1957; Carroll 1967; Rolfe 1969, 1980; Carroll *et al*. 1972; Solem & Yochelson 1979; Godfrey *et al*. 1987, 1991; Archer *et al*. 1995; Reisz & Modesto 1995; Milner 1996; Mossman & Grantham 1996; Calder 1998; Holmes *et al*. 1998; Falcon-Lang 1999, 2003*a*; Utting & Wagner 2005; Calder *et al*. 2005*b*). The approximate number of individual tetrapod skeletons per order is indicated by figures in parenthesis (Carroll *et al*. 1972), but may be inflated because of double counting of counterpart specimens (Milner 1996).

Heterolithic sandstone (HS facies)

The HS facies comprises heterolithic units, ≤2 m thick, which contain ripple cross-laminated sandstone and siltstone, locally showing paired mud drapes, bimodal palaeocurrent indicators, and grey, laminated mudstone interbeds. Beds contain small trunks of cordaitalean trees, preserved in an upright orientation (Falcon-Lang 2005*a*), and rooted within grey mudstone beds above Coals 7 (808 m) and 44 (46 m). Tree trunks are locally calcite-permineralized, may exhibit *Dadoxylon* wood, and have complex, shallow root systems (Dawson 1868). Associated strata contain adpressed plant assemblages dominated by cordaitaleans (*Cordaites*, *Cordaicladus*, *Dadoxylon*, *Cardiocarpus*, *Cordaianthus*) with rare pteridosperms (*Alethopteris*) and sphenopsids (*Asterophyllites*). Rare burrows, cf. *Asterichnus*, occur, and two surfaces preserve *Limnopus* temnospondyl trackways (Falcon-Lang 2005*a*).

Grey mudstone with channel bodies (GM facies)

The GM facies comprises grey mudstone beds, commonly rooted, and containing discontinuous, centimetre-thick coals and organic-rich shales (Calder *et al*. 2005*b*). Heterolithic sheet sandstone complexes occur at some intervals, and siderite nodules are ubiquitous. Sandstone bodies, ≤10 m thick, and locally showing inclined stratification, are present at other intervals (Davies & Gibling 2003).

Upright, sediment-cast lycopsid trees with attached *Stigmaria*, many showing surface features suggestive of *Sigillaria*, or rarely *Lepidodendron sensu lato*, are commonly rooted in organic-rich shales and coals. A few specimens, especially those rooted above Coal 30 (411 m), are calcite-permineralized, and according to Dawson (1877*b*) preserve cellular anatomy of the stele (his *Diploxylon*). Lycopsid trunks have preserved heights of ≤6 m (typically ≤2 m), and are buried by sandstone-dominated sheets, which locally coarsen upwards (Falcon-Lang 1999). Plant adpressions associated with the thin coals are dominated by lycopsids (*Sigillaria* 4 sp. and *Lepidodendron*; with minor *Lepidophloios*, *Bothrodendron*, *Paralycopodites*, *Cyperites*). Similarly, palynological assemblages are dominated by *Sigillaria* spores, with subordinate representatives of *Lepidodendron*, *Paralycopodites*, and *Diaphrodendron*. Indeterminate scorpion cuticle is common in some beds (Calder *et al*. 2005*b*).

Intervening mudstone and sandstone units contain a more diverse adpressed plant assemblage including, in addition to the lycopsids mentioned above, sphenopsids (*Calamites*, *Annularia*, *Asterophyllites*, *Palaeostachya*, *Sphenophyllum*), ferns (*Renaultia*, *Sphenopteris*, *Zeilleria*), pteridosperms (*Alethopteris*, *Karinopteris*, *Neuralethopteris*, *Neuropteris*, *Paripteris*, *Trigonocarpus*), and cordaitaleans (*Cordaites*, *Cordaicarpus*, *Cordianathus*; Calder 1998; Calder *et al*. 2005*b*). Upright *Calamites* stems are commonly rooted within sandstone beds, locally occurring with high stem densities (Falcon-Lang 1999).

Siderite nodules in the mudstone beds above Coal 14 (633 m) contain indeterminate tetrapod skeletal material, and a similar facies, probably positioned above Coal 29a (422 m), contains two articulated specimens of the basal tetrapod *Dendrerpeton acadianum* (Godfrey *et al*. 1987; Holmes *et al*. 1998), and the amblypygid arachnid *Graeophonus* (Dunlop 1994; Calder *et al*. 2005*b*). Siltstone and mudstone layers between Coal 29 and 32 (390–429 m) also contain *Naiadites* bivalves, a single specimen of the diplopod *Xyloiulus*, an insect referable to the Order Megasecoptera (probably also at 742 m; Dawson 1868) and trackways of basal tetrapods (*Limnopus*, *Matthewichnus*), microsaurs (*Ornithoides*), and 'captorhinomorphs' (*Notalacerta*, *Pseudobradypus*; Cotton *et al*. 1995; Calder *et al*. 2005*b*). Above Coal 4 (897 m) spines and scales of palaeoniscid fish occur (Dawson 1868).

Large channel sandstone bodies contain lycopsid trunk adpressions (*Lepidodendron*, *Lepidophloios*, *Sigillaria*), some several metres long, sphenopsids (*Calamites*), and cordaitaleans (*Artisia*, *Cordaites*, *Dadoxylon*; Falcon-Lang 2003*a*). A few *Diplichnites cuithensis* trackways (the walking traces of giant arthropleurids), and *Dromillopus* microsaur trackways (Cotton *et al*. 1995), occur on top of some channel bodies, especially above Coal 14 (646 m; Dawson 1861; Mossman & Grantham 1996). *Taenidium*, a type of meniscate back-filled burrow cf. *Beaconites* (probably produced by aestivating arthropleurids; Morrissey & Braddy 2004), found in a fallen block, is also attributed to this facies with uncertainty (Archer *et al*. 1995).

Sandstone-cast trees (LT facies)

The LT facies comprises the interior of upright sediment-cast lycopsid trees, which locally contain rich fossil assemblages, and are thus described separately from the enclosing GM facies. Fossiliferous trees have external ribbing suggestive of *Sigillaria* and always contain a basal layer of charred lycopsid periderm and wood (Dawson 1860; Falcon-Lang 1999). Overlying carbonate-cemented mudstone or sandstone layers, typically in the basal 15 cm of tree-casts, contain tetrapods and invertebrates, but fauna are also embedded in the charcoal layer (Dawson 1882). Plant remains occur in sandstone-rich intervals, above or below faunal layers, and include lycopsids (*Lepidodendron*, *Paralycopodites*, *Cyperites*, *Lepidostrobus*), sphenopsids (*Calamites*), pteridosperms (*Trigonocarpus*) and cordaitaleans (*Cordaites*; Dawson 1860, 1861, 1882). Also present are lycopsid steles, which Dawson (1860) erroneously referred to *Artisia* (his *Sternbergia*). Similar '*Artisia*-like' lycopsid steles have been observed by one of us (H.J.F.L.).

Tetrapod skeletal material was first discovered in a tree rooted within Coal 15 (627 m), and buried by sandstone sheets (Lyell & Dawson 1853). Further remains were collected from additional trees in precisely the same bed (Dawson 1860, 1861, 1863, 1876, 1882, 1891*a*,*b*), and later from below Coals 20 (544 m) and 31 (398 m), erroneously given as Coals 26 and 20–21 by an ageing Dawson (1896), and later uncritically repeated (Steen 1934, and all subsequent researchers). Other sporadic occurrences of tetrapod-bearing trees were then documented from above Coals 10, 26?, and 37 (precise metrage uncertain) by W. A. Bell and C. M. Sternberg (Carroll 1967). There have also been a few recent discoveries (Godfrey *et al*. 1991; Scott 1998).

In total, remains of <210 individual animals (Carroll *et al*. 1972; Godfrey *et al*. 1991) comprising 12 tetrapod species have been recovered from ≥24 trees (Dawson 1882, 1896). These include basal tetrapods, microsaurs, 'temnospondyls' and 'anthracosaurs', as well as representative of the earliest known reptiles from both the synapsid and sauropsid branches of evolution (Godfrey *et al*. 1991; Reisz & Modesto 1995; Milner 1996). Skeletons are disarticulated, poorly articulated, or very rarely complete. The remains of 1–20 (mean: 4.2) individuals, comprising up to 5–6 species, are present in single tree trunks, together with coprolites (Dawson 1882, 1896).

Several invertebrates occur in association with tetrapod remains in trees above Coal 15 (627 m). Most common are terrestrial gastropods (*Dendropupa*), one tree containing several hundred specimens, with other gastropods (*Pupa*, *Protodiscus*) occurring in smaller numbers (Dawson 1860, 1880; Solem &

Yochelson 1979). Also present are millipedes (*Xyloiulus*, *Archiulus*; Scudder 1873; Copeland 1957), arachnids (*Graeophonus*, *Coryphomartus*; Scudder 1895; Petrunkevitch 1913, 1953; Rolfe 1980), and a possible cockroach (Dawson 1892). A specimen of *Amynilyspes springhillensis* has also been recorded (Dawson 1860, 1861; Copeland 1957), but assignment to this genus has recently been questioned (Racheboeuf *et al*. 2004). Furthermore, rather than representing an oniscomorph diplopod, Rolfe (1969) has interpreted this specimen as a juvenile arthropleurid. Fossils described by Dawson (1863, 1891*a*) as tetrapod skin in fact comprise a putative scorpion (cf. *Mazonia*; Dawson 1891*b*, 1892; Scudder 1895; disputed by Petrunkevitch 1913), and eurypterids comparable with *Dunsopterus*, *Hibbertopterus*, *Vernonopterus* (Waterston 1968) or *Mycterops* (Dalingwater 1975; Briggs *et al*. 1979; Rolfe 1980). *Spirorbis* worm tubes and putative fish scales also occur (Carroll *et al*. 1972). Invertebrate remains are commonly embedded within tetrapod coprolites. *Dendropupa* gastropods also occur in a tree above Coal 5 (*c*. 885 m), which lacks tetrapod remains.

Well-drained alluvial plain (WDF) fossil assemblages

The WDF association represents well-drained alluvial plain deposits (terrestrial drylands). Sedimentary facies include green–red mottled mudstone intervals, and others consisting solely of red mudstone, sheet sandstones, and channel bodies. Each facies contains a distinct fossil assemblage (Table 3).

Green–red mottled mudstone (GR facies)

The GR facies comprises green–grey, laminated mudstone successions, <7 m thick, which contain siderite nodules, <1 cm thick organic-rich, rooted intervals, and show red mottling (Falcon-Lang 1999). Plant adpressions in green–grey mudstone beds include lycopsids (*Sigillaria*, *Lepidodendron*, *Cyperites*, *Stigmaria*), sphenopsids (*Calamites*, *Annularia*, *Asterophyllites*, *Pinnularia*), ferns (*Sphenopteris*), pteridosperms (*Eusphenopteris*, *Neuralethopteris*, *Neuropteris*, *Trigonocarpus*) and abundant *Cordaites* (Falcon-Lang 1999; Mösle *et al*. 2002). Permineralized pteridosperm roots occur in siderite nodules. Mottled green–red units with *Stigmaria* above Coal 38 (*c*. 167 m) contain terrestrial gastropods (*Protodiscus*, *Dendropupa*), occurring as agglomerations of tens of individuals (Dawson 1861, 1867).

Organic-rich laminae, interbedded within the green–grey mudstone beds above Coals 34 (309 m, 227–230 m), 35 (214–219 m) and 43 (64 m), contain numerous lycopsid stumps with *Stigmaria* in growth position. Stumps are 5–15 cm high, locally calcite-permineralized, and preserve periderm anatomy suggestive of *Sigillaria*. Charred mesofossils within the stump interior comprise lycopsid wood and periderm. The remains of lycopsids, medullosan pteridosperms, and cordaitaleans dominate charcoal assemblages in organic-rich laminae outside the stumps (Falcon-Lang 1999). Palynological assemblages are rich in the spores of *Sigillaria* and palynodebris of medullosan pteridosperms.

Well-laminated organic-rich mudstones, which infill localized depressions, up to 15 cm deep and several metres wide, in green–grey mudstone above Coal 34 (218 m), contain rare *Naiadites* bivalves, and the cuticle of indeterminate scorpions and eurypterids (Stankiewicz *et al*. 1998). Plant adpressions include medullosan pteridosperms (*Neuralethopteris*, *Eusphenopteris*, calcite-permineralized *Trigonocarpus*) and abundant *Cordaites* leaves (Mösle *et al*. 2002).

Table 3. *Fossil assemblages occurring in the well-drained coastal plain (WDF) association*

Animals	
Phylum Mollusca	
Class Gastropoda	
	Dendropupa vestusta (GR, RM, MC)
	Protodiscus priscus (GR)
Class Pelecypoda	
	Archanodon westoni (MC)
Phylum Chordata	
Superclass Tetrapoda	
Class Amphibia	
Order 'Anthracosauria'	
	2 undescribed taxa (MC)
Order Microsauria	
	1 undescribed taxon (MC)
Trace fossils	
Phylum Arthropoda	
Class Arthropleurida	
	Diplichnites cuithensis (RM)
Phylum Chordata	
Superclass Tetrapoda	
	Several ichnotaxa (RM)
Plants	
Class Lycopsida	
	Cyperites sp. (GR)
	Lepidodendron sp. (GR, RM, MC)
	Sigillaria scutellata (GR, RM, MC)
	Stigmaria ficoides (GR, RM, MC)
Class Sphenopsida	
	Annularia sp. (GR)
	Asterophyllites sp. (GR)
	Calamites sp. (GR, RM, MC)
	Pinnularia sp. (GR)
Class Filicopsida	
	Sphenopteris sp. (GR)
	cf. *Artisophyton* (RM)
Class Cycadopsida	
	Alethopteris decurrens (RM)
	Eusphenopteris cf. *laxifolia* (GR, RM)
	Neuralethopteris cf. *schlehanii* (GR)
	Neuropteris sp. (GR)
	Trigonocarpus sp. (GR)
Class Coniferopsida	
	Artisia transvera RM, MC)
	Cordaites principalis (GR, RM, MC)
	Cordaicarpus dawsoni (RM)
	Dadoxylon 3 sp. (RM, MC)
	Mesoxylon cf. *sutcliffii* (RM)

GR, green–red mudstone, interpreted as seasonally wet floodplain deposits; RM, red mudstone with channel bodies, interpreted as permanently well-drained alluvial plain deposits; MC, mud-rich channel bodies, interpreted as waterhole deposits. Sources: Dawson 1861, 1867, 1868, 1880; Whiteaves 1893; Solem & Yochelson 1979; Stankiewicz *et al*. 1998; Falcon-Lang 1999, 2003*a*,*b*,*c*, 2005*b*; Mösle *et al*. 2002; Falcon-Lang *et al*. 2004; Hebert & Calder 2004.

Red mudstone with channel bodies (RM facies)

The RM facies comprises red mudstone successions containing scattered pedogenic carbonate nodules, sandstone sheets, and small, ribbon-like sandstone channel bodies (Davies & Gibling 2003). Red mudstone and sheet sandstone complexes contain common upright calamiteans, and a few upright, sandstone-cast lycopsids (*Sigillaria*) with attached *Stigmaria* (Dawson 1868; Falcon-Lang 2003*b*). One horizon above Coal 34 (270 m) contains a *Dadoxylon* stump in growth position (Falcon-Lang 2003*c*). A tree-fern base, presumably also in growth position, is present above Coal 34 (*c*. 260 m). At several intervals, 'sediment downturns' mark the position of other indeterminate trees in growth position (Gibling 1987; Rygel *et al*. 2004). Plant impressions are dominated by cordaitaleans (*Cordaites*, *Cordaicarpus*, *Dadoxylon* 3 sp.), with common medullosan pteridosperms (*Eusphenopteris*, *Alethopteris*), calamiteans, and rare lycopsids. Agglomerations of the terrestrial gastropod, *Dendropupa*, are present on mudstone beds above Coal 5 (Dawson 1880; Hebert & Calder 2004), whereas on others *Diplichnites cuithensis* trackways occur.

Channel sandstone bodies contain plant assemblages dominated by charred, calcite-permineralized, and impressed cordaitalean remains (*Dadoxylon*, *Mesoxylon*, *Cordaites*, *Artisia*, indeterminate cones), as well as a few lycopsids (*Sigillaria*, *Lepidodendron*) and calamiteans (Dawson 1896; Falcon-Lang & Scott 2000; Falcon-Lang 2003*a*,*b*,*c*). The rarest floral element in this facies is the schizeacean tree-fern trunk cf. *Artisophyton* (Falcon-Lang 2005b). Rare *Stigmaria* are rooted within the base of some channels with upright *Calamites* present on channel margins. Fauna is limited to the arthropleurid trackway *Diplichnites* (Briggs *et al*. 1979) located on the upper part of a channel body above Coals 40 (114 m; Ferguson 1966) and 45 (11 m), and a few occurrences of the terrestrial gastropod, *Dendropupa*, within intraformational conglomerates, especially above Coal 45 (9 m; Falcon-Lang 1999).

Mud-rich channel bodies (MC facies)

The MC facies comprises ribbon-like channel bodies, which contain a high proportion of mudstone. These beds include similar plant assemblages to those described above but, in addition, a few examples contain common invertebrate and vertebrate fossils. The invertebrate fauna includes the giant unionoid bivalve *Archanodon*, two specimens of which were first discovered in fallen blocks by T. C. Weston in 1892. With uncertainty, Whiteaves (1893) maintained that the blocks had fallen from high in the sea-cliffs above Coal 32 (394 m), a thin OW interval. However, had the fossils fallen from a lower cliff horizon then they would have come from underlying red WDF beds (*c*. 384 m). This latter origin was supported by Dawson (1896), who indicated that the fossils were associated with ‘reddish beds’ containing *Lepidodendron* and *Sigillaria* trunks, and *Cordaites* leaves, observations incompatible with the sharp-based sandstone units of the OW association.

A recent second discovery of 17 *Archanodon* specimens in a mud-rich channel body within the WDF association above Coal 37 (262 m; Falcon-Lang *et al*. 2004) further supports the assertion that earlier discoveries derived, not from OW units (Hebert & Calder 2004; Calder *et al*. 2005*b*), but from similar WDF units. Co-occurring invertebrates in this latter assemblage include the gastropod *Dendropupa*, which occurs in channel lags or as agglomerations of ⩽20 individuals surrounding plant debris (Falcon-Lang *et al*. 2004). More than 50 specimens occur in single channel bodies.

Vertebrate remains in mud-rich channel bodies are limited to the two intervals with *Archanodon* bivalves (262 m, *c*. 384 m). One assemblage comprises a single indeterminate tetrapod jaw (Whiteaves 1893). A second assemblage shows moderate to high disarticulation and includes ‘anthracosaur’, microsaur, and basal tetrapods (Falcon-Lang *et al*. 2004).

Unprovenanced fossil remains

Despite the fact that many key fossil discoveries from the Joggins Formation date from the 19th century, almost all records may be related with confidence to individual beds. This unusual precision has resulted from bed-by-bed logging of the section (Logan 1845), prior to the first major fossil discoveries (Lyell & Dawson 1853; Dawson 1854, 1865, 1868), and owes much to the meticulous work of Dawson (Falcon-Lang & Calder 2005). Nevertheless, there are a number of taxa that cannot, at present, be assigned to specific intervals and facies.

Unprovenanced tetrapod fossils include two very large vertebrae reported by Marsh (1862) under the name *Eosaurus acadianus*, and basal tetrapod remains noted from a channel sandstone body at an undisclosed locality between Ragged Reef and Joggins coal mine (Dawson 1870), and referred to *Baphetes minor* (Steen 1934; Romer 1963). The former fossils were initially thought to have been derived from sharp-based sandstone facies in an OW unit above Coal 5 (Dawson 1865, 1868), and represent the remains of aquatic Pennsylvanian tetrapods of unprecedented size (10 m long). However, later workers speculated that the specimens are in fact Liassic ichthyosaur remains from Lyme Regis, UK (Romer 1963; Carroll *et al*. 1972). The origin of these specimens is highly questionable.

Ichnotaxa are amongst the most poorly provenanced fossil remains in the Joggins Formation. Numerous tetrapod trackway specimens collected from the type section cannot, at present, be referred to specific beds and facies. These include trackways produced by ‘temnospondyls’ (*Antichnium* 2 sp., *Cursipes*, *Limnopus*), microsaurs (*Barillopus* 3 sp., *Dromillopus* 2 sp., *Salichnium*), ‘anthracosaurs’ (*Baropezia*) and ‘captorhinomorphs’ (*Hylopus*, *Asperipes*), among others (*Quadropedia*; Dawson 1882; Matthew 1903*a*,*b*, 1904; Sternberg 1933; Haubold 1971; Sarjeant & Mossman 1978; Cotton *et al*. 1995; Lucas *et al*. 2005). Several specimens may have been derived from rPDF and pPDF units at 545 m, 647 m, and *c*. 885 m (Dawson 1868), but others originated in WDF units. Also unprovenanced are the small myriapod trackways of *Diplichnites gouldi* (Matthew 1903*a*). This situation may be soon improved by continuing ichnological studies (Hunt *et al*. 2004), which may, in addition, show that some ichnotaxa (*Asperipes*, *Barillopus*, *Salichnium*) represent extramorphological variants of other well-defined ichnotaxa (Lucas *et al*. 2005).

With regard to plant fossils, only two taxa are currently unprovenanced. An allochthonous schizeacean trunk, *Aristophyton magnificum* (Dawson 1868, p. 449) cannot at present be placed in its facies context, although one poorly preserved specimen has recently been discovered in the WDF facies association. A similar situation exists for the several upright tree fern stems (cf. *Caulopteris*) briefly noted from the section (Dawson 1868, p. 486).

Joggins ecosystems

Analysis of taxa within the detailed facies context allows co-occurring communities of organisms to be identified in specific palaeoenvironments. These data form the basis for the inferences about food webs and ecology discussed below.

Retrograding coastal plains and brackish seas (Fig. 5)

Coal zones at the base of each sedimentary cycle (CZ facies) represent deposits of peat-forming forests developed in retrograding coastal plain settings (rPDF) during periods of sustained base-level rise (Falcon-Lang 2003*a*). Peat mire accretion kept pace with rising base-level for long periods (10^2–10^3 years), based on coal seam thickness and compaction coefficients, before finally being drowned by a brackish sea represented by bituminous limestones and platy shales of the overlying OW association

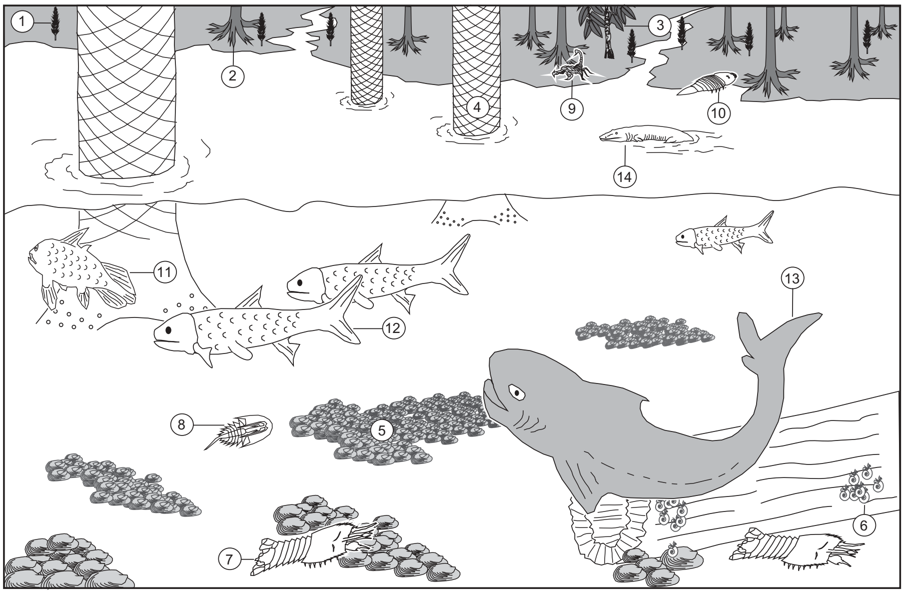

Fig. 5. Ecosystem reconstruction of retrograding coastal plain (rPDF) and open water (OW) facies associations. 1, *Calamites*; 2, *Lepidodendron*/*Lepidophloios*; 3, *Alethopteris*; 4, *Paralycopodites*; 5, *Naiadites*/*Curvirimula*; 6, *Spirorbis*; 7, *Pygocephalus*; 8, *Bellinurus*; 9, indet. scorpion; 10, *Hastimima*; 11, *Rhabdoderma*; 12, indet. palaeoniscid; 13, *Ctenacanthus*; 14, *Baphetes*.

(Falcon-Lang 2005*a*). Elevated water tables, necessary for mire accretion, were maintained by fluvial drainage, as indicated by metal enrichment of the coals (Kaplan *et al*. 1985; Hower *et al*. 2000), and rising base-level (Davies & Gibling 2003). Brackish incursions occurred throughout mire development, as indicated by high coal sulphur content, fish and invertebrate remains, plants encrusted by *Spirorbis*, and limestone interbeds (Davies & Gibling 2003).

Based on palynology, retrograding mires were forested by *Diaphorodendron*, *Lepidodendron*, and *Lepidophloios*, with an understorey of ferns, sphenopsids, and cordaitaleans. Such communities were characteristic of locally submerged mires, subject to occasional brackish incursions (DiMichele & Phillips 1994). The low spore abundance of *Sigillaria*, despite its dominance in the megafossil record, represents, as yet, poorly understood taphonomic biases (Hower *et al*. 2000). Scorpions populated emergent peat surfaces, as at many other Pennsylvanian tropical sites (Bartram *et al*. 1987), and giant eurypterids made occasional amphibious excursions across the mires (Braddy 2001). Blackwater drainage channels dissecting the mires locally teemed with molluscs, arthropods and fish, the fauna penetrating the forested wetlands during short-term brackish incursions, some elements such as *Pygocephalus* perhaps able to tolerate freshwater (Schram 1980, 1981).

As base-level rise began to outpace mire accretion, stands of *Paralycopodites*, an ecotonal lycopsid (DiMichele & Phillips 1994), and medullosan pteridosperms, replaced peat-forming lepidodendrid communities, until water depths finally precluded vegetation. The seas that subsequently developed (BL facies) were brackish, based on faunal content (Calver 1968), dysaerobic (Gibling & Kalkreuth 1991), and probably less than several tens of metres deep, although depth indicators are equivocal. Bivalves, byssally attached to the sea bed, developed thick banks in these extensive shallow embayments, their disarticulation suggesting either predation or wave reworking. This latter interpretation is supported by the fact that one of the Joggins bivalve genera, *Curvirimula*, occurs in (sub)littoral deposits in the Viséan of Scotland (Guirdham *et al*. 2003). Some *Naiadites* may also have attached to floating plant fragments, as they are encrusted by *Spirorbis* (Calver 1968). Fragmentary plant assemblages preserved in these open water settings may contain an amplified signal from upland forests of pteridosperms, progymnosperms, and cordaitaleans (Falcon-Lang 2003*a*).

Several fish genera, including *Ctenoptychius*, were bottom-dwellers with extensive tooth plates, and may have browsed molluscan communities. *Haplolepis*, another carnivore, was adapted to stagnant shallow water environments characterized poorly oxygenated, organic-rich bottom waters (Westoll 1944). In contrast, acanthodians such as *Gyracanthus* were probably mid- to surface-feeders, utilizing gill-rakers to strain out ostracodes and other small animal food (Moy-Thomas & Miles 1971; Benton 2005). Basal tetrapods such as *Baphetes*, with its long eel-like body and diminutive limbs, and sharks such as *Xenacanthus* and *Ctenacanthus*, were the largest aquatic predators, feeding on fishes including other sharks (Moy-Thomas & Miles 1971; Milner 1980; Benton 2005).

These brackish seas were probably long-lived (10^3–10^4 years), but after base-level reached its zenith, gradually became infilled as deltas prograded into the shallow embayment. Brackish communities comprising xiphosurans, such as *Bellinurus*, and a variety of other arthropods, annelids and molluscs (Archer *et al*. 1995; Anderson *et al*. 1997), existed in prodelta environments, close to wave-base, as indicated by the trace fossil record. Traces are principally preserved in sheet sandstone beds (SS facies) deposited by hyperpycnal flows, sourced off the delta front (Davies & Gibling 2003). Test size distribution of agglutinated Foraminifera extracted from these beds implies an upper estuarine salinity (Archer *et al*. 1995). The *Carbonita* ostracode fauna, which ranges through the BL and SS facies, is a recurrent component of Carboniferous non-marine biotas, associated with the freshwater–brackish settings (Tibert & Scott 1999) in shallow marginal embayments, lagoons, estuaries, and coastal lakes (Vannier *et al*. 2003), but also includes open marine elements (Tibert & Dewey 2005).

Wetland terrestrial ecosystems (Fig. 6)

Heterolithic successions at the base of two pPDF units (HS facies), locally containing mud-draped cross-lamination, probably represent the deposits of microtidal lagoons (Falcon-Lang 2005*a*;

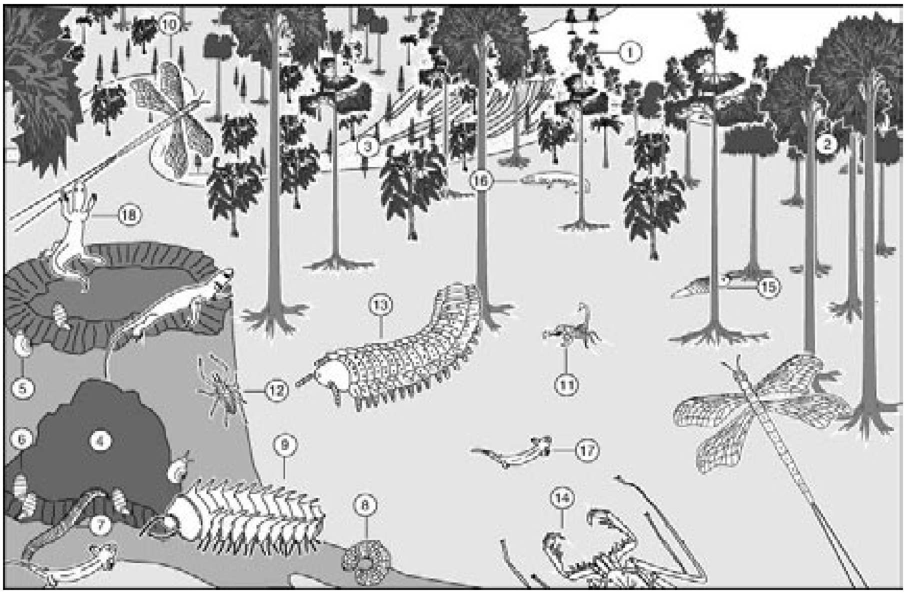

Fig. 6. Ecosystem reconstruction of poorly drained coastal plain (pPDF) facies association. 1, Cordaitalean coastal forests; 2, lepidodendrid peat-forming forests; 3, pteridosperm–calamitean–fern riparian forests; 4, rotten sigillarian stump; 5, *Protodiscus*; 6, *Dendropupa*/*Pupa*; 7, *Archiulus*; 8, *Xyloiulus*; 9, *Amynilyspes*; 10, Megasecoptera; 11, cf. *Mazonia*; 12, *Coryphomartus*; 13, *Arthropleura*; 14, *Graeophonus*; 15, indet. eurypterid; 16, *Baphetes*; 17, microsaur; 18, *Hylonomus*.

Wells *et al*. 2005). These brackish-influenced coastal shallows were not widespread, but supported distinctive ecosystems. Most common in these settings were small cordaitalean trees, their adventitious roots able to readjust to burial in coastal sediments. Temnospondyl amphibians populated emergent surfaces as indicated by their trackways.

Further shoreline progradation led to the establishment of freshwater delta-plains (GM facies). Successions of grey, coal-bearing mudstone and sandstone sheets were deposited in interdistributary wetlands, and thick sandstone bodies containing lateral accretion were formed in sinuous distributary channels (Davies *et al*. 2005; Rygel 2005). Thin coals, the product of short-lived, nutrient-rich peat mires, were dominated by *Sigillaria*, as was common in such settings (DiMichele & Phillips 1994). Mire accretion was regularly disturbed by input of clastic sediment from localized splays and levees, resulting in the formation of buried forest profiles (Scott & Calder 1994; Calder *et al*. 2005*b*). Diverse vegetation comprising pteridosperms, ferns, lycopsids, cordaitaleans, and calamiteans grew on adjacent mineral soils. Forest fires occasionally occurred in some communities, as indicated by localized charcoal deposits (Falcon-Lang 1999, 2000).

Interdistributary wetland forests were populated by a range of animals, as indicated by rich fauna preserved inside some lycopsid trees (LT facies), and depauperate coastal plain assemblages (GM facies). We leave discussion of the unusual taphonomy of these deposits to a later paper. Communities were dominated by arthropods (millipedes, arachnids, eurypterids, insects), including giant arthropleurids, and terrestrial gastropods, encompassing a variety of feeding strategies (detritivores, predators). Gut content suggests that arthropleurids fed, in part, on the rotten trunk wood of lycopsid trees (Rolfe & Ingham 1967), perhaps explaining why a juvenile representative of this group occurs within the hollow interior of one lycopsid tree. Diverse amphibian and reptile communities, including small ($\leqslant$5–30 cm long) to large ($\leqslant$1 m) individuals, were the main predators. The fossil content of coprolites implies a diet of arthropods and fish. Tetrapod trackways preserved on the levee deposits of major distributary channels may record such fishing activity. Large back-filled burrows, and trackways, indicate that some channels were populated by arthropleurids (Archer *et al*. 1995), another potential food source for tetrapods. Associated plant debris with *Arthropleura* at other localities may suggest that these arthropods preferred to live in the better-drained fern–pteridosperm levee forests (Proctor 1998).

Dryland terrestrial ecosystems (Fig. 7)

Red mudstone and sandstone successions containing scattered carbonate nodules accumulated on well-drained alluvial plains with a suppressed water table (RM facies). Channel sandstone ribbons at many levels represent deposits of an anastomosed river channel network similar to the ephemeral drainages of central Australia (Gibling *et al*. 1998; Davies & Gibling 2003). Mud-rich channel bodies (MC facies) are interpreted as waterholes formed by the seasonal cessation of flow (Falcon-Lang *et al*. 2004). Green–red mottled units (GR facies) with millimetre-thick coals represent seasonally flooded soils (Falcon-Lang 1999). This terrestrial dryland environment may have formed as base-level fell, and the sea withdrew many hundreds of kilometres to the east.

Based on megafossil assemblages, alluvial dryland environments were dominated by cordaitaleans and medullosan pteridosperms (Falcon-Lang 2003*b*,*c*). These seed-bearing plants had a distinct reproductive advantage in water-stressed settings. Rare calamiteans and sigillarian lycopsids were restricted to riparian niches, where water availability was greater. Some lycopsid trees grew within the seasonal river channels, an unusual phenomenon also seen in central Australian analogues (Gibling *et al*. 1998). A high proportion of plant material in the WDF units is preserved as charcoal, implying that wildfires were especially common in dryland settings. Despite dry conditions, there must have been sufficient vegetation to support giant detritivores such as *Arthropleura*, whose existence is indicated by common trackways on river channel levees. In comparison with an arthropleurid trail on the Isle of Arran, Briggs *et al*. (1979) suggested that the smaller Joggins arthropleurids had a greater variation in appendage length and flexibility.

Most other fauna in these red beds is restricted to localized waterhole deposits. These contain abundant *Archanodon* bi-

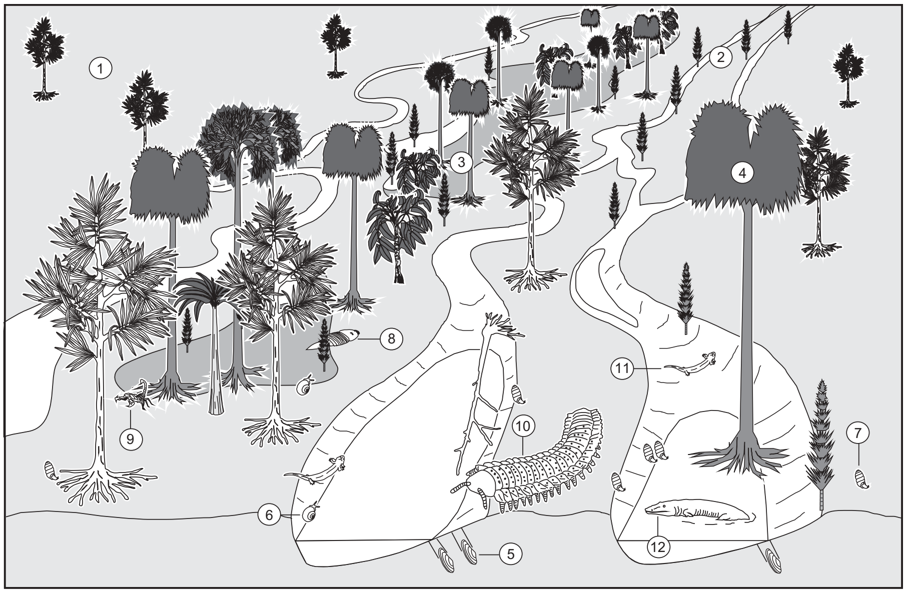

Fig. 7. Ecosystem reconstruction of well-drained alluvial plain (WDF) facies association. 1, Sparse, well-drained cordaitalean scrub; 2, riparian *Calamites*; 3, poorly drained regions with ponds dominated by *Sigillaria*, *Lepidodendron*, pteridosperms, and ferns; 4, *Sigillaria* growing within an inactive channel; 5, aestivating *Archanodon*; 6, *Protodiscus*; 7, *Dendropupa*; 8, indet. eurpyterid; 9, indet. scorpion; 10, *Arthropleura*; 11, indet. microsaur; 12, *Baphetes*.

valves, found locally within putative burrows in channel point bars, and representing filter-feeders, which aestivated through the dry season when channel flow ceased. Associated terrestrial gastropods, *Dendropupa*, were probably detritivores, and occur in clusters on plant debris. Tetrapod material includes the skeletal remains of aquatic organisms such as *Baphetes*, which may have lived in the alluvial watercourses, and more terrestrial forms, perhaps drawn to the waterholes during drought (Falcon-Lang *et al*. 2004).

Fossiliferous assemblages are more common in the red–green mottled units, which represent floodbasin environments intermediate between pPDF and WDF settings. These are dominated by sigillarian lycopsids, medullosan pteridosperms, and cordaitaleans, all of which were fire-prone. Terrestrial fauna included scorpions, and localized ponds contained eurypterids. As in WDF units, and the driest parts of pPDF units, detritivorous terrestrial gastropods such as *Dendropupa* and *Protodiscus* were common.

Pennsylvanian tropical biome

Sediments from the Pennsylvanian tropical zone have been preserved very widely in, from west to east, the Western Interior, Eastern Interior, Appalachian, Black Warrior, Maritimes, North Variscan, and Donetz basins (Fig. 8). By virtue of extensive outcrop and intensive mining operations, Pennsylvanian terrestrial and coastal ecosystems are amongst the best understood in the Phanerozoic (DiMichele *et al*. 2001). Although a few small intermontane basins are positioned within the Variscan mountain belt of central Europe, the Maritimes Basin (containing the Joggins Formation) represents the only major intra-continental basin complex. At times of sea-level lowstand, the region probably lay some 2500 km upstream of the marine coastline.

The continental nature of the Joggins Formation is indicated by the absence of marine bands (only brackish limestone beds are locally present), the predominance of red beds (forming some 31% of the type section), and the limited thickness of coals (typically <0.1 m thick). To these properties of the physical environment can be added aspects of the fossil record, which include the earliest known terrestrial gastropods (Solem & Yochelson 1979) and reptiles (Milner 1996) and the occurrence of *Archanodon* bivalves, more typical of Devonian red bed successions than Pennsylvanian coal measures (Friedman & Chamberlain 1995).

The Joggins Formation is particularly significant because it contain rich par(autochthonous) fossil assemblages within a narrow time-interval and from a distinctly intra-continental province of Pennsylvanian tropical biome, very different from more coastal sites such as Mazon Creek in Illinois (Nitecki 1979). It therefore sheds light on ecologically stressed regions where allopatric speciation might be expected to be greatest. Future work comparing the Joggins Formation to other Pennsylvanian tropical localities will help clarify the fine-scale ecological heterogeneity of this tropical biome.

Conclusion

(1) The fossil biota of the famous Pennsylvanian Joggins Formation of Nova Scotia comprises *c*. 96 genera (*c*. 148 species) of protist, animal, and plant body fossils, and *c*. 20 ichnogenera, one of the richest assemblages of this age in the world, second only to Mazon Creek, Illinois.

(2) Collector curves constructed for the interval 1850–2003 indicate that the Joggins fossil record is relatively complete, although new discoveries will probably continue to accumulate slowly in the future.

(3) (Par)autochthonous fossil assemblages are described from three facies associations, permitting the reconstruction of brackish bay ecosystems, terrestrial wetland ecosystems, and terrestrial dryland ecosystems.

(4) Results show that the Joggins Formation contains an amplified terrestrial record, and in contrast to coeval sites, sheds significant light on the nature of poorly resolved intra-continental environments and ecosystems.

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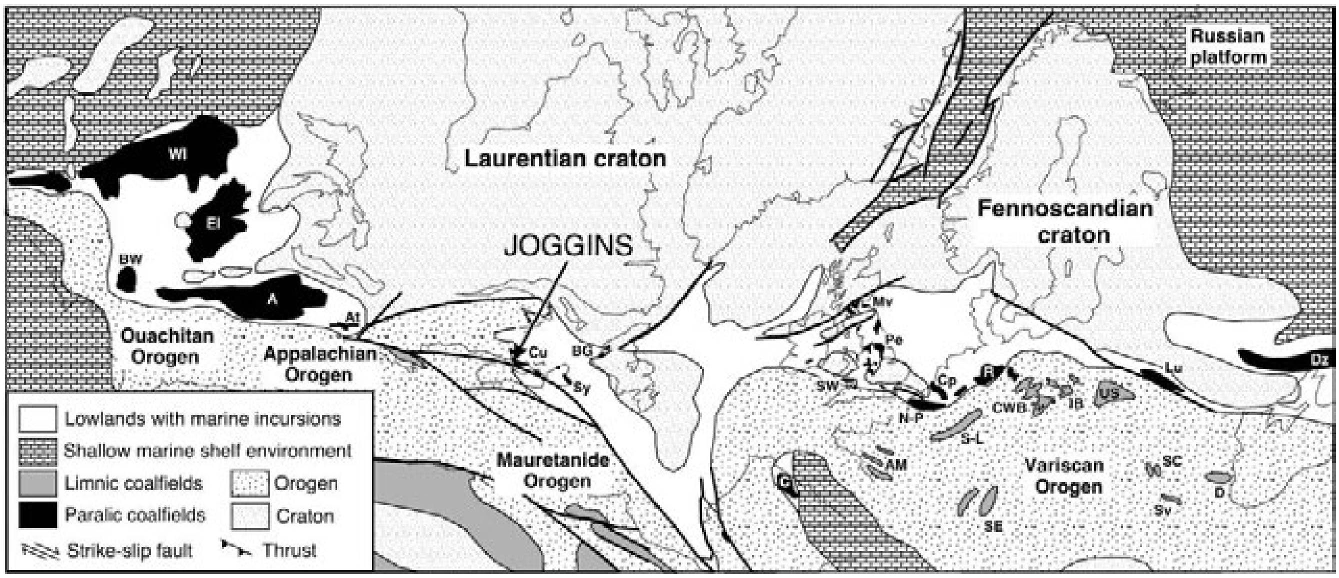

Fig. 8. The Pennsylvanian tropical biome showing the geographical location of Joggins and its relationship to other major paralic and limnic basins (after Opluštil 2004). WI, Western Interior; EI, Eastern Interior; A, Appalachian; BW, Black Warrior; At, Anthracite; Cu, Cumberland; Sy, Sydney; BG, Bay St. George; C, Cantabria; SW, South Wales; Mv, Midland Valley; Pe, Pennine; Cp, Campine; R, Ruhr; N-P, Pas-de-Calais, Nord, Namur; AM, Armorican; S-L, Saar–Lorraine; SE, Saint Etienne; CWB, Central and Western Bohemia; IB, Intrasudetic Basin; US, Upper Silesia; SC, South Carpathians; Sv, Svorge; D, Dobrudzha; Lu, Lublin; Dz, Donetz.

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Stratigraphy and sedimentology of early Pennsylvanian red beds at Lower Cove, Nova Scotia, Canada: the Little River Formation with redefinition of the Joggins Formation

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Abstract

The coastal cliffs along the eastern shore of Chignecto Bay, Nova Scotia contain one of the finest Carboniferous sections in the world. In 1843, Sir William Logan measured the entire section as the first project of the Geological Survey of Canada, and defined eight stratigraphic divisions. We have re-measured a section corresponding almost exactly with Logan's Division 5 in bed-by-bed detail. The strata are exposed in the wave-cut platform and low-relief bluffs of a 2 km-long section at Lower Cove, near Joggins, north and south of Little River. This 635.8 metre thick succession until now has been included within the basal part of the Joggins Formation, and overlies the Boss Point Formation. However, the studied strata are lithologically distinct, and are formally recognized as the new Little River Formation. This formation is bounded by regionally important surfaces and is traceable inland for 30 kilometres from its Lower Cove type section. Facies analysis indicates that it represents the deposits of a well-drained alluvial plain dissected by shallow rivers characterized by flashy flow. It can be clearly distinguished from the underlying Boss Point Formation (Logan's Division 6) by its much smaller channels, and from the overlying Joggins Formation (Logan's Division 4) by lack of coal seams and bivalve-bearing limestone beds. Palynological assemblages indicate that the Little River Formation is of probable late Namurian to basal Westphalian (basal Langsettian) age, and is a likely time-equivalent of the informal Grand-Anse formation of southeast New Brunswick.

Résumé

Les falaises côtières longeant le rivage oriental de la baie Chignectou, en Nouvelle-Écosse, abritent l'un des stratotypes carbonifères les plus intéressants dans le monde. Sir William Logan avait mesuré en 1843 l'ensemble du stratotype dans le cadre du premier projet de la Commission géologique du Canada et il avait défini huit divisions stratigraphiques. Nous avons mesuré à nouveau un stratotype correspondant presque exactement dans ses détails couche par couche à la division 5 de Logan. Les strates affleurent dans une plate-forme d'érosion et des falaises de relief émoussé d'un secteur de deux kilomètres de longueur à l'anse Lower, près de Joggins, au nord et au sud de la rivière Little. Cette succession de 635,8 mètres d'épaisseur avait jusqu'à maintenant été incluse à l'intérieur de la partie basale de la Formation de Joggins et elle recouvre la Formation de Boss Point. Les strates étudiées sont cependant lithologiquement distinctes et on les reconnaît officiellement en tant que nouvelle Formation de Little River. Cette formation est limitée par des surfaces importantes à l'échelle régionale; on peut la retracer à l'intérieur des terres sur 30 kilomètres à partir de son stratotype de l'anse Lower. Une analyse du faciès révèle qu'il représente les dépôts d'une plaine alluviale bien drainée, sectionnée par des rivières peu profondes caractérisées par des crues éclair. On peut nettement la distinguer de la Formation sous-jacente de Boss Point (division 6 de Logan), grâce à ses canaux beaucoup plus petits, ainsi que de la Formation sus-jacente de Joggins (division 4 de Logan), par l'absence de couches houillères et de couches de calcaire abritant des lamellibranches. Les assemblages palynologiques révèlent que la Formation de Little River remonte probablement à la période du Namurien tardif au Westphalien basal (Langsettien basal) et qu'elle constitue vraisemblablement un équivalent chronologique de la Formation officieuse de Grande-Anse dans le sud-est du Nouveau-Brunswick.

[*Traduit par la redaction*]

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INTRODUCTION

The cliffs along the eastern shore of Chignecto Bay, Nova Scotia (Fig. 1), have been long considered one of the world's classic Carboniferous sections (Lyell 1871; Gibling 1987). The seminal work that defined the stratigraphy of these cliffs was that of Sir William Logan, who undertook bed-by-bed measurement of the section as the first project of the Geological Survey of Canada (Logan 1845; Rygel and Shipley 2005). In this paper, we examine in detail for the first time since that work the section of low topographic relief between the Boss Point Formation, with its prominent, thick sandstone bodies that were a valued source of grindstones in the Nineteenth Century, and the cliff section of the Joggins coal measures. These coal-bearing strata provided Sir William Dawson and Sir Charles Lyell their seminal paleontological discoveries in the mid-Nineteenth Century (Falcon-Lang and Calder 2004).

The strata described herein are exposed in the wave-cut platform and bluffs in the 2 km-long red bed section at Lower Cove, near Joggins, north and south of Little River, near the village of Lower Cove. This stratal interval, 636 m thick, almost exactly corresponds with Division 5 of Logan (1845). Our newly measured section log (Appendix A), recorded in the field at 1:100, and digitally transcribed by Andrew Henry, adjoins a similar log of the overlying Joggins Formation undertaken concurrently by Sarah Davies and Martin Gibling (see Davies *et al.* 2005). Together, these papers provide a continuous reference log of the Joggins section from South Reef at the upper contact of the Boss Point Formation to the contact of the Joggins Formation with the overlying Springhill Mines Formation, north of MacCarrons Creek. Together, the two papers thus incorporate the first comprehensive log of the classic Joggins section to have been completed since that of Logan (1845).

The section of red beds described in this paper provides a clear basis for the division and redefinition of stratigraphic units, in particular the relationship of the Boss Point and Joggins formations with coeval units exposed across Chignecto Bay in New Brunswick. Furthermore, the Lower Cove red beds are key to understanding the evolution of the coeval landscape, setting the stage for the environment recorded in the overlying Joggins Formation.

GEOLOGIC SETTING

The western Cumberland Basin, now represented by the Athol Syncline, was an active depocentre within the broader Maritimes Basin during Carboniferous time. At this time, the basin was then positioned close to the equator, east of the rising Appalachian mountains and midway between the Appalachian and western European foreland basin complexes (Calder 1998). Highland massifs bordered the Cumberland Basin to the south (Cobequid Highlands) and west (Caledonia Highlands) (Fig. 1). The western part of the basin, in which the Lower Cove section occurs, experienced subsidence rates unsurpassed in coeval coal basins of Europe and North America (Calder 1994; Davies and Gibling 2003). Contributing to this subsidence history was the halokinetic withdrawal of thick Mississippian salt deposits (Waldron and Rygel 2005). The age of coastal exposures of the Carboniferous basin-fill on the western coast of Chignecto Bay spans the Visean through early Westphalian (Duckmantian) interval.

Stratigraphic History

The first stratigraphic account of the Carboniferous section at Joggins, and for the Maritimes Basin in general, was the pioneering work of Brown and Smith (1829). Their stratigraphic framework, and subsequent modifications (Fig. 2; Gesner 1836, 1843; Lyell 1843; Dawson 1878), underscore the geologic parallels between once-contiguous Nova Scotia and British Isles (Calder 1998).

The Carboniferous strata exposed along the eastern shore of Chignecto Bay were first measured by William Logan during the summer of 1843 (Logan 1845; reprinted in Poole 1908). Logan measured about 15 km of virtually continuous coastal section from Minudie south to Shulie, a succession that, by his calculation, totalled 4442.4 m (14 570 feet, 11 inches). Incredibly, this feat was achieved during a five-day stop en route from London to the Gaspé Peninsula (Rygel and Shipley 2005) as he began the search for coal-bearing strata in Lower Canada; it constituted the first field project of the fledgling Geological Survey of Canada.

Logan subdivided his section into eight lithologically distinct divisions, numbered from youngest (1) to oldest (8). The red beds of Lower Cove were assigned to Division 5, and the overlying coal measures of the Joggins and Springhill Mines formations to Divisions 4 and 3 respectively. The sandstone-dominated strata of the underlying Boss Point Formation were assigned to Division 6. Logan placed the lower contact of Division 5 at the top of "South Reef" (Fig. 3), which we consider to represent the uppermost sandstone body of the Boss Point Formation. He placed the upper contact 5 ft, 6 in (1.65 m) below the stratigraphically lowest coal (no. 45) of Division 4, a bed that we propose herein as the basal datum of the revised Joggins Formation (see below).

Logan's "Recapitulation" of Division 5 reads as follows: "dominated by red shale, reddish grey sandstone with occasional "drift plants" and "concretionary limestone", and minor greenish grey sandstone, totally 2082 ft 0 in". The thickness of the Lower Cove red beds (634.6 m) obtained by Logan agrees remarkably closely with the thickness of 635.8 m measured in this study (a mere 1.26 m difference). Despite minor modifications and combinations over the years, Logan's (1845) measurements and subdivisions form the basis for all later stratigraphic studies of the Carboniferous basin fill of the Cumberland Basin.

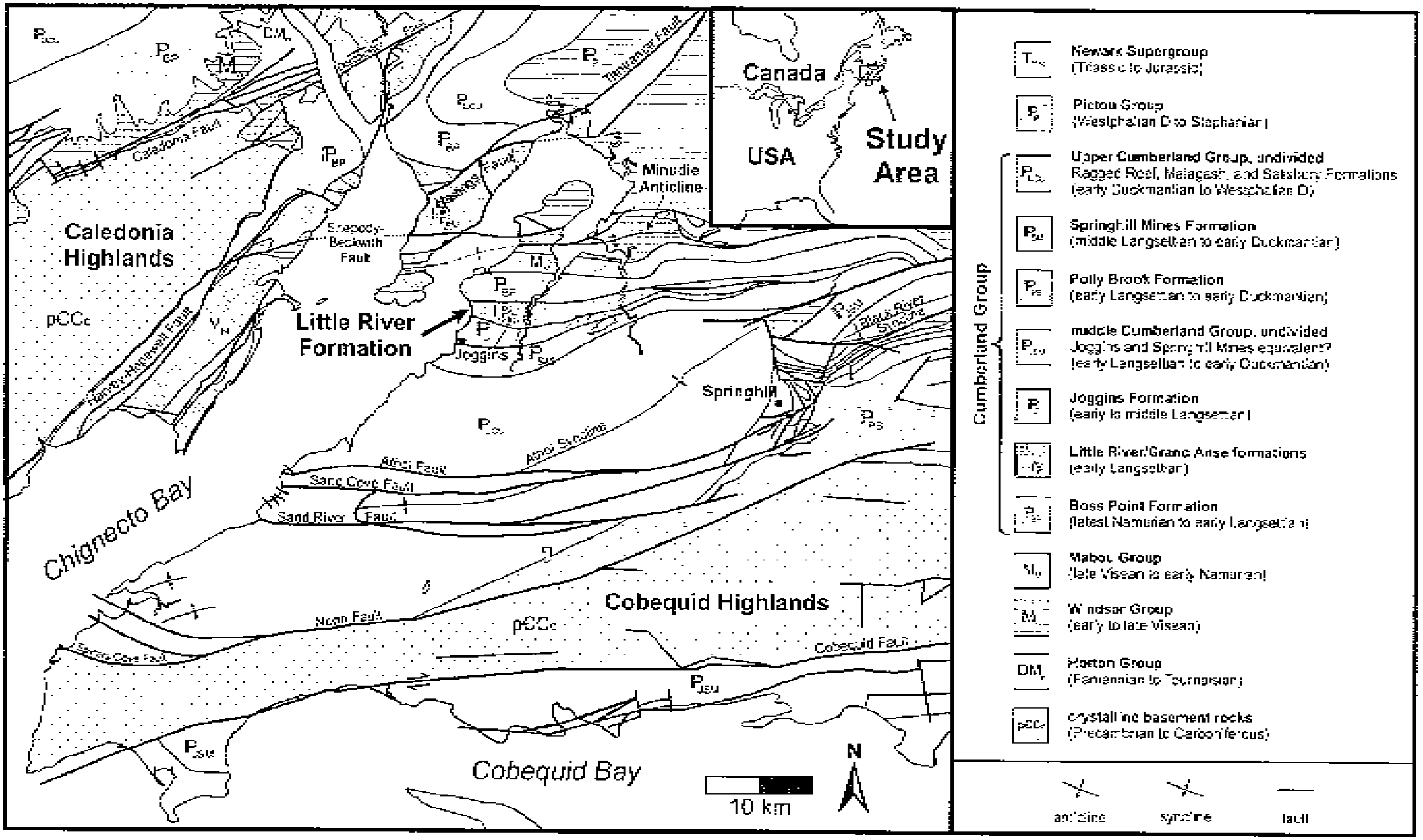

Fig. 1 Location and geology of the western Cumberland Basin. Modified from Ryan *et al.* (1990a,b), New Brunswick Department of Natural Resources and Energy (2000), and St. Peter (2001).

Relationship to other units within the Cumberland Basin

The stratigraphic relationship of the Lower Cove red beds to other units within the Basin (other than those in direct contact in the coastal exposures) has long been enigmatic. Brown and Smith (1829) did not distinguish the Lower Cove beds from their "Millstone Grit" and overlying "Coal Measures" (Fig. 2). Dawson (1855) originally assigned Divisions 5–8 to the "Lower or Older Coal-Formation", broadly analogous to the Lower Carboniferous, but later reconsidered and correlated these strata with the "Millstone-grit Series" (Dawson 1868). Grouping of Logan's Divisions into more broadly recognized lithostratigraphic units represented an attempt to correlate these strata packages beyond the confines of the basin, but required an understanding of local sedimentation patterns within the tectonically active Cumberland Basin.

During the first half of the Twentieth Century, Bell (1912, 1914, 1927, 1938, 1944, 1958) studied the paleontology and regional stratigraphy of the Carboniferous of Nova Scotia. Well aware of the lithostratigraphic complexities of the Cumberland Basin, Bell felt that the basin fill could be more naturally subdivided on the basis of unconformities as indicated by the floral and faunal record. Bell's regional stratigraphy, grounded in his steadfast belief in unconformity-bound groups, became the definitive work of the Twentieth Century, but his combined use of bio- and lithostratigraphic definitions proved impractical. Influential advocates of a purely lithostratigraphic approach to the regional stratigraphy of the Maritimes Basin have been Belt (1964, 1965) and Kelley (1967), and their viewpoint was followed, at least in part, by Ryan *et al.* (1991).

In his first round of stratigraphic revisions, Bell (1912, 1914, 1938) grouped Logan's Divisions 3–5 and basal Division 2 into his "Joggins Formation". His grouping of the Lower Cove red beds (Division 5) with the overlying coal-bearing strata (Division 3–4) was based, in part, on the lack of contrary (or indeed any) macrofloral evidence within the red beds. Bell (1914, 1927) correlated the contact between coal-bearing strata and conglomerate at Spicer's Cove (Fig. 1) on the south limb of the Athol Syncline (Fletcher 1908) with the contact between Divisions 5 and 6 at Lower Cove. This correlation, later shown to be incorrect by Ryan *et al.* (1990a, 1990b), contributed to the impracticality of mapping his Shulie and Joggins formations inland (see map notes of Bell 1938). Consequently, Bell (1938) later advocated for an undivided Cumberland Series; later still, Bell (1944, 1958) defined the Cumberland Group, comprising Divisions 1–5, and the Riversdale Group, comprising Divisions 6–7.

In the mid Twentieth Century, efforts were renewed to map the basin fill. Central to this work was the goal of establishing stratigraphic relationships between the coastal section and the economically important coal measures of Springhill. In the course of this work, Shaw (1951) recognized the red beds of Lower Cove as a lithologically distinct subunit (10a) of his "coal-bearing facies" and considered the red beds to be coeval with basin-margin conglomerates (his map unit 9, the Polly Brook Formation of later authors) near Springhill (Fig. 1). Copeland (1959) concurred, but grouped the Lower Cove red beds with the basin-margin conglomerates (his "Facies A").

On the strength of their interpretation that the coal-bearing strata of Spicer's Cove were correlative with the Joggins coals and were underlain by conglomerates exposed at the south of Spicer's Cove, Bell, Shaw and Copeland correlated the Lower Cove red beds with basin margin conglomerates. Palynostratigraphic studies (Hacquebard and Donaldson 1964; Dolby 1991) have demonstrated, however, that the Spicer's Cove section is younger than that of Lower Cove, a conclusion supported by the macrofloral record (R.H. Wagner, personal communication, 2000). A growing body of evidence further suggested that the contact between the Lower Cove red beds

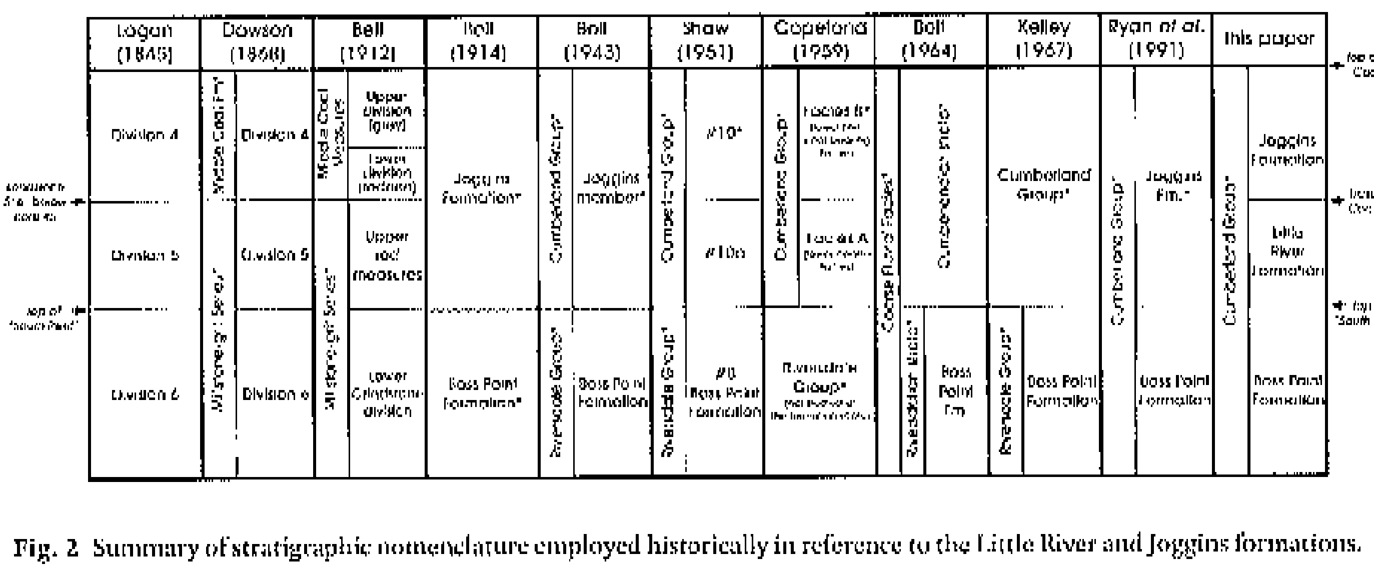

Fig. 2 Summary of stratigraphic nomenclature employed historically in reference to the Little River and Joggins formations.

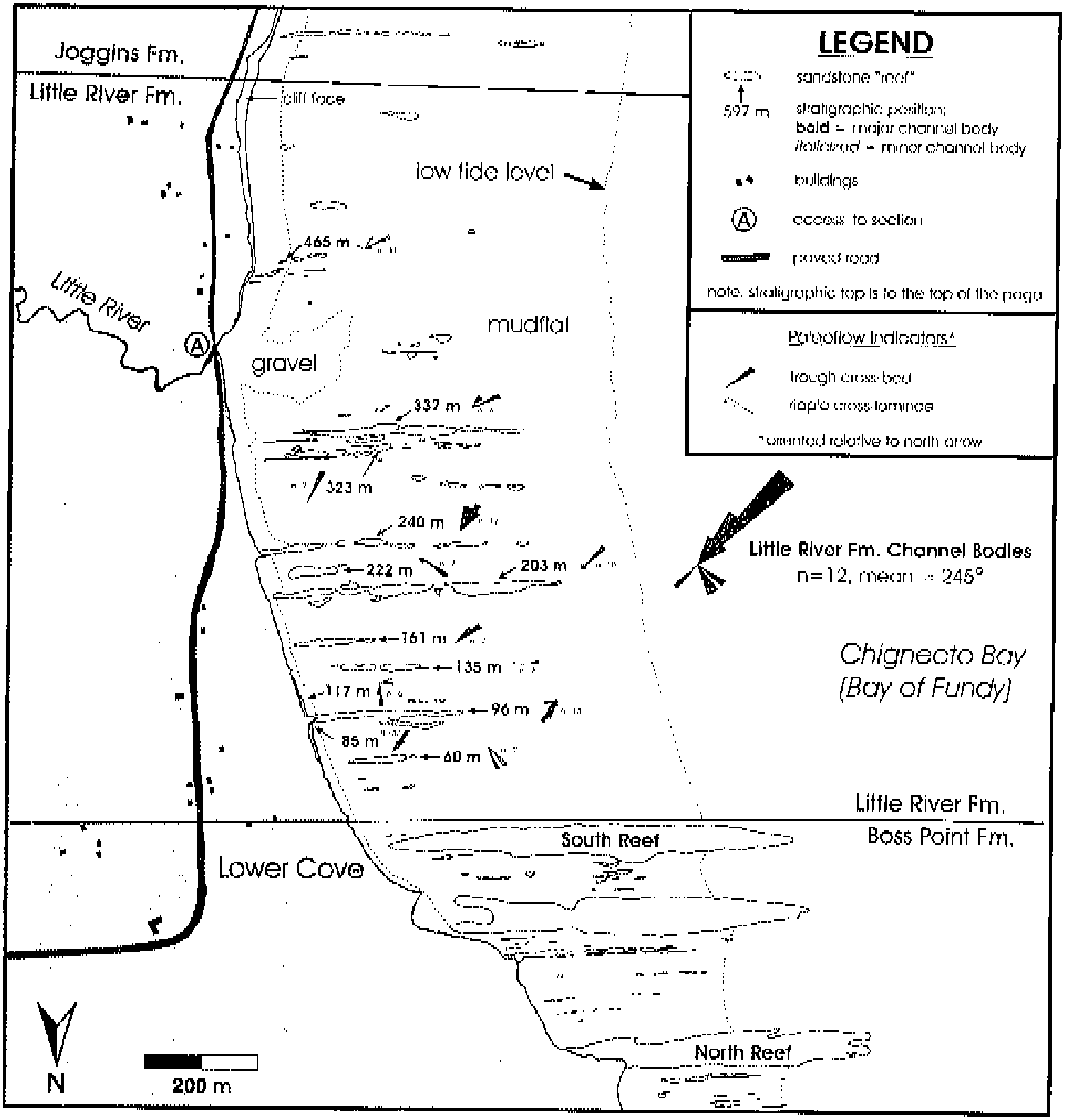

Fig. 3 Outcrop map of the type section at Lower Cove. Map based on air photograph A18580-125 (1:15 840), available from the Nova Scotia Department of Housing and Municipal Affairs, Land Information Services Division. For consistency with adjacent maps in Davies *et al.* (2005) and future aerial photography, the map is presented at *1:10 000* scale.

and the underlying Boss Point Formation was likely conformable (Hacquebard 1972; Howie and Barss 1975).

Later in the century, a subsequent round of mapping and stratigraphic investigations in the Cumberland Basin was undertaken by the Nova Scotia Department of Natural Resources (Ryan *et al.* 1990a,b,c, 1991; Calder 1995). The lithostratigraphic distinctiveness and regionally mappable boundaries of the Lower Cove red beds were acknowledged by Ryan *et al.* (1990a) on their geological map, but this unit was nonetheless included with the coal-bearing strata of Division 4 and the basal 51 m of Division 3 in their revised and reinstated Joggins Formation (Ryan *et al.* 1991). Members were not formally defined within this 1433 m thick unit, although the informal term "Little River Bridge member" was used by Ryan *et al.* (1991, their fig. 5) and Ryan and Boehner (1994, their figs. 2–13) in reference to the Lower Cove red beds.

LITTLE RIVER FORMATION

Definition

Here we formally propose the elevation of the Lower Cove red beds to the status of formation, and coin the name Little River Formation for these beds. Our proposed unit is defined purely on the basis of lithostratigraphy, being a non-coal-bearing, red bed succession positioned conformably above the Boss Point Formation and conformably beneath the coal-bearing strata of the Joggins Formation. The formation is named after Little River, the mouth of which crosses the type section where it enters Chignecto Bay at Lower Cove. For the sake of clarity, it is important to note that this newly proposed unit bears no relationship to the now historically obsolete "Little River Group" of southern New Brunswick (Dawson 1868, p. 506), despite these strata being approximately time-equivalent. These strata are now assigned to the Lancaster Formation of Alcock (1938), and include the classic "Fern Ledges" of Stopes (1914).

Justification

The Little River Formation comprises a lithologically distinctive and regionally mappable unit. It lacks both coal and bivalve-bearing limestone beds, the two defining hallmarks of the overlying Joggins Formation (Ryan *et al.* 1991). It is also lithologically distinct from the underlying Boss Point Formation, which is characterized by thick, multistorey, well sorted grey sandstones, features absent from the Little River Formation. Similarly, although it is considered to be, in part, coeval with the Polly Brook Formation, it is lithologically distinct from that polymictic conglomerate succession. Both the base and top of the Little River Formation are regionally important surfaces.

Type locality

The type section comprises outcrops in the intertidal zone and low-relief coastal bluffs on the eastern shore of Chignecto Bay, at Lower Cove, near Joggins, Cumberland County, Nova Scotia (Fig. 3). The section begins at the top (southern edge) of the South Reef of the Boss Point Formation (UTM Coordinates 5066450N, 388000E; NAD 83 datum) and extends 1500 m southward to a point 500 m south of the mouth of Little River (5063200N, 388400E). The top of the section coincides with the base of the lowest coal bed (Coal 45 of Logan 1845) of the Joggins Formation, near the start of the continuous cliff section.

Reference localities

Strata of the Little River Formation are known to occur inland on four stream sections east of the type section (Fig. 1; and see Ryan *et al.* 1990a). These include, from west to east: 1) exposures on a small tributary to the Maccan River north of the village of Maccan; 2) along Baird Brook at Chignecto; 3) near the contact with the Polly Brook Formation on Saint George's Brook east of Chignecto, which at this locality underlies the Little River Formation; and 4) on Styles Brook south of Stanley.

Boundaries

The basal contact of the Little River Formation is placed at the top of the highest multistorey sandstone bed of the Boss Point Formation, which at the type section is the top of the South Reef, coinciding with the base of Division 5 of Logan (1845). Inland, to the east, the base of the formation progressively onlaps against polymictic conglomerates of the Polly Brook Formation (Ryan *et al.* 1990a). The upper contact of the formation is placed at the base of the stratigraphically lowest coal bed, which at the type section is coal 45 of Logan (1845), 1.65m above the base of Logan's Division 4. This upper contact defines the base of the revised Joggins Formation (see Davies *et al.* 2005). The onset of grey mudrock and sandstone in the Joggins Formation provides a secondary criterion in mapping incompletely exposed sections. The formation has been mapped by the first author inland from the type section, its boundaries indicated on the map of Ryan *et al.* (1990a), where the formation, then unnamed, was designated "abundant redbeds"

Thickness and distribution

The type section at Lower Cove, constituting a remeasurement of Division 5 of Logan (1845), is 635.8 m thick. The formation can be traced 30 km to the east along the north limb of the Athol Syncline to Styles Brook (Ryan *et al.* 1990a), where it eventually pinches out between the underlying Polly Brook Formation and overlying Joggins and Springhill Mines formations (Fig. 1). Because of many similarities, the Lower Cove beds may be laterally equivalent to fault-bound strata exposed across Chignecto Bay to the west on Maringouin Peninsula, New Brunswick, assigned to the informal Grande Anse formation (St. Peter and Johnson 1997), as well as to undesignated strata along strike of the Grand Anse beds at Minudie Point.

Correlation

Inland, the Little River Formation is in part laterally time-equivalent to coal-bearing strata of the Joggins Formation and is inferred to be laterally equivalent to the Polly Brook Formation on the south limb and in the east of the Athol Syncline (Figs. 1, 4). Although it is probable that the Grande Anse formation in southeast New Brunswick may represent a facies of the Little River Formation, the correlation of the two units is problematic due to uncertainties in the stratigraphic relationship of the Grande Anse formation with adjacent geologic units. The lower contact of the Grand Anse section is in faulted contact with the Boss Point Formation at the coast, although the contact is reported to be conformable in the axis of the Hardledges Syncline south of the Shepody-Beckwith Fault (Johnson 1996). At its upper contact, the Grand Anse formation is in faulted contact with the Mississippian Windsor Group. Johnson (1996) suggested correlation of the Grande Anse with the Polly Brook Formation and lower Joggins (Little River of this paper) Formation.

Age

Age determination of the Little River Formation is problematic due to its sparse paleontological record and, in particular, the complete absence of key age-diagnostic marine index fossils (Calder 1998; R.H. Wagner, personal communication, 2004). Furthermore, although palynology offers an alternative means to date strata, difficulties exist in disentangling evolutionary signatures from paleoecological effects. With these uncertainties in mind, comprehensive palynostratigraphic studies of the type section place the Little River Formation within the upper Namurian (Kinderscoutian) to basal Westphalian (basal Langsettian) according to Dolby (1991, 2003), or entirely within the upper Namurian (Marsdenian to Yeadonian) according to J. Utting (personal communication, 2004). Extensive revision by R.H. Wagner of the macroflora of the overlying Joggins Formation demonstrated a floral assemblage consistent with the Langsettian of Europe, and Langsettian floral elements are present along with problematic "hinterland" taxa in the underlying Boss Point Formation (Utting and Wagner 2005).

The miospore *Cananoropolis mehtae* until recently was known only from strata in the informal "Coal Mine Point member" of the Joggins Formation (Ryan *et al.* 1991), and was used therefore as local index taxon. Its occurrence in red beds of the Grande Anse section on Cape Maringouin, New Brunswick, was cited as evidence of a late Langsettian age for these strata (Dolby 1999). Subsequent sampling of the formation at Lower Cove, however, yielded a much earlier, albeit solitary specimen of *Cananoropolis mehtae* (Dolby 2003), suggesting that it may be less useful as a local index taxon than previously assumed, and therefore giving cause to reconsider the late Langsettian age for the Grande Anse formation. Its presence within the Lower Cove and Grande Anse strata further suggests that the two formations are possible correlatives.

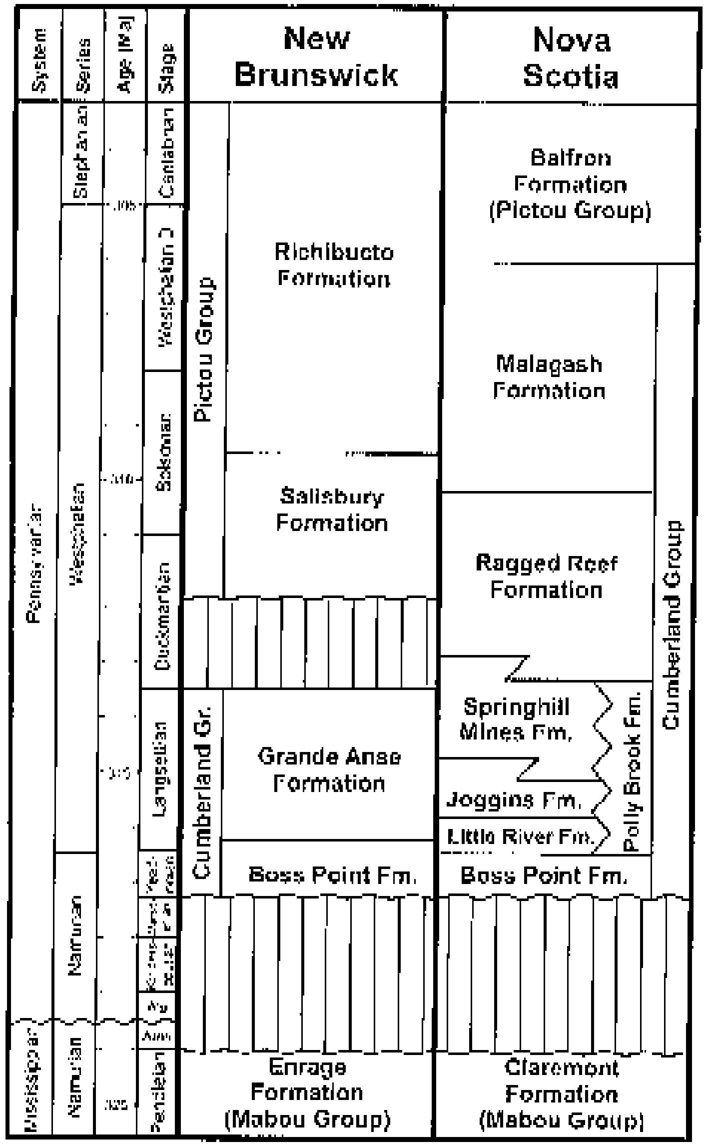

Fig. 4 Stratigraphic units of the Joggins coastal section and their relationship to basin-fill units inland and in New Brunswick. Modified from Ryan *et al.* (1990a) and St. Peter (2001).

SEDIMENTOLOGY OF THE LITTLE RIVER FORMATION

Major sandstone channel bodies

Twelve prominent (>2m-thick) channel bodies crop out on the wave cut platform as prominent "reefs", and vary in width from 31–534 m. Channel bodies have been assigned numerical designations (Fig. 3) that correspond to the stratigraphic position in metres of the top of their uppermost bed in the measured section. Channel bodies are described using the bounding surface and lithofacies terminology of Miall (1996). Smaller channel bodies (<2 m thick) also occur, but are dealt with separately below.

Channel body geometry

The lateral exposure of Little River channel bodies varies depending on their size and position on the shoreline. Five fully exposed channel bodies are 2.4 to 6 m thick and have width:thickness (W:T) ratios ranging between 6 and 43 when measured perpendicular to paleoflow. Seven incompletely exposed channel bodies are 3.1 to 10 m thick and have minimum W:T ratios of 13.6 to 147 when measured perpendicular to paleoflow.

The architecture of these sandstone channel bodies is defined by 5th order (channel body-) bounding surfaces, which both separate them from the underlying mudrocks and compartmentalize them into vertically stacked, or abutting, storeys. The basal storey/storeys of many channel bodies comprise(s) an obviously erosional 5th order surface, which forms one or more concave-up channel bases. These U-shaped forms are 3.1 to 7 m thick with W:T ratios between 5 and 25. Where concave-up surfaces flatten, they pass into the relatively bedding-parallel, 5th order surface that defines the base of the overlying, more tabular storey. These uppermost tabular storeys are 1 to 4 m thick with W:T ratios greater than 35. The overlying storeys are similar to the thick sandstone "wings" of Friend *et al.* (1979). In summary, the composite sandstone channel bodies are amalgamations of U-shaped erosional storeys and overlying, more laterally extensive storeys.

Internally, storeys contain numerous 3rd and 4th order bounding surfaces (macroform growth increment and macroform bounding, respectively) that separate the sandy fill into channel elements and sandy bedforms. Individual channel elements are generally 1.5 to 6 m thick and have a narrow, U-shape in cross-section (W:T ratio <10). Inclined stratification within sandy bedforms is variably oriented with dips ranging from perpendicular to oblique to the channel margin. Third and fourth order surfaces divide the basal part of most storeys into stacked packages of crudely stratified intraformational conglomerate (Gh) overlain by trough, planar, or low-angle cross-bedded sandstone (St, Sp and Sl, respectively). The upper portions of these channel bodies, and the entirety of others (e.g. the channel body at 465 m), contain varying proportions of horizontally, low-angle, and/or ripple cross-laminated sandstone (Sh, Sl, and Sr respectively). These intervals commonly contain 3rd order bounding surfaces, which are expressed as either low angle or channel-element bounding erosional surfaces.

A shallow erosional scour atop the channel body at 96 m (see Appendix A) contains an assemblage of lithofacies unique within the Little River Formation. The 2.45 m-deep and 20 m-wide scour is incised into a 3 m-thick package of trough to low angle cross-bedded sandstone and intraformational conglomerate. The basal 0.70 m of the scour is filled with two sets of planar cross-bedded sandstone that are overlain by approximately 15 cm of horizontally laminated sandstone. A "sigmoidal" erosional surface (Fig. 5) cuts down from the channel margin, truncating these basal units. The erosion surface is draped by a form-concordant, sigmoidal blanket of ripple cross-laminated sandstone that gradually becomes flat lying and passes upward into a sheet that extends beyond the margin of the scour and caps the entire channel body.

Fig. 5 Large, sigmoidal bedform at 96 m of the measured section (Appendix A).

Sediment composition

Channel bodies generally are composed of quartz- and calcite-cemented, very fine- to medium-grained feldspathic arenites. Sandstones additionally contain abundant sand-sized clay particles with bright clay fabric, which may represent mud aggregates (Gierlowski-Kordesch and Gibling 2002; Müller *et al.* 2004). Erosion surfaces are lined locally with crudely stratified intraformational conglomerate (Gh) containing medium- to coarse-grained sandstone (Ss), which is either interspersed as a matrix or co-occurs within separate lenses. Lag deposits are clast supported and contain pebble-sized rip-up clasts of red and green mudstone with rare granule-sized quartz clasts (channel body at 90 m). Locally abundant calcareous rip-up clasts are composed of concentric layers of finely crystalline calcite developed around a core of sparry calcite. Although no root tissue was observed, these clasts are otherwise identical to the calcareous rhizoconcretions described by Falcon Lang *et al.* (2004) from red beds in the overlying Joggins Formation.

Paleoflow

The orientation of trough cross-beds and ripples in the channel bodies are plotted as rose diagrams (10° petals) on the measured section (Appendix A) and outcrop map (Fig. 3). Planar cross-beds and primary current lineations are locally abundant, but these structures are relatively unreliable indicators of paleoflow, and omitted from analysis. Measurements are grouped by structure type within individual channel bodies to allow for comparison between different scales of structures and for intrachannel variation. Because the orientation of troughs and ripples are linear features, they need not be corrected for the < 25° regional dip at the Lower Cove type section (Potter and Pettijohn 1977).

Where ripples and trough cross-beds are measurable within the same channel body (n=3), their mean orientation varied by 1° to 19° (mean = 7.7°). Given this similarity, these structures are treated as equally reliable and used to calculate a mean paleoflow direction for each channel body (Fig. 3). The twelve Lower Cove channel bodies showed a reasonably strong southwest trend (mean = 245°, r = 0.6). Of the four bodies that deviate from this trend, three exhibit paleoflow to the northwest with the remaining one to the northeast. In comparison, trough cross-beds within Grand Anse strata at Black Point and at Grande Anse, New Brunswick, record a NNE paleoflow (Browne 1991).

Comparison with bracketing formations

Channel bodies of the Little River Formation are an order of magnitude smaller than those of the underlying Boss Point Formation and exhibit considerable differences in alluvial lithofacies and paleoflow direction. Browne and Plint (1994) describe the Boss Point Formation as being characterized by 20 to 90 m thick braidplain sandstone packages, which are underlain by 6th order bounding surfaces and extend several hundred metres across the intertidal zone. These bodies are composed dominantly of trough cross-bedded sandstone and have individual channel elements up to 35 m thick. Furthermore, the 245° (southwesterly) trend of the Little River Formation channel bodies differs from the southeasterly trend of the underlying Boss Point Formation by 70° (Browne and Plint 1994).

Little River Formation channel bodies also differ from those of the overlying Joggins Formation in terms of both geometry and internal architecture. Red beds in both formations contain channel bodies between 5 and 10 m thick, but examples in the Joggins Formation contain significant amounts of interstratified mudrock, are contained within small incised valleys, and are not capped by laterally extensive storeys (Davies and Gibling 2003). Although some Joggins Formation channel bodies (e.g., Coal Mine Point) are similar in size and geometry to those in Lower Cove, these bodies are single storey and contain well developed lateral accretion surfaces (Davies and Gibling 2003). Paleoflow within the Little River and Joggins formations is variable, but large channel bodies in both tend to have a southerly or southwesterly flow orientation.

Mudrock-dominated intervals

Mudrocks

The Little River Formation is mudrock-rich, which contributes to its low relief in the Lower Cove type section. Mudrocks, comprising claystone to silty claystone, are predominantly red in colour. Ubiquitous drab haloed root compressions are characteristic of the Formation; calcareous rhizoconcretions and amalgamated (dm-scale) carbonate nodules occur locally. Discrete, thin (cm-scale), dark grey, organic-rich mudrock intervals may occur at some horizons, and may persist laterally for tens of metres, but true coal beds are absent.

Paleosols

Mudrocks within the Little River Formation contain three types of paleosol, which are described here using standard terminology (Retallack 2001; Soil Survey Staff 2003). By far the most common type comprises intervals containing drab haloed root compressions, locally associated with standing vegetation. These weakly developed mineral paleosols lack horizons and represent very weakly developed entisols. Their common occurrence indicates pervasive pedogenesis throughout the accretion of the Little River Formation. Smith (1991) studied similar, but better developed paleosols in the overlying Joggins Formation and interpreted them as paleo-alfisols formed under warm, oxidizing conditions. The absence of pedogenic carbonate in the Joggins Formation paleosols conflicts, however, with the interpretation of alfisols by DiMichele *et al.* (in press) from Early Permian red beds of north-central Texas (see below). Other paleosols in the Little River Formation exhibit surficial horizons <10 cm thick that are composed of green or grey mudstone with variable amounts of organic material and rooting. The most organic-rich of these horizons consist of incipient histic epipedons (surface horizons) capping weakly developed entisols.

A distinctive aspect of the paleosols of the Little River Formation that contrasts with those of the Joggins Formation is the development of calcic (Bk) horizons. These horizons contain discontinuous carbonate-cemented nodules (<20 cm thick) that reach Machette's (1985) Stage III of carbonate accumulation. Such pedogenic carbonate development indicates xeric conditions and a semi-arid to arid climate with seasonal drying and incomplete leaching (Soil Survey Staff 2003; DiMichele *et al.* in press). Paleosols with vertically oriented calcareous rhizoconcretions are similar to paleosols described from the Early Permian of north-central Texas interpreted by DiMichele *et al.* (in press) as alfisols; more extensively cemented pedogenic carbonate was considered by these authors to be indicative of inceptisols. Clay mineralogy and petrographic studies of the Little River paleosols at Lower Cove will be required to refine these preliminary interpretations.

Small channel bodies

Small (<2 m thick), U-shaped (W:T <5) channel bodies occur throughout the Little River Formation, hosted within the mudrock-dominated intervals. These features have convex-down bases and flat tops; mounded tops occur locally. Channel bodies commonly occur in stacked groups where individual channel bodies are obliquely offset from one another. Small channel bodies are either isolated within mudrock or pass laterally into thin (<1 m thick) sheet sandstones. Channel fill consists of varying proportions of horizontal, low-angle, and ripple cross-laminated sandstone (Sh, Sl, and Sr respectively), or more rarely may largely contain laminated, grey/green mudstone.

Sheet sandstone bodies

Thin (<1 m thick) sheet sandstones are commonly interbedded with red mudrocks of the Little River Formation. These beds typically extend for several tens of metres, their complete extent being unknown due to limited exposure at Lower Cove type section. Internally, sheet sandstones are often massive with localized areas of horizontal or ripple cross-laminated sandstone (Sh and Sr, respectively). The presence of drab haloed root compression and occasional calamitean plants in growth position suggests that these beds experienced some pedogenic overprinting. A few beds near the top of the section are very strongly cemented by calcite, a phenomena that may reflect pedogenic accumulation of calcite at or near the water table.

PALEONTOLOGY

In spite of 150 years of investigation of the rich terrestrial fossil record of the Joggins section (Falcon-Lang and Calder 2004), no floral or faunal records exist from the red beds of the Little River Formation. The first records that have emerged in the course of this study likely afford but a glimpse of the total biota of the Little River ecosystem.

Fauna

Invertebrates

Aggregations of the land snail *Dendropupa vetusta* occur concentrated on discrete drab horizons (98 m, Appendix A). These aggregations represent surface litter accumulations (mode 2 occurrence of Hebert and Calder 2004) that are consistent with the snail's detritivorous autecology (Solem and Yochelson 1979). The Lower Cove occurrences predate those of the Joggins Formation and so push back in time the first appearance of pulmonate gastropods in the fossil record. The presence of the largest known terrestrial detritivore, the gargantuan millipede-like *Arthropleura*, is recorded by a 23 cm wide *Diplichnites* trackway (Fig. 6; 335 m, Appendix A). The polychaete worm *Spirorbis* is abundant in a single, small, grey mud-filled channel at 352 m in the measured section, where the epifauna densely adheres to drifted cordaitalean trunks (see below).

Vertebrates

The solitary vertebrate record as yet obtained from the Little River Formation is an occurrence at one horizon of large tetrapod footprints (96.5 m, Appendix A) provisionally assigned to the ichnogenus *Pseudobradypus*. The possible affinity of this ichnotaxon with the baphetid stem tetrapods and its occurrence in stratigraphic proximity to the land snail *Dendropupa* recall their association in the Hebert sandstone of the Joggins Formation (Hebert and Calder 2004; Falcon-Lang *et al.* 2004).

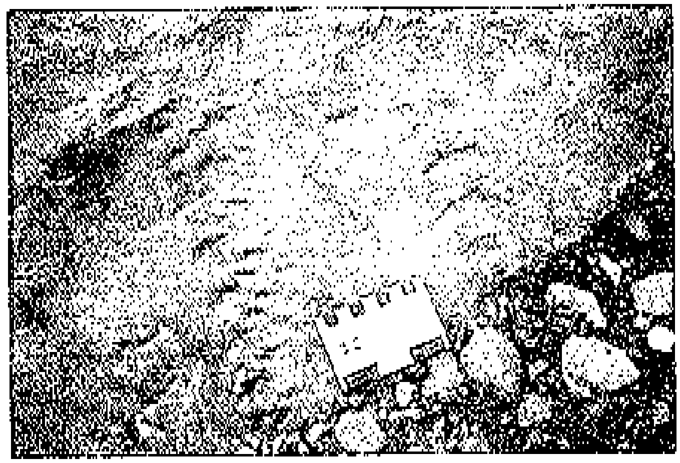

Fig. 6 *Diplichnites* trail, ascribed to the huge detritivorous arthropod *Arthropleura*, from approx. 335 m of the measured section (Appendix A).

Flora

Plant compression assemblages

By far the most abundant macrofloral impressions are sphenopsid stems (*Calamites cistii* and less commonly *Calamites suckowii*), which occur throughout the section as prostrate axes in channel lag deposits, and less commonly in growth position. Unfragmented *Cordaites* leaves, up to 22 cm in length, are common locally in red mudrock beds and channel sandstone bodies. Less commonly recorded are medullosan pteridosperm axes, rare foliage (*Alethopteris* sp.) and seeds (*Trigonocarpus* cf. *parkinsonii*). Lycopsid remains are very rare indeed, represented only by leaf compressions (*Cyperites* sp.) at 220 m in the measured section, and at 241 m, by trunk compressions (*Lepidodendron* sensu lato and *Sigillaria* cf. *rugosa*). Stigmarian rootstocks are completely absent. An enigmatic plant (Fig. 7) recovered from the measured section is similar to *Rhacopteris busseana* (R.H. Wagner, personal communication, 2004), and may represent a rarely encountered dryland or hinterland floral element.

Anatomically preserved woods

Multiple channel sandstone units, in particular those at 96 m and 240 m in the measured section, contain allochthonous charred blocks of wood (up to 17 mm diameter), and more rarely calcite-permineralized trunk fragments. These anatomically preserved woods are present both in channel lags and in cross-bedded intervals higher in the channel bodies. In addition, a single small mud-filled channel, hosted in a mudrock-dominated interval at 352 in the measured section, contains a further four calcite-permineralized trunks, 18–24 cm in diameter.

Scanning electron microscopy and thin section analysis shows all specimens comprise pycnoxylic coniferopsid wood of *Dadoxylon*-type. The best preserved examples are assigned to *Dadoxylon recentium*, a wood characterized by biseriate,

Fig. 7 Enigmatic hinterland plant similar to *Rhacopteris busseana*.

alternate, bordered tracheid pitting (Fig. 8A), cupressoid pits per cross-field (Fig. 8B, C), and low rays (Fig. 8D). In the Joggins Formation, *Dadoxylon recentium* wood has been recorded in biological attachment to septate axes of *Mesoxylon* type (Falcon-Lang 2003), indicating that at least some of the charred wood in the Little River Formation is cordaitalean. However, some of the calcite-permineralized woods in the Little River Formation are attached to non-septate axes (up to 3–4 cm diameter, up to 45 cm long). At present it is unclear whether the absence of pith septa is a biological or taphonomic feature, but in either case, the most likely affinity of these woods is cordaitalean (Falcon Lang 2005).

DEPOSITIONAL ENVIRONMENT OF THE LITTLE RIVER FORMATION

Facies interpretation

Major channel sandstone bodies of the Little River Formation represent the deposits of alluvial drainage channels. Channels are characterized by moderate incision, subsequent infilling and, where the rivers were shallow and broad, a final abandonment phase. These contrast markedly with channel deposits of similar size associated with red mudrock beds of the overlying Joggins Formation, which are incised and confined within shallow valleys (Davies and Gibling 2003). The channel forms of the Little River Formation facilitated aggradation, whereas sediment bypass and cannibalization typified the Joggins paleochannels. The flashy flow and rapid aggradation of the Little River Formation drainage channels are indicated by a sigmoidal barform preserved at 95 m (Fig. 5), which may represent a transitional antidune, and by sandy wings, which record periods of maximum discharge when flow topped levees (Friend *et al.* 1979). Sand-size clay grains, associated with this and other channel complexes, may represent mud aggregates or finely ground intraformational mud clasts indurated by drying and reworked from floodplain deposits.

The presence of petrocalcic paleosol horizons indicates pronounced rainfall seasonality and greater soil longevity than in the overlying Joggins Formation, which is characterized by weakly developed, immature paleosols (Smith 1991). Local gleyed horizons represent wetting or ponding on the floodplain, which may have been facilitated by induration

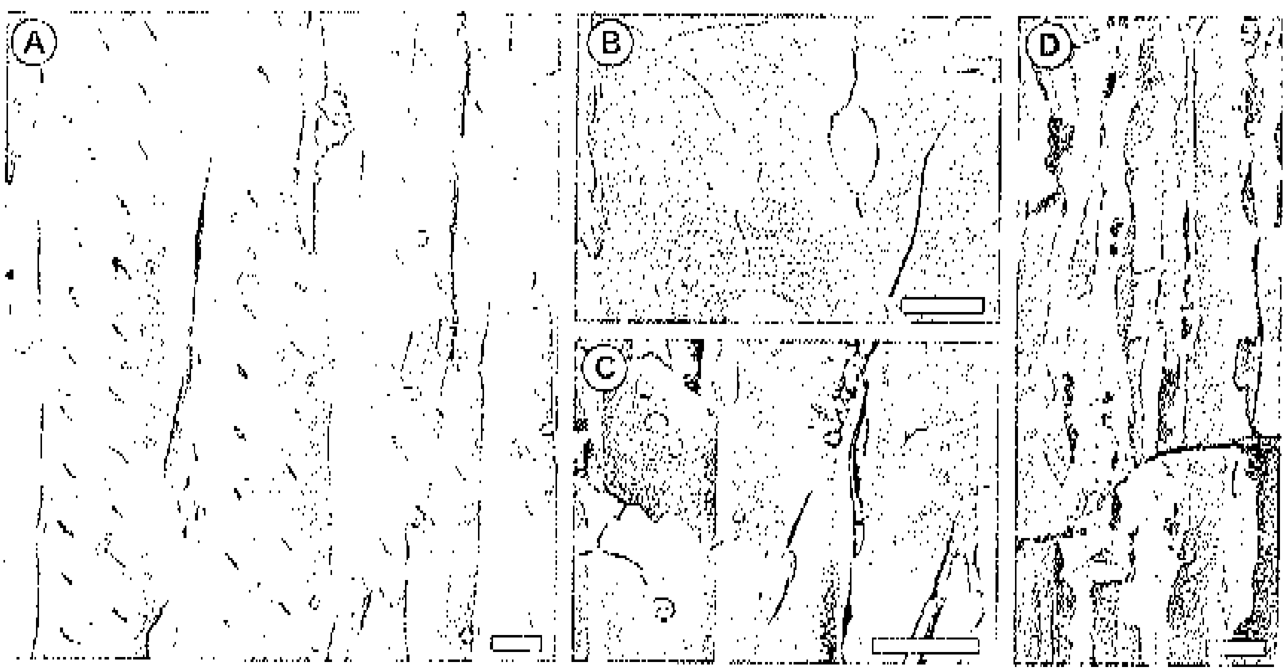

Fig. 8 Scanning electron micrographs of *Dadoxylon recentium* wood charcoal from 240 m (A-C) and 352 m (D) of the measured section. A: alternate, biseriate tracheid pitting; radial view, scale represents 10 µm. B: Cupressoid cross-field pits; radial view, scale represents 10 µm. C: 1-2(-4) cupressoid cross-field pits; radial view, scale represents 40 µm. D: uniseriate rays (1-8 cells high); tangential view, scale represents 40 µm.

of the dessicated mudrocks. Alternatively, rare *Spirorbis*-rich grey mudstone beds may indicate cryptic transgressive events. Although the ecological affinity of this fauna is poorly defined in the fossil record with respect to marine or freshwater environments, it is locally associated with brackish facies in the overlying Joggins Formation (Duff and Walton 1973; Skilliter 2001; Falcon-Lang 2005). Although the red beds generally reflect oxidizing, well drained conditions with sufficient sediment input to prevent extensive pedogenesis, drab haloed root compressions indicate that neither moisture deficit nor disturbance prevented plant life.

The reproductive and growth strategies of the most common plant groups within the Little River red beds show adaptation consistent with the sedimentological record of periodic moisture deficit and aggrading sediment. The persistence of calamiteans, perhaps the most ecologically resilient of the Late Paleozoic plant groups (Calder *et al.* in press; DiMichele *et al.* in press), was aided by their prolific vegetative propagation by adventitious roots and underground rhizomes (Gastaldo 1992). Medullosan pteridosperms and cordaitaleans were assisted through dry periods by a substantial root system, which allowed them to tap deep groundwater sources (Falcon-Lang and Bashforth 2004). Although sparse, the presence of lycopsid foliage and aerial stems in the upper two-thirds of the section indicates that standing water was available for their reproduction (Phillips and DiMichele 1992), at least temporarily or in restricted areas of the landscape.

Stratigraphic relationships indicate that the red beds of the Little River Formation were largely coeval with the conglomerates of the Polly Brook Formation at the southern basin margin, which represent extensive alluvial fan deposits derived from the Cobequid Highlands massif to the south (Calder 1991, 1994). Paleoflow indicators within the Little River Formation at Lower Cove, however, indicate a dominant source to the northeast of the type section (potentially the Caledonia Highlands), which argues against the Little River Formation as distal deposits of the Polly Brook Formation alluvial fans. The immature, feldspathic composition of certain horizons within the channel sandstone bodies at 90 and 160 m suggests, however, that the Little River Formation may include distal deposits derived from fans along the Caledonia Highlands of southern New Brunswick. Equivocal support for this hypothesis comes from the Grand Anse strata to the north and east of the type section, which exhibit a coarser, more feldspathic composition than at Lower Cove. As discussed earlier, however, the age and fault boundaries of the Grande Anse cast uncertainty on correlation of the two units.

Little River drylands as climate or topographic indicators

The clear evidence of prevailing dry conditions during deposition of the Little River Formation speaks convincingly of climate as an underlying control. However, the stratigraphic relationships within such an active basinal setting also require consideration of topographic factors that may have come into play in imparting the well-drained character of these red beds. Evidence supporting a dry or dry seasonal climate includes in situ pedogenic carbonate development, absence of coal beds, flashy paleoflow recorded within channel bodies, and the pervasive reddening of mudrocks and some sandstone bodies. The possibility of topographically related drainage effects comes indirectly from possible relationships with basin margin alluvial fan systems. Although calcareous rhizoliths are present in the Joggins Formation (Davies and Gibling 2003; Falcon-Lang *et al.* 2004), no *in situ* source beds are present in that interval, nor within the Joggins Formation. This raises the possibility of reworking from an upstream source, namely the Little River Formation red beds. The absence of bivalve-bearing beds, which record flooding events (Davies and Gibling 2003), suggests that base level was not felt within the Little River environment, with the possible exception of a single *Spirorbis*-rich interval. This further suggests that gradient may have enhanced drainage and so have been a factor in the development of the red beds. However, the general lack of evidence of incision by channel bodies within the Little River Formation, which would be expected if base level was lowered, does not support the enhancement of drainage by topographic relief.

In summary, while there is cause for considering topographic factors in draining the Little River drylands, the development of calcareous soils, complete absence of coal beds and supporting sedimentological evidence clearly required a climate regime with pronounced dry intervals. Topographically enhanced drainage may have played a contributing role.

CONCLUSIONS

The 635.8 m section of red beds at Lower Cove is sedimentologically and stratigraphically distinct from adjacent units within the Cumberland Basin, and so warrants designation as a separate formation, as first recognized by Sir William Logan. Additionally, recognition of the Little River Formation better circumscribes the definition of the overlying Joggins Formation as coal-bearing and enhances its utility as a regionally recognizable stratigraphic unit. These revisions (summarized in Appendices B and C) confirm the pioneering work of Logan, and formally elevate his Divisions 3 and 4 to formation status. The fluvial style recorded in the Little River Formation records a dramatic change from that of the underlying Boss Point Formation, although the onset of reddening is presaged in the upper mudrocks of the Boss Point. This dramatic cessation of the Boss Point fluvial systems and their replacement by mud-rich systems is also found in other depocentres of the Maritimes Basin (Rehill *et al.* 1995). The landscape during deposition of the Little River Formation was substantially better drained than that of the succeeding Joggins Formation, including the seasonal dryland environments (Falcon-Lang *et al.* 2004; Hebert and Calder 2004). The absence of coal beds, pervasive reddening of mudrocks and sandstones and development of pedogenic carbonate within the Little River Formation are all consistent with xeric conditions and a pronounced dry season, although topographic effects may have enhanced drainage. The Little River red beds provide limiting constraints on the interpretations of seasonal drylands in the succeeding Joggins Formation, which in contrast records a gradual shift to wetter conditions with peat formation and flooding events near base level.

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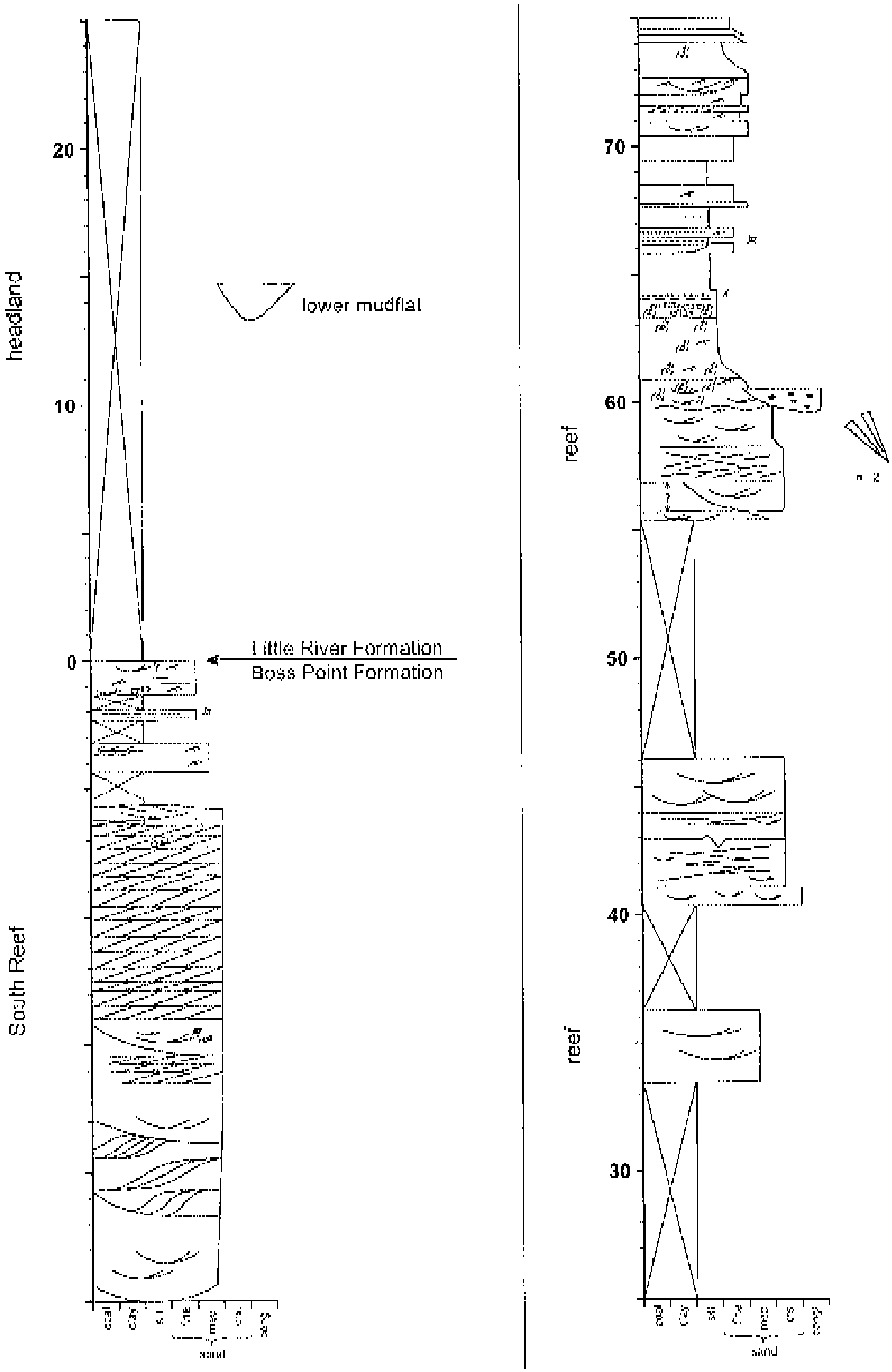
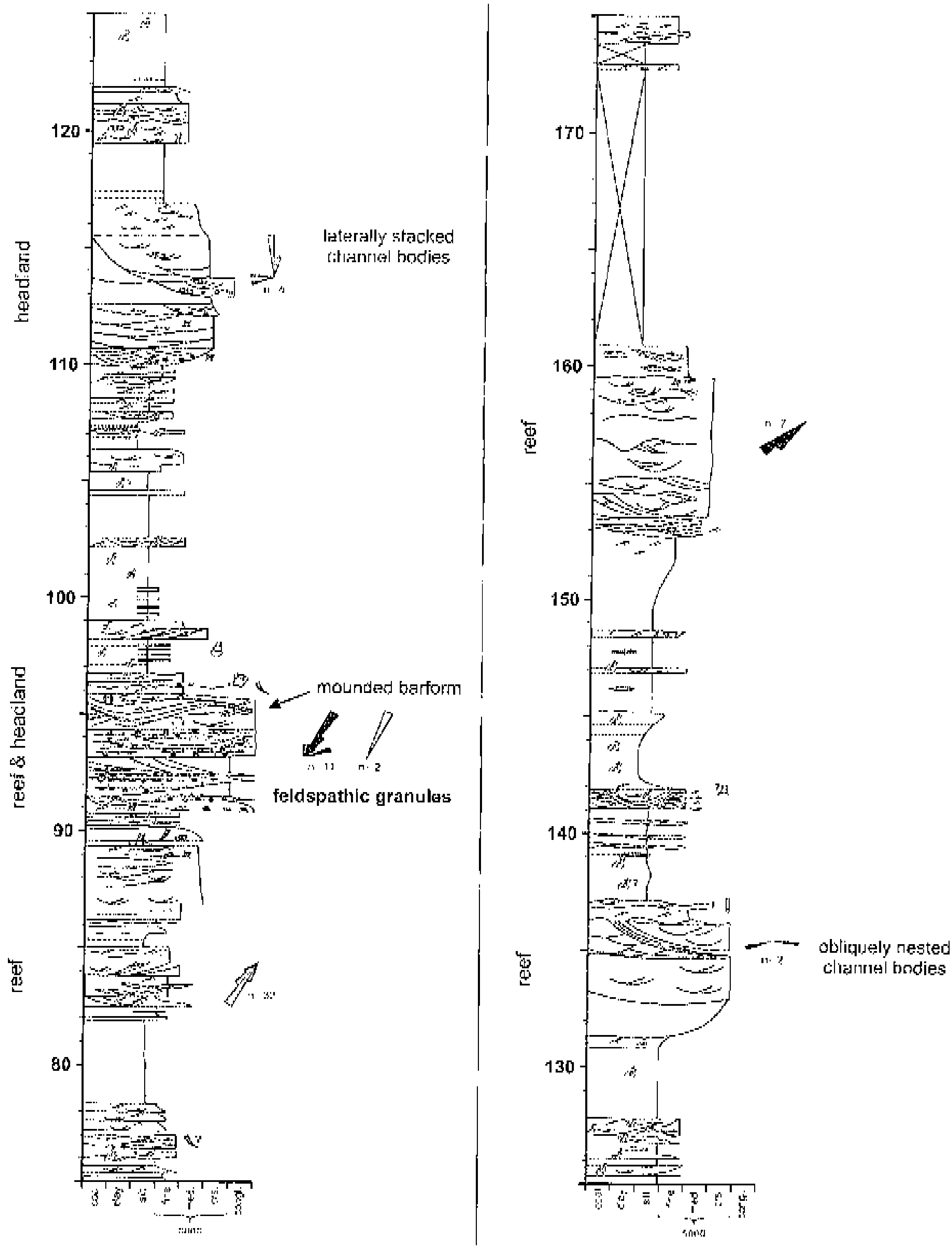
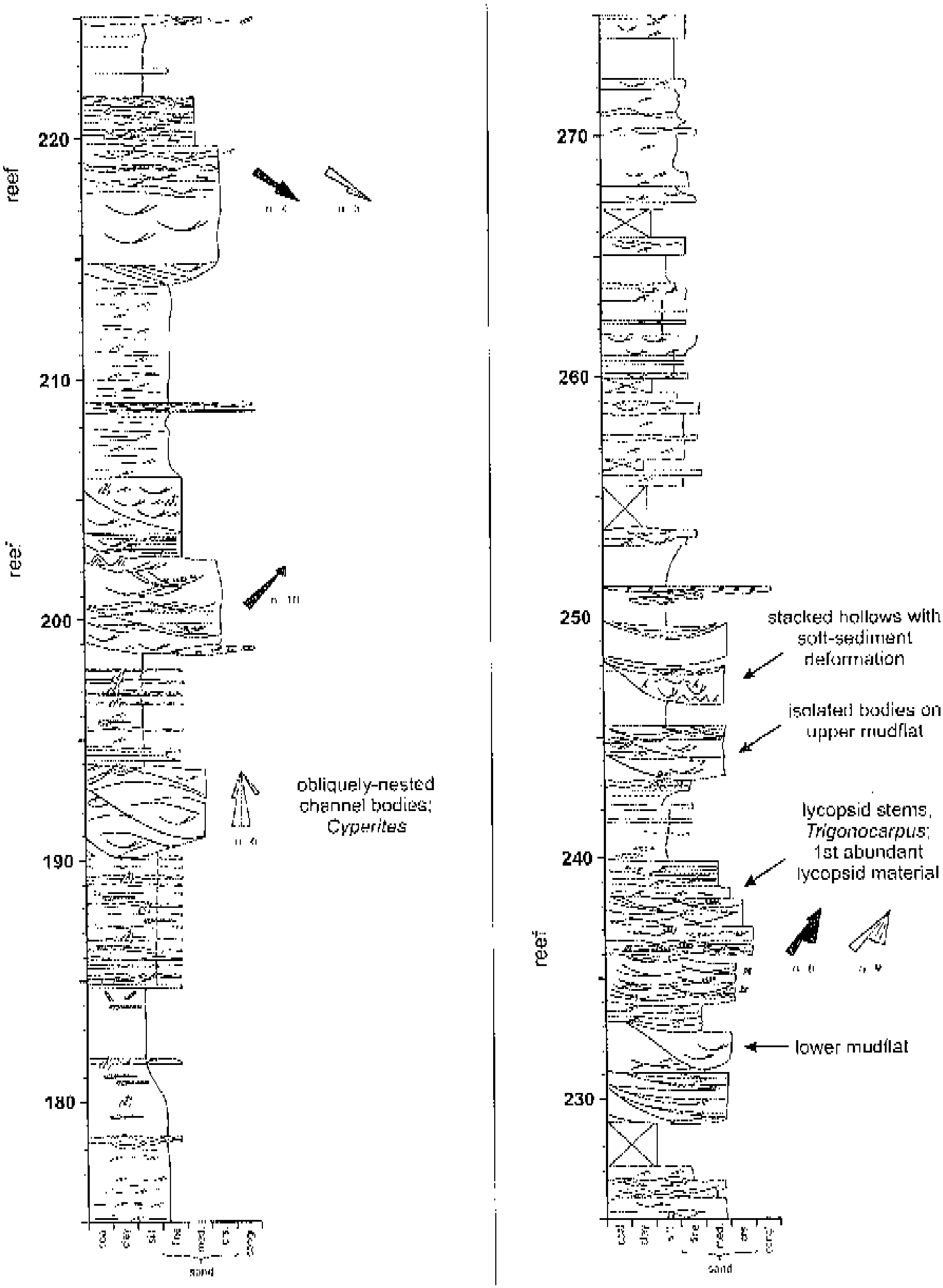
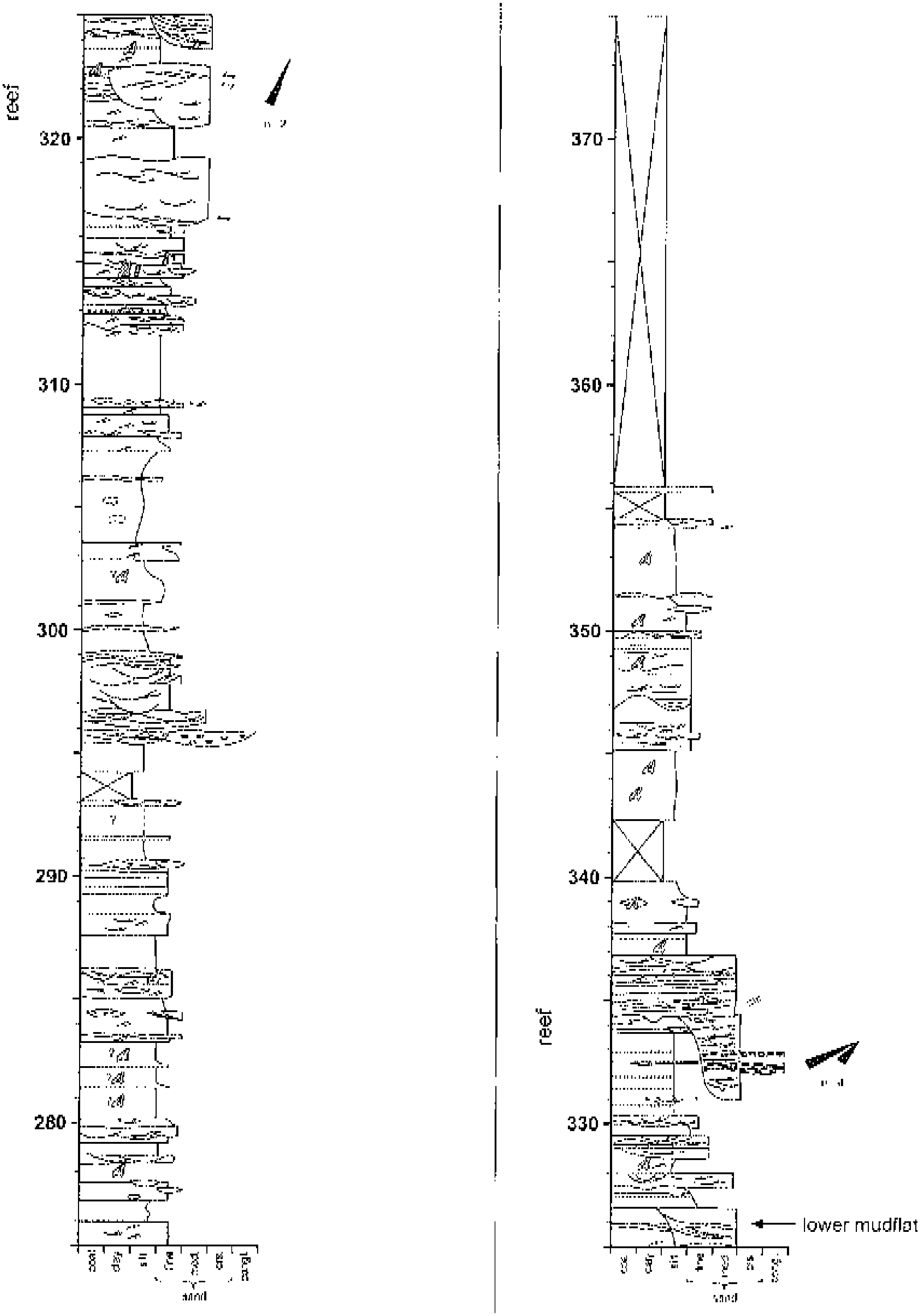
Editorial responsibility: Robert A. Fensome

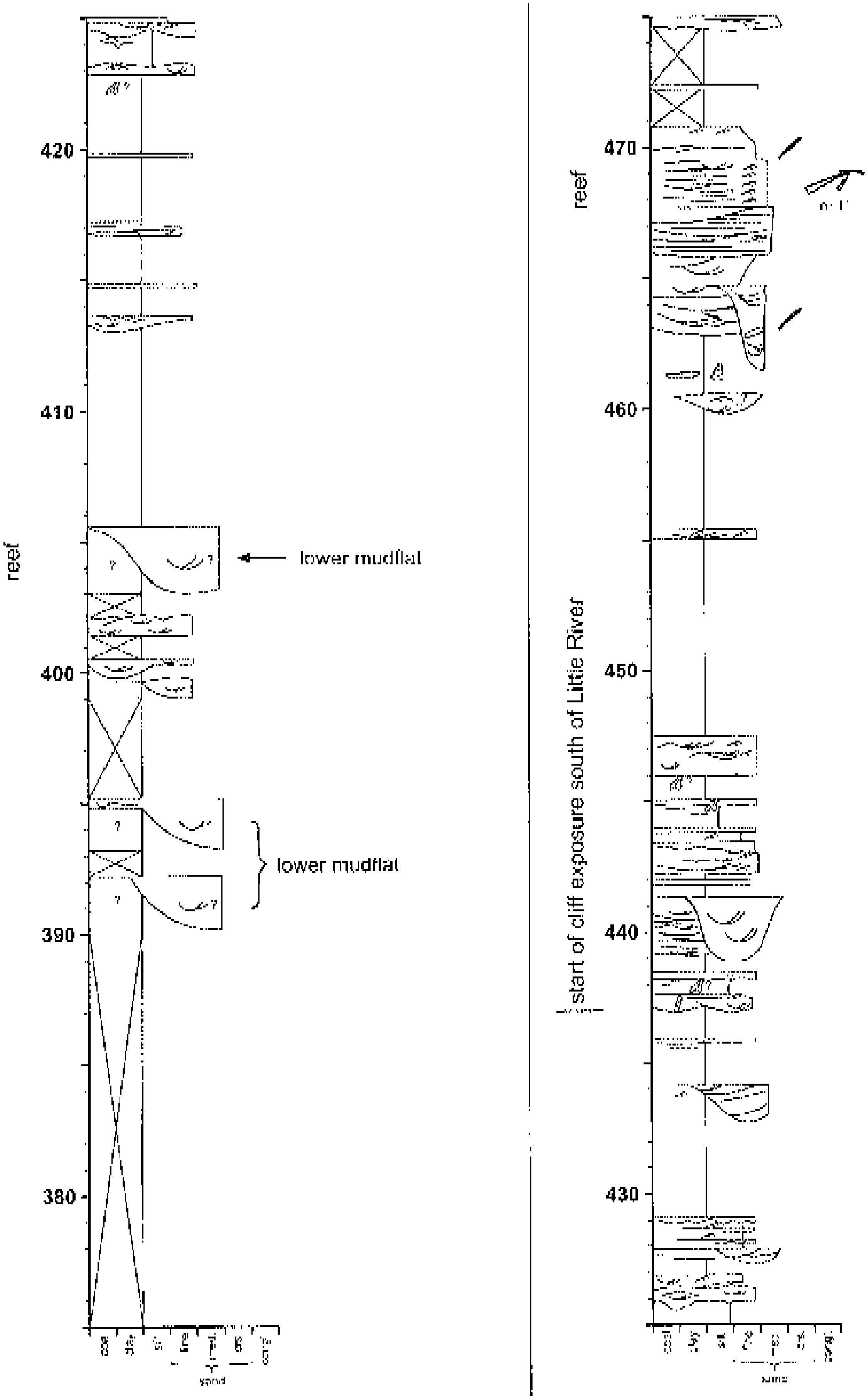
APPENDIX A

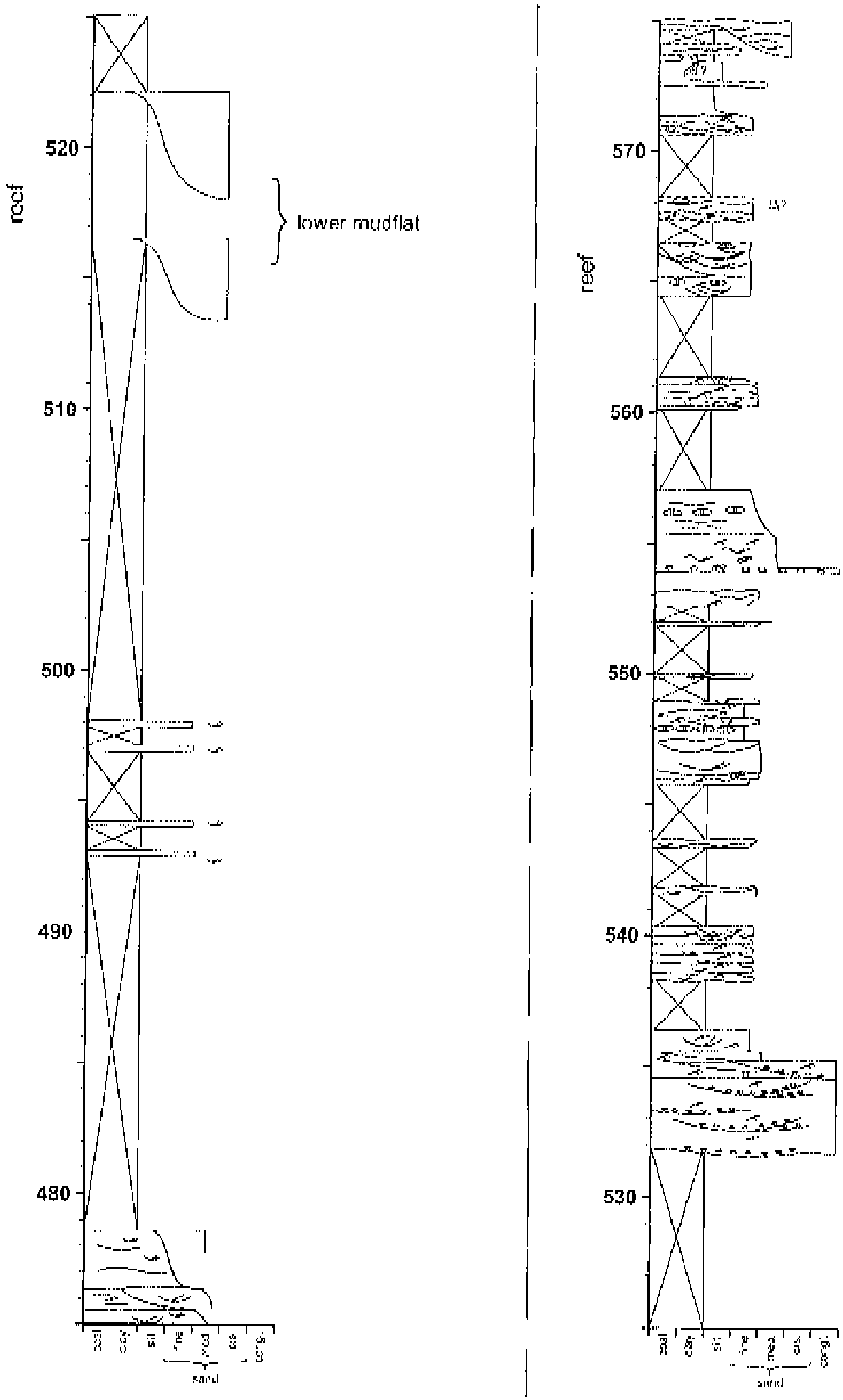

headland
South Reef
20
10
0
lower mudflat
Little River Formation
Boss Point Formation
coal
clay
silt
fine
med
crs
cong
sand
reef
reef
70
60
50
40
30

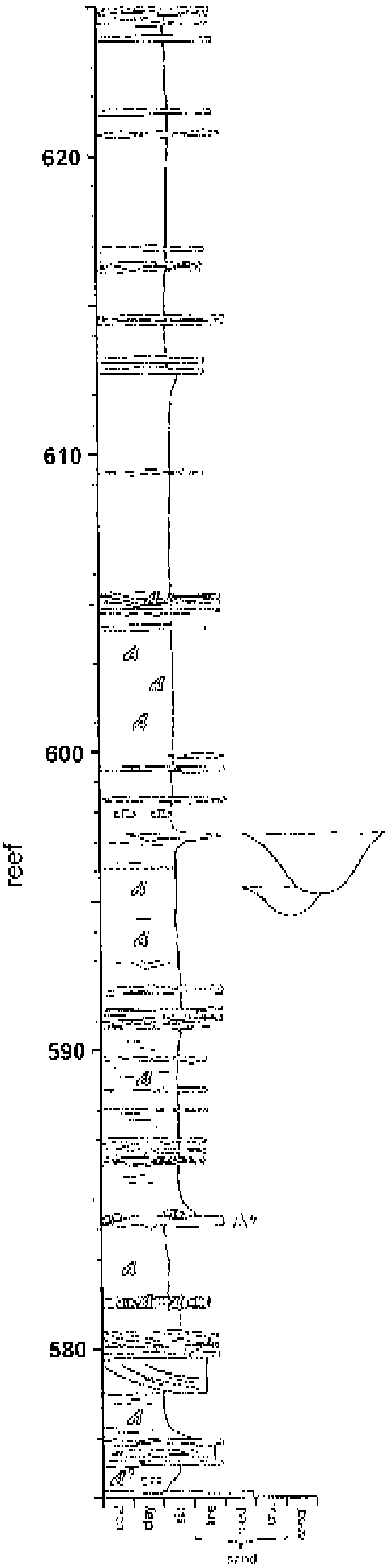

120
110
100
90
80
headland
reef & headland
reef
laterally stacked channel bodies
mounded barform
feldspathic granules
170
160
150
140
130
reef
reef
obliquely nested channel bodies


220
210
200
190
180
reef
reef
obliquely-nested channel bodies; *Cyperites*
coal clay silt fine med. crs. cong
sand
270
260
250
240
230
reef
stacked hollows with soft-sediment deformation
isolated bodies on upper mudflat
lycopsid stems, *Trigonocarpus*; 1st abundant lycopsid material
lower mudflat
coal clay silt fine med. crs. cong
sand


reef
320
310
300
290
280
coal
clay
silt
fine
med
crs
congl
sand
370
360
350
340
330
reef
lower mudflat
sand


420
410
400
390
380
reef
lower mudflat
lower mudflat
470
460
450
440
430
reef
start of cliff exposure south of Little River


reef
520
lower mudflat
510
500
490
480
coal
clay
silt
fine
med
cs
cong.
sand
reef
570
560
550
540
530
coal
clay
silt
fine
med
cs
cong.
sand


620
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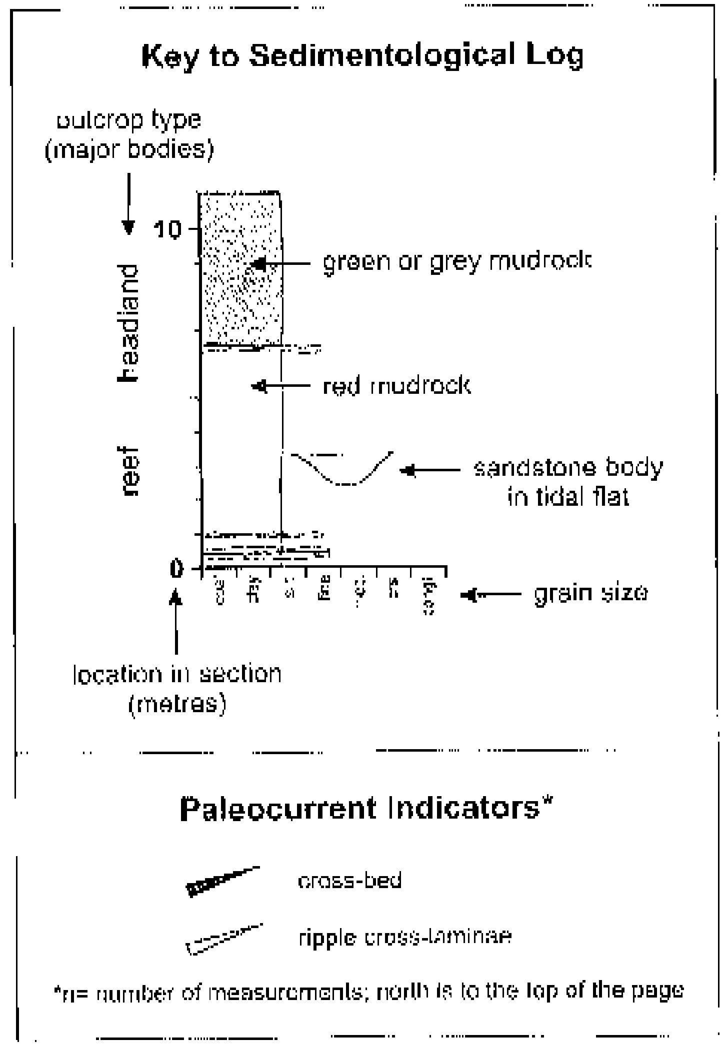
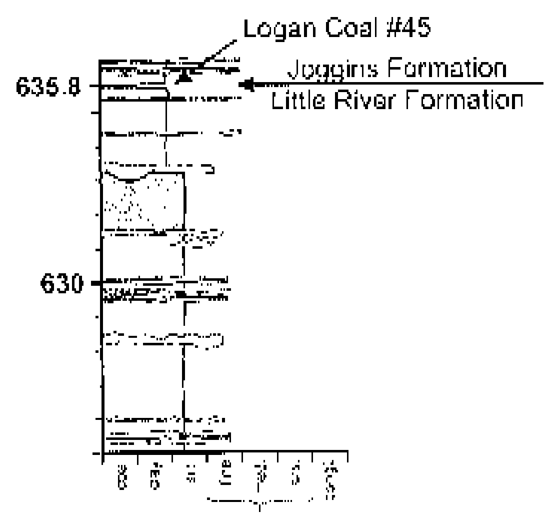
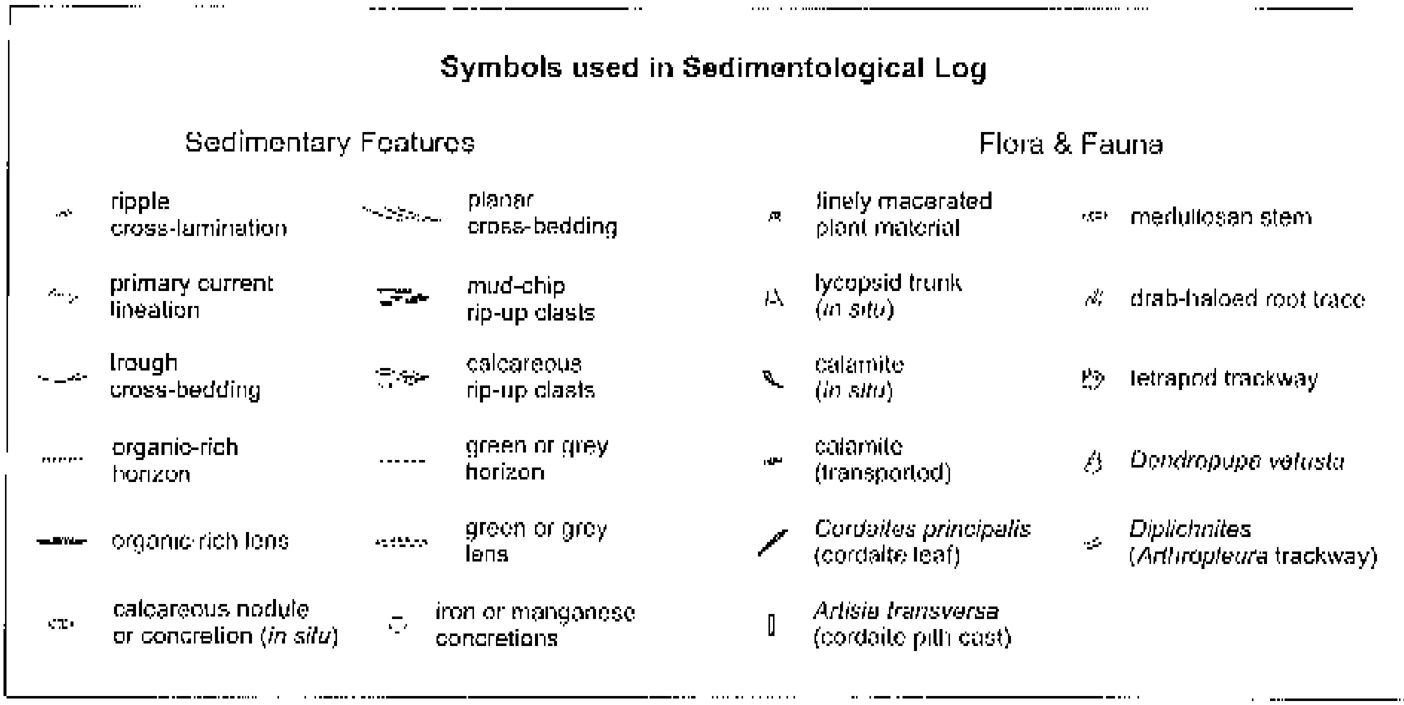
600
590
580
reef
sand


Key to Sedimentological Log
outcrop type
(major bodies)
10
headland
reef
0
green or grey mudrock
red mudrock
sandstone body
in tidal flat
grain size
location in section
(metres)
Paleocurrent Indicators*
cross-bed
ripple cross-laminae
*n= number of measurements; north is to the top of the page


Logan Coal #45
Joggins Formation
Little River Formation
635.8
630



APPENDIX B

Standard lexicon entry for the Little River Formation.

Author: Calder, Rygel, Ryan, Falcon-Lang and Hebert 2005

Type locality: Outcrop in the intertidal zone and low-relief coastal bluffs on the eastern shore of Chignecto Bay, at Lower Cove, near Joggins, Cumberland County, Nova Scotia. The type section begins at the top (southern edge) of the South Reef of the Boss Point Formation (UTM Coordinates 5066450N, 388000E; NAD 83 datum) and extends 1500 m southwards to a point 500 m south of the mouth of Little River (5063200N, 388400E). The top of the section coincides with the base of the lowest coal bed (Coal 45 of Logan 1845) of the Joggins Formation, near the start of the continuous cliff-section.

Lithology: A red bed succession dominated by mudrocks, which exhibit pervasive mottling from root traces and local pedogenic carbonate, with sandstone bodies typically 3–6 m thick. Coal beds and bivalve-bearing limestones are absent.

Thickness and distribution: The type section at Lower Cove is 635.8 m in thickness. The formation can be traced 30 km to the east along the north limb of the Athol Syncline to Styles Brook ("abundant red beds" of Ryan *et al.* 1990a), where it eventually pinches out between the underlying Polly Brook Formation and overlying Joggins and Springhill Mines formations (Fig. 3). The Lower Cove beds exhibit many similarities with fault-bound strata exposed to the west across Chignecto Bay on Maringouin Peninsula, New Brunswick, assigned to the informal Grande Anse formation (St. Peter and Johnson 1997) and strata along strike at Minudie Point, Nova Scotia.

Relations to other units: The basal contact of the Little River Formation is placed at the top of the highest multistorey sandstone bed of the Boss Point Formation, which at the type section is the top of the South Reef, coinciding with the base of Division 5 of Logan (1845). Inland, to the east, the base of the formation progressively onlaps against polymictic conglomerates of the Polly Brook Formation (Ryan *et al.* 1990a). The upper contact of the formation is placed at the base of the stratigraphically lowest coal bed, which at the type section is coal 45 of Logan (1845), 1.65 m above the base of Logan Divison 4. This upper contact defines the base of the revised Joggins Formation (Calder *et al.* this paper; Davies *et al.* 2005). Although it is probable that the Grande Anse formation in southeast New Brunswick may represent a facies of the Little River Formation, the correlation of the two units is problematic due to uncertainties in the stratigraphic relationship of the Grande Anse formation with adjacent geologic units: the base of the Grand Anse section is in faulted contact with the Ross Point Formation at the coast, although the contact is reported to be conformable in the axis of the Hardledges Syncline south of the Shepody-Beckwith Fault (Johnson 1996); the top of the Grand Anse section is in faulted contact with the Mississippian Windsor Group. Johnson (1996) suggested correlation of the Grande Anse with the Polly Brook Formation and lower Joggins (Little River) Formation.

Age justification: Age determination of the Little River Formation is problematic, due to its sparse paleontological record, and in particular, the absence of key age-diagnostic marine index fossils (Calder 1998). Palynostratigraphic studies of the type section place the Little River Formation within the upper Namurian (Kinderscoutian) to basal Westphalian (basal Langsettian) (Dolby 1991, 2003; Utting and Wagner 2005).

History: First mapped by Logan (1845), the Little River Formation coincides almost precisely with his Division 5. Dawson (1855) originally included these strata in his "Lower or Older Coal Formation", but later (Dawson 1868) referred them to his "Millstone-grit Series". Bell (1912, 1914) included the Lower Cove red beds in his Joggins Formation, but later abandoned the term (Bell 1938, 1944). Ryan *et al.* (1991) reconstituted the Joggins Formation to be inclusive of the Lower Cove red beds but Ryan *et al.* (1990a) mapped their boundary with the Joggins Formation inland.

References: Bell 1912, 1914, 1938, 1944; Calder *et al.* this paper; Davies *et al.* 2005; Dawson 1855, 1868; Dolby 1991, 2003; Johnson 1996; Logan 1845; Ryan *et al.* 1990a; Ryan *et al.* 1991, Utting and Wagner 2005.

APPENDIX C

Standard lexicon entry for the Joggins Formation.

Author: Calder, Rygel, Ryan, Falcon-Lang and Hebert 2005; Davies, Gibling, Rygel and Calder 2005.

Type locality: Outcrop in the coastal cliffs and wave-cut platform on the eastern shore of Chignecto Bay, near the village of Joggins, Cumberland County, Nova Scotia. The base of the type section coincides with the base of the lowest coal bed (Coal 45 of Logan 1845) near the start of the continuous cliff-section south of Little River (UTM Coordinates 5063200N, 388400E, NAD 83 datum) and extends 2800m southwards to a point south of Bell Brook and north of Dennis Point (5060700N, 386950E) that coincides with the top of the uppermost limestone unit.

Lithology: A coal-bearing succession comprising grey, siderite-bearing and reddish mudrocks, grey sandstones ranging from 3–30 m thick (Rygel 2005), bituminous coal beds typically less than one metre in thickness and associated black bivalve-bearing limestones and shales; all occurring in cycles from 16–212 m thick (Davies and Gibling 2003).

Thickness and distribution: The type section at Joggins is 915.5 m thick (Davies *et al.* 2005). Within the Cumberland Basin, the formation can be traced inland continuously for 40 km to the east along the north limb of the Athol Syncline, where it thins dramatically (Copeland 1959; Waldron and Rygel 2005). The formation persists as far south as Springhill, where it pinches out against, and apparently onlaps, the Polly Brook Formation (Ryan *et al.* 1990a; Calder 1991, 1994). To the east, in the Wallace Syncline, it has been mapped through drilling in the Roslin area (Calder and Naylor 1985; Ryan *et al.* 1990c). The Joggins Formation is lithologically similar to the bivalve-bearing coal measures assigned to the Port Hood Formation of western Cape Breton Island, and bears lithologic similarities to the Parrsboro Formation in the Minas Basin south of the Cobequid Highlands, although bivalve-bearing shale sequences there attain greater thickness.

Relations to other units: The basal contact of the Joggins Formation is placed at the base of the lowermost coal bed, which at the type coastal section is coal 45 of Logan (1845). This contact is shared conformably with the older Little River Formation, a lithologically distinct non-coal-bearing, red bed unit (Calder *et al.* this paper). The formation thins to the east and south, where it overlaps the Little River red beds and progressively onlaps coarse basin margin conglomerates of the Polly Brook Formation (Ryan *et al.* 1991). The upper contact of the formation is given as the top of the uppermost limestone (Davies *et al.* 2005), which at the type section occurs in coal group 1 of Logan (1845). The upper boundary is conformable with the basal boundary of the Springhill Mines Formation which also is coal-bearing but devoid of continuous fossiliferous limestone beds.

Age justification: The age of the Joggins Formation has long been held to be early Westphalian, although precise correlation with European stages has been hindered by lack of open marine index fossils. Bell (1944) gave the age range as late Westphalian A-early B on the basis of macroflora but favoured an early Westphalian B (Duckmantian) assignment, later supported by Hacquebard and Donaldson (1964). Extensive palynostratigraphic analysis of the Joggins and inland sections by Dolby (1991) led him to revise the age downward to Westphalian A (Langsettian). Subsequent palynostratigraphic and macrofloral analysis have recognized Namurian elements within the paleobotanical record but place the Joggins Formation most parsimoniously within the basal Westphalian (early Langsettian). (Calder *et al.*, in press; Utting and Wagner 2005)

History: First mapped by Logan (1845), the Joggins Formation coincides almost precisely with his Division 4. Dawson (1868) originally included these strata in his "Middle Coal Formation". Bell (1912, 1914) introduced the name Joggins Formation but later abandoned the term (Bell 1938, 1944) due to difficulties in mapping the unit inland, a problem that arose in part due to inclusion of the Lower Cove red beds of Logan's Division 5 (Little River Formation of Calder *et al.* this paper) and in part due to his correlation of the Joggins Formation with younger coal-bearing strata at Spicer Cove. Subsequently, Shaw (1951) referred these same strata to his informal "coal-bearing facies". Copeland (1959) designated the Joggins coal-bearing strata, exclusive of the Little River red beds, as his informal "Facies B". Ryan *et al.* (1991) reconstituted the Joggins Formation to be inclusive of the Little River Formation red beds, although the lithological distinctiveness of the two units was recognized as a mappable boundary by Ryan *et al.* (1990a). Calder *et al.* (this paper) formally recognized the lower 635.8m red bed succession as the Little River Formation, and re-established the Joggins Formation as a coal- and bivalve limestone-bearing unit. Davies *et al.* (2005) suggest that the upper boundary of the Joggins Formation be modified to coincide with the top of the uppermost limestone unit as originally proposed by Logan in his Division 4. This suggestion is formalized in the present paper.

References: Bell 1912, 1914, 1938, 1944; Calder 1991, 1994; Calder and Naylor 1985; Calder *et al.* this paper; Calder *et al.*, in press; Davies and Gibling 2003; Davies *et al.* 2005; Dawson 1868; Dolby 1991; Hacquebard and Donaldson 1964; Logan 1845; Ryan *et al.* 1990a; Ryan *et al.* 1991, Rygel 2005; Utting and Wagner 2005; Waldron and Rygel 2005.

Sedimentology (2003) **50,** 415–439

Architecture of coastal and alluvial deposits in an extensional basin: the Carboniferous Joggins Formation of eastern Canada

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ABSTRACT

The Joggins Formation was deposited in the Cumberland Basin, which experienced rapid mid-Carboniferous subsidence on bounding faults. A 600 m measured section of coastal and alluvial plain strata comprises cycles tens to hundreds of metres thick. The cycles commence with coal and fossiliferous limestone/siltstone intervals, interpreted as widespread flooding events. These intervals are overlain by coarsening-upward successions capped by planar-based sandstone mounds, up to 100 m in width that represent the progradation of small, river-generated delta lobes into a standing body of open water developed during transgression. The overlying strata contain sand-rich heterolithic packages, 1–8 m thick, that are associated with channel bodies 2–3 m thick and 10–50 m wide. Drifted plant debris, *Calamites* groves and erect lycopsid trees are preserved within these predominantly green-grey heterolithic sediments, which were deposited on a coastal wetland or deltaic plain traversed by channel systems. The cycles conclude with red siltstones, containing calcareous nodules, that are interbedded with thin sandstones and associated with both single-storey channel bodies (1–1·5 m thick and 2–3 m wide) and larger, multistorey channels (3–6 m thick) with incised margins. Numerous channel bodies at the same level suggest that multiple-channel, anastomosed river systems were developed on a well-drained floodplain. Many minor flooding surfaces divide the strata into parasequences with dominantly progradational and aggradational stacking patterns. Multistorey channel bodies are relatively thin, fine grained and modestly incised, and palaeosols are immature and cumulative. The abundance and prominence of flooding surfaces suggests that base-level rise was enhanced, whereas the lack of evidence for abrupt basinward stepping of facies belts, coupled with the absence of strong fluvial incision and mature palaeosols, suggests that base-level fall was suppressed. These architectural features are considered to reflect a tectonic architectural signature, in accordance with the high-subsidence basinal setting. Evidence for restricted marine influence and variation in floral assemblages suggests modulation by eustatic and climatic effects, although their relative importance is uncertain.

Keywords Accommodation, Canada, Carboniferous, coal, extensional basins, flooding surfaces, high subsidence, Joggins Formation, parasequences, sequence stratigraphy.

INTRODUCTION

The subsidence history of any basin fundamentally controls the distribution of accommodation in time and space. The stratal architecture should therefore reflect regional and temporal variations in subsidence rate (Diessel *et al.*, 2000). The complex subsidence and uplift patterns generated in foreland and extensional basins and their influence on accommodation generation, sediment supply and the sequence stratigraphic development of the basin fill are now widely recognized (e.g. Posamentier & Allen, 1993; Schlager, 1993; Gawthorpe *et al.*, 1994).

Controversy surrounds the interpretation of Upper Carboniferous strata of North America and Europe in terms of controls on facies succession. In question is the relative importance of high-frequency and high-magnitude glacioeustatic sea-level fluctuations as a driving mechanism in the development of basin fill over the controls exerted by the prevailing tectonic regime, climate in the source area and depositional basin and sediment supply. The tectonic component of relative sea-level variation is likely to be important in active tectonic settings.

The influence of primary eustatic sea-level change has been demonstrated through the successful application of sequence stratigraphic concepts to a number of Carboniferous basins (e.g. Maynard, 1992; Church & Gawthorpe, 1994; Gibling & Wightman, 1994; Heckel, 1994; Archer & Greb, 1995; Martinsen *et al.*, 1995; Hampson *et al.*, 1997). The recognition of time-equivalent, major sea-level fluctuations from a number of European (Davies *et al.*, 1999) and US (Ross & Ross, 1985) basins provides corroborating evidence for eustatic changes. Coeval sea-level falls have been documented to produce fluvial incision in tectonically diverse basins (Hampson *et al.*, 1997; Davies *et al.*, 1999). The systematic variation of depositional architecture in alluvial and coal-bearing strata, subject to eustatic influence, has also been demonstrated by Shanley & McCabe (1991), Blum (1993) and Tornqvist (1993). The importance of climate change in promoting fluctuations in sediment supply cannot be underestimated, particularly in fluvial successions that are physically distant from the landward limit of sea-level fluctuations (Schlager, 1991, 1993; Blum, 1993).

Excellent exposures of the Joggins Formation in the broadly extensional Cumberland Basin, eastern Canada, provide an opportunity to examine the stratigraphic response of a coastal–alluvial depositional system to a high-subsidence tectonic setting. A critical appraisal of key surfaces for identification of base-level changes within this succession demonstrates an abundance and a hierarchy of flooding events. However, no evidence was found for significant base-level falls through 600 m of strata, because the following key characteristics were not observed: (1) major relief associated with the base of multistorey systems; (2) basinward stepping of facies belts; or (3) mature interfluve palaeosols (*sensu* Van Wagoner *et al.*, 1988).

GEOLOGICAL SETTING

The Cumberland Basin (Fig. 1) forms part of the regional Maritimes Basin of Atlantic Canada within which the Devonian to Permian fill was deposited in a series of interconnected depocentres. During the Carboniferous, the Maritimes Basin lay in palaeoequatorial latitudes (Scotese & McKerrow, 1990) within the northern Appalachian mountain belt. The region formed part of the Maritime–West European Province of Leeder (1987), and the sub-basins may have been linked to a ‘Mid-Euramerican’ Sea during times of high sea level (Calder, 1998; Davies *et al.*, 1999).

In the Cumberland Basin, Viséan to earliest Namurian sedimentation was characterized by thick carbonate–evaporite cycles of the Windsor Group and overlying lacustrine and alluvial beds of the Mabou Group (Fig. 2). The later Namurian and Westphalian basin fill was dominated by alluvial sedimentation (Fig. 2), including the braidplain successions of the Boss Point Formation (Ryan *et al.*, 1991; Browne & Plint, 1994; Plint & Browne, 1994). The Boss Point/Joggins Formation transition represents a major lithostratigraphic change from a sand-dominated to a sand-poor succession and can be mapped across much of the Maritimes Basin (Rehill *et al.*, 1995). The exact age of the Namurian–Westphalian successions remains in doubt, and the Joggins Formation has been variously dated as Namurian or Langsettian to Duckmantian (Ryan *et al.*, 1991; Wagner, 2003).

The Cobequid Highlands border the Cumberland Basin to the south, with the Spicers Cove and Cobequid faults on their northern and southern sides respectively (Fig. 1). The Joggins Formation passes southward into a thick conglomerate wedge bordering the highlands (Polly Brook Formation; Calder, 1994). To the north, the basin is bordered by a basement horst on the Harvey-Hopewell Fault near the Caledonia Highlands, with a north-eastward splay into the Hastings Fault (Fig. 1). The Joggins section lies within the Athol syncline, bounded to the north by the Minudie anticline, cored by Windsor Group evaporites, and to the south by the Black River Diapir and Athol–Sand Cove Fault Zone (Fig. 1). About 4 km of strata of probable Namurian to Westphalian B age are exposed within the syncline, and

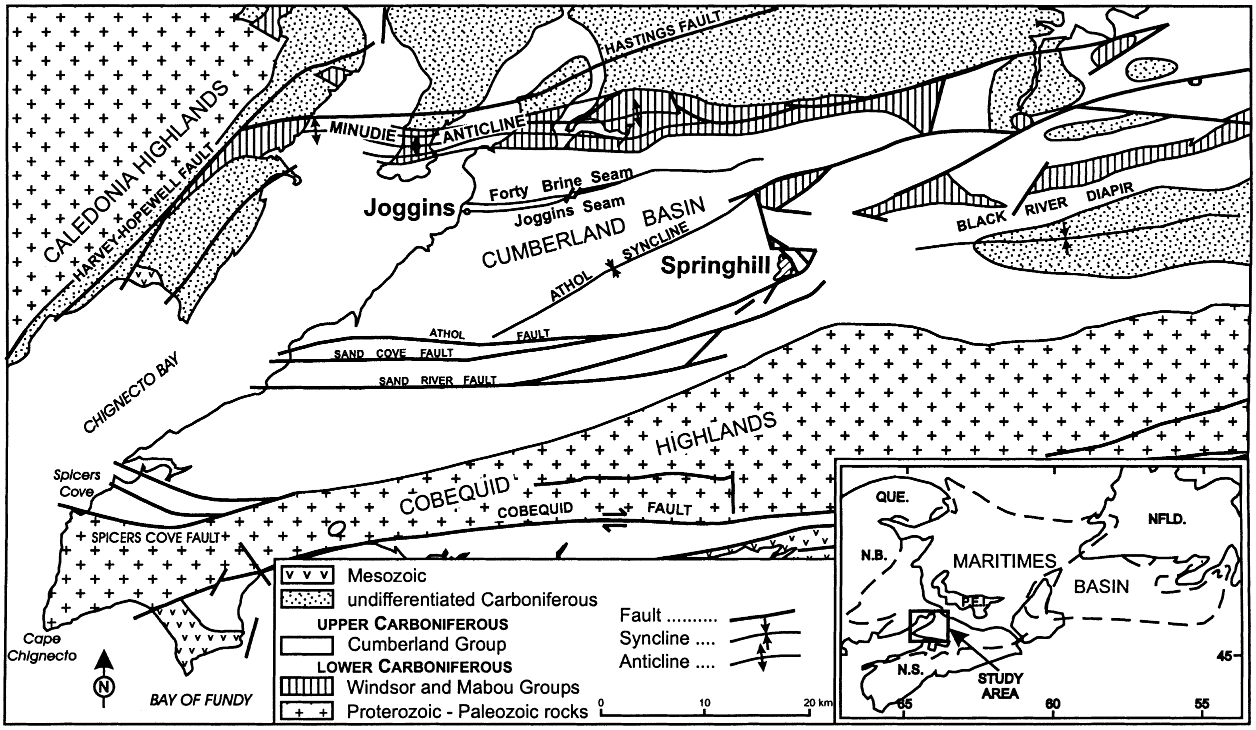

Fig. 1. Map of the Cumberland Basin, eastern Canada, modified from Calder (1994). The sub-basin is bordered by the Caledonia and Cobequid Highlands to the north and south respectively.

seismic profiles illustrated in Calder & Bromley (2003) show that the strata thicken into the syncline axis. Although the timing of fault activity is not fully known, many of the major fault systems were clearly active during the Namurian to early Westphalian, many with a prominent strike-slip component. The Harvey-Hopewell and Hastings faults have a complex history of motion (Webb, 1963; Browne & Plint, 1994). Likewise, the Athol–Sand Cove Fault Zone has a complex history that includes dextral offset, displacing Upper Carboniferous strata downward on its northern side (Reed *et al.*, 1993). The Cobequid Fault shows dextral motion (Eisbacher, 1969; Donohoe & Wallace, 1985), with thrusting during the Namurian to early Westphalian at fault bends (Plint & van de Poll, 1984; Nance, 1987; Waldron *et al.*, 1989). Halokinesis of the Windsor Group evaporites is dated as intra-Westphalian and may have assisted in creating accommodation locally (Calder, 1994; Ryan & Boehner, 1994). Thus, the Cumberland Basin underwent rapid subsidence in a broadly extensional setting, during the Namurian–Westphalian, accumulating an estimated 4 km of strata in 4 Myr (Calder, 1994). Gibling (1995) linked the onset of the Alleghanian Orogeny in the US Appalachians, to the south, to the phase of Namurian–Westphalian deformation and subsidence in the Maritimes. Some later movement on the faults may reflect Mesozoic extension in the Fundy Rift (Reed *et al.*, 1993).

The Joggins Formation is $\approx$1433 m thick at Joggins (Ryan *et al.*, 1991). It is continuously exposed for more than 3 km in 20 m high cliffs (Fig. 3), which together with the adjacent 300 m wide wave-cut platform provide an unrivalled three-dimensional perspective of the strata. The formation represents deposition on an alluvial to coastal plain where periodically high water tables promoted the development of wetland forests. The spectacular fossil forests of Joggins constitute one of the world's most famous fossil sites (Scott & Calder, 1994), and tetrapods preserved within ancient tree boles provide a unique glimpse of Carboniferous palaeoecology (Carroll *et al.*, 1972; Milner, 1987).

Inland exposures are limited, subsea geology poorly known, and the basin's tectonic history has been long and complex; consequently, the precise relationship of the Joggins section to the tectonic framework is unclear (for example, its position with respect to hangingwalls and footwalls of the extensional basin). Palaeoflow in the Boss Point, Joggins and Springhill Mines Formations near Joggins was predominantly to the south-east and east (Rust *et al.*, 1984; Browne &

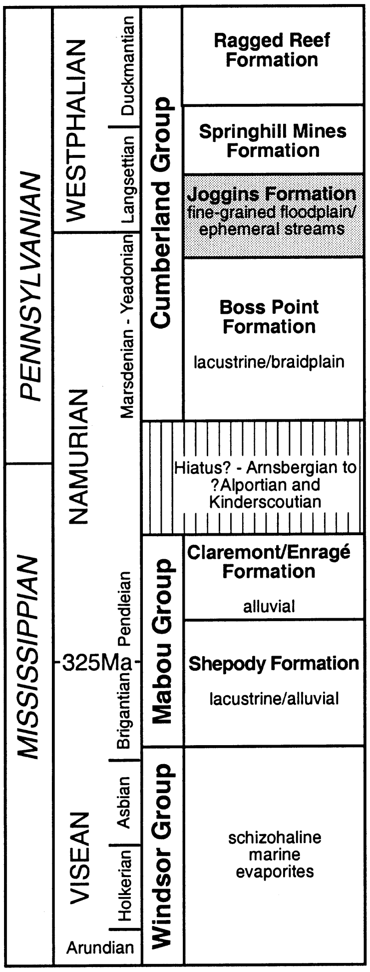

Fig. 2. Stratigraphy of the Cumberland Basin. The stratigraphy, palynostratigraphy and macroflora are currently under review.

Plint, 1994; Ryan & Boehner, 1994), suggesting source areas in the Caledonia Highlands and to the north of the Hastings fault.

Despite the significance of this succession, little detailed facies analysis of the Joggins Formation has been undertaken since the measurement of the first detailed sections (Logan, 1845; Dawson, 1854). More recent studies have investigated the cyclicity (Duff & Walton, 1973), selected palaeosols (Smith, 1991), trace fossils (Archer *et al.*, 1995) and the importance of wildfire on the floodplains (Falcon-Lang, 1999). This paper provides the first comprehensive stratigraphic analysis and sedimentological interpretation.

The Joggins Section

The exposed strata of the Joggins Formation dip ≈20° to the south (Fig. 3), and the 600 m thick measured section commences below the first coal horizon ≈600 m above the formation base (Fig. 4). The section was measured at the base of the cliff and logged at the cm-scale. Aerial photographs taken at low tide were used to match the sedimentological log to the wave-cut platform (Fig. 5), where the location and geometry of channel bodies within the finer floodplain sediments could be studied.

The measured section was divided into eight cycles (Figs 4 and 5), with boundaries at the level of major flooding surfaces. A thin coal is present at ≈32 m above the base of the measured section, but the base of cycle 1 is defined at the first coal/limestone interval at ≈ 60 m (Fig. 4). The inland extent of these cycles is not known, although economic coals have been traced inland for up to 40 km (Fig. 1). The strata can be divided into three facies assemblages: (1) open water; (2) poorly drained floodplain; and (3) well-drained floodplain, which tend to be superimposed in that order (Fig. 4). All three assemblages are arranged in relatively thin cycles at the base of the section (cycles 1–3), followed by a thick, predominantly redbed interval dominated by the well-drained floodplain assemblage (cycle 4). This cycle is capped by a thick interval of open water and poorly drained floodplain deposits (cycles 5–8), which contain the Fundy and Forty Brine Coals (Fig. 4).

OPEN-WATER FACIES ASSEMBLAGE

Description

Occurrences of the open-water assemblage extend from the base of a prominent limestone to above an uppermost sharp-based sandstone body (e.g. Fig. 7). The lower boundary is sharp and easily defined, but the upper boundary is more gradational from sandstones into siltstones. Cycles 1–8 (Fig. 4) begin with this facies assemblage, which ranges in thickness from 4 to 23 m. The assemblage represents only 14% of the succession but is very significant.

Fossiliferous limestones, which pass vertically into or are interbedded with fossiliferous siltstones, abruptly overlie several thick coals (Fig. 6). Common fauna include bivalves, ostracods, spirorbids, gastropods, fish, insects and arthropods (cuticles of crab-like organisms). Rare agglutinated foraminifera have been recorded in the fossiliferous siltstones (Archer *et al.*, 1995). *Curvirimula* and *Naiadites* are predominant bivalve genera (Duff & Walton, 1973; Calder,

Fig. 3. View of the Joggins section looking north towards the oldest part of the succession. The alternation of red and green intervals and the ≈20° dip of the succession are observed. Cliffs are ≈20 m high.

1998). A broad faunal acme may typically be followed by a sharp decrease in faunal abundance in some limestones but, in general, faunal abundance and relative proportions of bivalves, ostracods and plant debris vary non-systematically through these intervals. The thickest limestone interval at 570 m (Figs 4 and 6) contains fauna throughout 2·3 m of finely laminated limestones, carbonate-rich and organic-rich siltstones.

Siltstones typically overlie the basal limestone-rich intervals. In Fig. 7, a ≈4 m interval of claystone to coarse siltstone, with occasional sideritic nodules, is arranged in 1–1·5 m thick coarsening-upward packages. The grey and laminated ('platy-weathering') siltstones are generally less calcareous, have abundant drifted plant material and contain scattered bivalves or fauna-rich laminae. Layers commonly contain either bivalves or ostracods as the sole faunal element. No *in situ* vegetation has been observed in these limestones or overlying siltstones. Red siltstone layers are rare. Distinctive fine-grained sandstone units between these grey shales and overlying red mudstones (above 178 m; Fig. 7) have sharp, planar bases and distinct top surfaces (Figs 7 and 8). Low-angle planar surfaces within beds may also be present. The sandstones are interbedded with thin grey platy siltstones without fauna. Flute and groove casts are common on bed bases (Fig. 9A).

Climbing ripples and plane beds with primary current lineation are the dominant sedimentary structures in the sandstones, which have unidirectional flow patterns. At 572–574·5 m in cycle 8, unidirectional ripples are associated with mud drapes, some of which are paired. Soft-sediment deformation, including ball-and-pillow structures, is common, usually beneath the first sandstone bed (Fig. 10). The uppermost bed tops are wave rippled with some truncated ripples (Fig. 9B), and most bed tops are root penetrated. However, root systems rarely extend down more than 10–15 cm, are generally sparse and never completely destroy primary sedimentary structures.

In five examples, sandstone units comprise large-scale mounds that project upwards from the planar bases and can be traced laterally for 75–100 m (Figs 8 and 10). In some examples, mounds have an '*en echelon*' relationship. Some mounds show an upward change from unidirectional climbing ripples into hummocky cross-stratified sandstones (Fig. 7). Some sandstone unit tops are cut by shallow channels 10–50 m wide; palaeoflow from cross-lamination in channel fills and sandstone mounds is broadly coincident.

Delicate grazing and walking traces are preserved in the sandstones. The most extensively studied examples are in sandstone beds 13 m above the Forty Brine limestone, at 590 m,

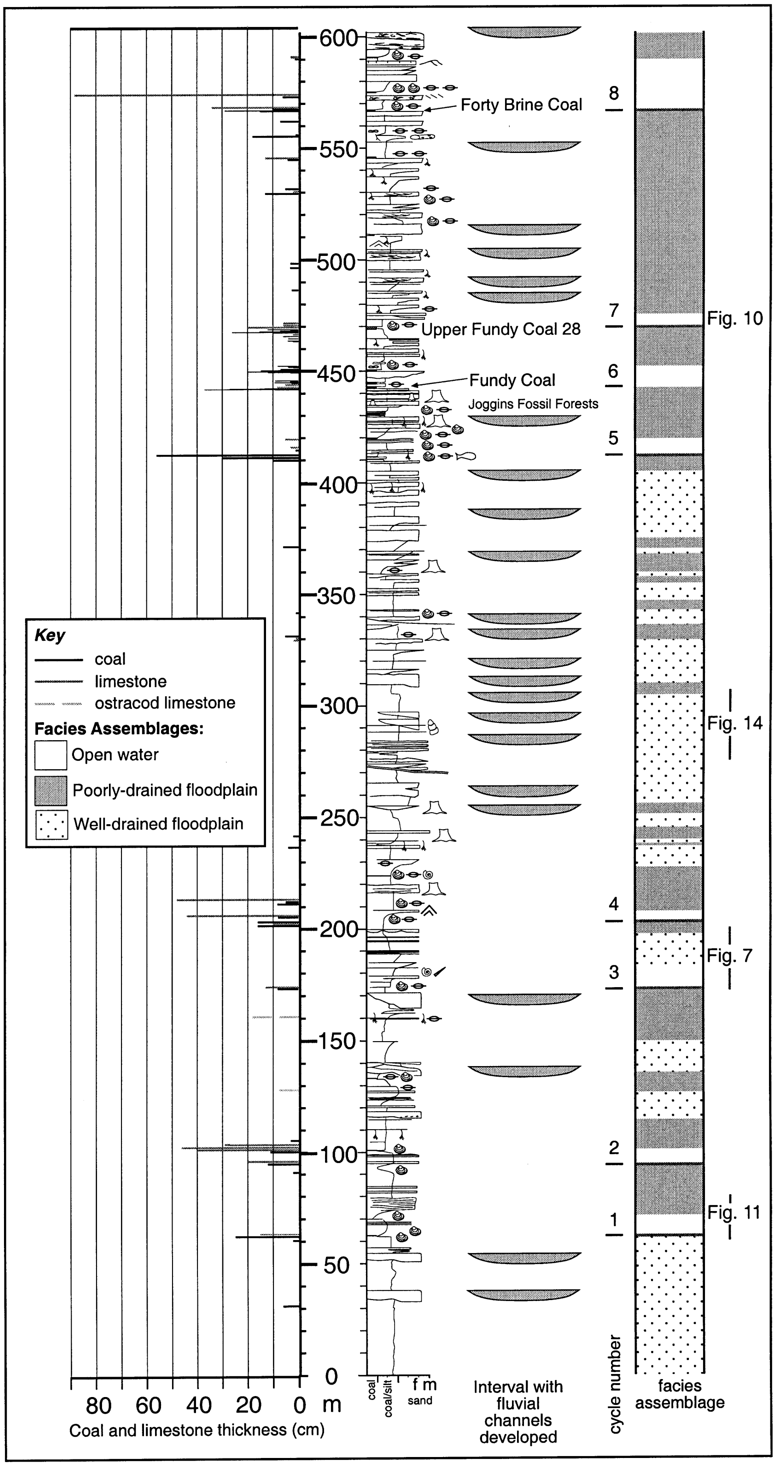

Fig. 4. Summary section through 600 m of the Joggins Formation. The section highlights the location and thickness of the coals and limestones, the distribution of channel bodies and the temporal organization of the three main facies assemblages.

co-occurring with foraminifera with coastal affinities (Archer *et al.*, 1995). Similar suites of trace fossils, always in association with the planar-bedded sandstones, have been recognized throughout the measured section. Vertical, possibly paired, burrows and horseshoe crab resting traces are also present. This distinctive trace fossil suite is unique to the open-water assemblage.

Interpretation

The open-water facies assemblage provides evidence for prolonged subaqueous deposition,

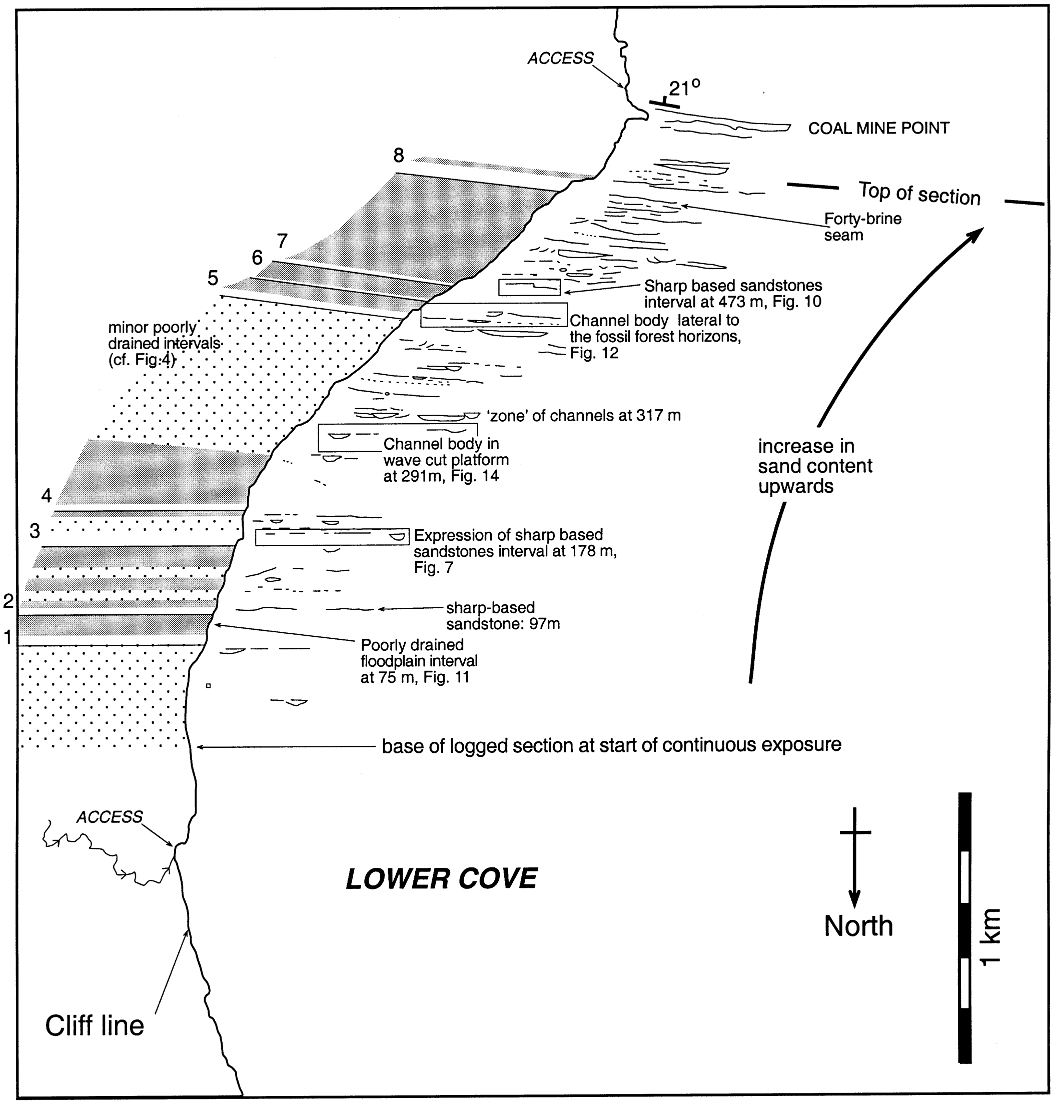

Fig. 5. Sketch of an aerial photograph. The figure illustrates the temporal and lateral distribution of the facies assemblages and the lateral distribution of the channels. Note that north is oriented towards the base of the figure, and the succession is younging to the south.

following a major transgression. Flooding commences with the basal coal overlain by fossiliferous limestone and platy siltstone. There is no evidence of ravinement, and hence flooding events rapidly but passively drowned the floodplains. Clastic supply was greatly reduced during deposition of the limestones, and the overlying coarsening-upward successions represent the re-establishment of clastic input and progradation of small ($\approx$ 75–100 m wide) sediment bodies into a standing body of water. The laminated character and absence of root systems, in contrast with other silt-dominated facies, suggest sufficient water depth to prevent the growth of standing vegetation.

The Joggins fauna and their association with floodplain clastic sediments have justified the inference of deposition in a freshwater setting (Gibling, 1995). However, *Curvirimula* could tolerate brackish water, and Duff & Walton (1973) proposed a marine influence during limestone formation. Recent descriptions of trace fossil assemblages, foraminifera and other faunal elements (Archer *et al.*, 1995; Calder, 1998) also suggest a distant marine connection without a fully open-marine setting being established. The open-water facies may have been deposited in a large, but restricted, body of brackish water, such as a marine gulf, that periodically developed within the relatively narrow Cumberland Basin.

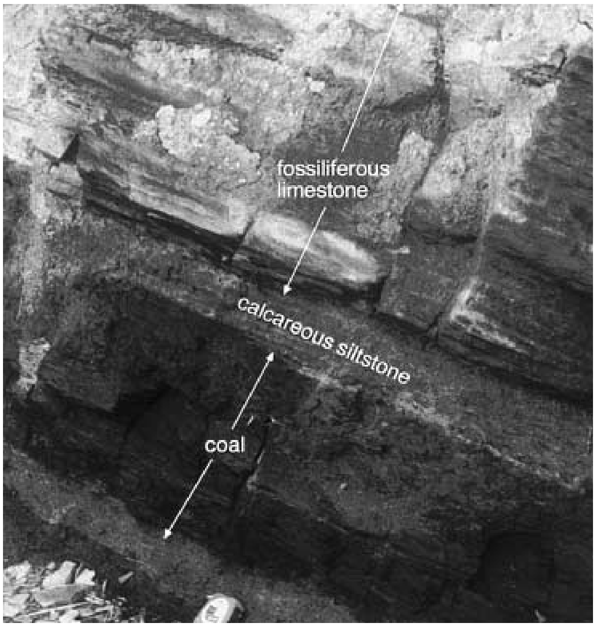

Fig. 6. Major flooding interval at 570 m. Coal is overlain by limestone and siltstone, which contains fauna throughout a 230 cm thickness. The fossiliferous limestones (see text for details) are brown weathering and are overlain by grey, laminated ('platy') siltstones containing less abundant fauna. Tape measure is 10 cm long.

Sandstone units with planar-based beds, unidirectional sole structures and low-angle mounds are restricted to this facies assemblage. Climbing ripples are commonly capped by wave ripples, and these sedimentary structures are indicative of deposition from unidirectional flows with subsequent wave reworking. The presence of occasional hummocky cross-stratification suggests some storm wave deposition or modification. Sharp-based sandstone beds represent the rapid emplacement of sand across an even surface by rapidly decelerating flows within a standing body of water several metres deep. Evidence for wave action only in the uppermost beds may imply that the water depth exceeded normal wave base, possibly only a few metres deep. The occurrence of truncated ripples and roots at the unit tops implies that the mounds built up into shallow water with at least periodic exposure. Poorly drained or well-drained floodplain deposits overlie the occurrences of the open-water facies assemblage.

The sandstone beds may reflect storms that transferred sediment from the bay shoreline further offshore in geostrophic flows. The range of structures observed could be attributed to the inherent variability associated with unsteady, waning combined flows. Deformation structures, including ball-and-pillow, can be generated by the passage of storm waves over water-saturated sediments. An alternative possibility is that river output generated hyperpycnal underflows that brought sediment out into deeper waters, where rapid waning gave rise to the climbing ripples. The abundance of large channel bodies in the overlying floodplain assemblages suggests that the mounds represent the fringes of small, river-generated delta lobes. This interpretation is consistent with prevailing unidirectional flow and minor wave reworking. Some sandstone unit tops are also cut by shallow channels that could represent parts of distributary systems. Ebb-tidal deltas are an unlikely setting in view of the great lateral extent of the mound-bearing units and apparent scarcity of channels and tidal structures (aside from rare paired mud drapes).

The sharp-based nature of the sandstones probably reflects abrupt switching of supply systems and rapid progradation of sediment bodies. However, some abrupt bases may indicate rapid change in level of the Joggins brackish bays driven by climate change, as documented for the Holocene evolution of the Volga Delta in the Caspian Sea (Kroonenberg *et al.*, 1997).

POORLY DRAINED FLOODPLAIN FACIES ASSEMBLAGE

Description

The poorly drained floodplain assemblage comprises 53% of the measured succession above the limestone horizon at 60 m (Fig. 4). This highly heterolithic assemblage comprises sand-poor and sand-rich packages (Figs 11 and 12). The sand-poor subgroup is predominant in the lower part of the succession, cycles 1–3. In cycle 4, strata of the poorly drained assemblage are interbedded with well-drained floodplain deposits and are represented by the sand-poor subgroup. The sand-rich subgroup is best developed in cycles 5–7 (Figs 4 and 12). An increase in sand content through the 600 m section can be observed in both the summary log (Fig. 4) and the aerial photograph (Fig. 5), even though the subgroups are intergradational, with sandstone bedsets and sand-filled channels observed to pass laterally into silt-rich successions. In cycle 1, sand-poor subgroup strata pass upwards into the sand-rich subgroup, which suggests a progradational trend over 11 m (Fig. 11).

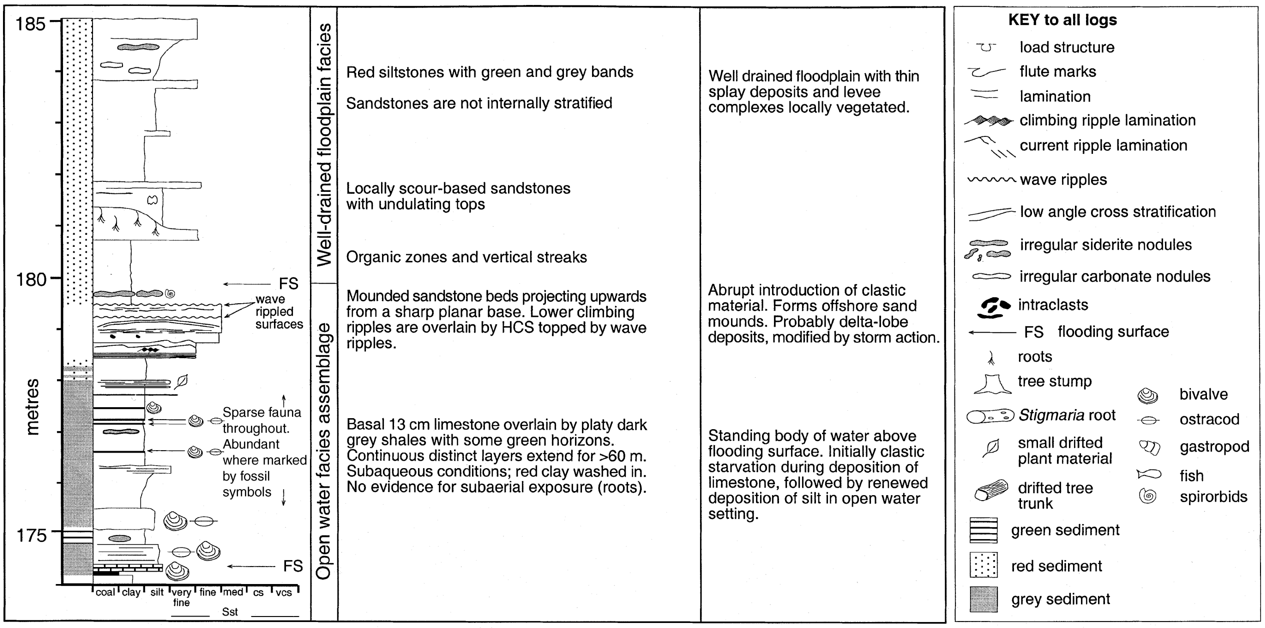

Fig. 7. Sedimentary log and interpretation through the open-water facies assemblage, 174 m to 180 m at the base of cycle 3.

Sand-poor subgroup

Silt-grade material is the dominant component in the sand-poor subgroup, and is interlayered with carbonaceous, organic-rich layers, nodular sideritic layers and 25–45 cm beds of fine-grained sandstone. The pervasive grey-green colour is a distinguishing feature. The siltstones are weakly stratified and contain abundant carbonized hair-like roots and predominantly sideritic rhizoconcretions. In cycle 1 (Fig. 11), platy siltstones above the main flooding surface at 70·5 m coarsen up into friable, blocky siltstones where vegetation has disrupted the lamination. Standing trees are commonly preserved as cryptic carbonaceous outlines. In other examples, the strata contain occasional thin limestone beds, rich in ostracods to the virtual exclusion of other fauna, and dark platy shales with a sparse ostracod and bivalve fauna.

Sandstone intervals are either laterally continuous horizons or form scour-based lenses encased in siltstone. Closely spaced sandstone beds are laterally highly variable, thinning and thickening over short distances, and many appear unstratified. Channel bodies are uncommon and are typically <5 m wide and <1 m thick.

Sand-rich subgroup

Sand-rich heterolithic packages, 1–8 m thick, are the major component of the subgroup (Fig. 12) with sandstone beds 30–80 cm thick. Lower and upper bed surfaces are generally gradational with interbedded siltstone, but can be sharp with scours up to 50 cm deep. Drifted plant debris, including trunks up to 1 m in length, is concentrated in the scours. These bedsets are commonly laterally equivalent to channel bodies 2–3 m thick and 10–50 m wide.

Standing vegetation is an important element of this subgroup. The root systems of erect lycopsid trees, up to 3 m high, and *Calamites* groves extend upwards from discrete siltstone layers below and within the sandstone units (Fig. 12). Trees are commonly associated with sandstone-filled hollows up to 1 m thick and up to 4 m in apparent width (Fig. 13). These hollows, which appear to be subcircular in plan view, are commonly developed around a single standing tree or lie between adjacent trees. The hollow fills can have planar cross-sets, up to 60 cm thick, which are either centroclinal or have a uniform foreset direction on both sides of a central tree, and pass up into climbing ripple-laminated sandstones. Low-relief mounds are also common features. These combined characteristics, termed here ‘scour-and-mound features’, range from small, isolated types, <1 m wide and a few tens of centimetres thick, to grouped sets and much larger features around the larger trees (Fig. 13).

Channel sandstone bodies are associated with the fossil forest intervals in the 425–450 m

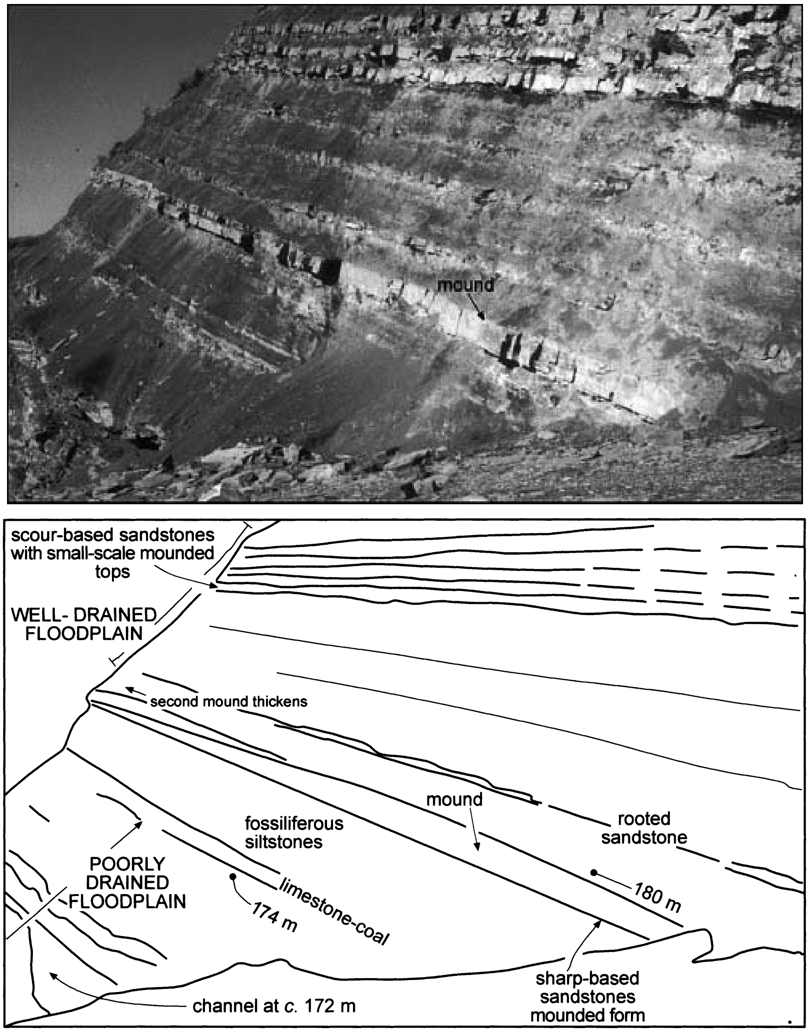

Fig. 8. Cliff exposure of the open-water facies assemblage in cycle 3 (174–180 m). Note the planar/sharp-based sandstone with mounded form (arrowed), which thins away from observer. A second mound thickens up-cliff. Contrast this geometry with the mounded forms above scoured base in the overlying well-drained floodplain association.

interval and elsewhere. They are consistently 2·5–3 m thick, 10–50 m wide and with apparent width to thickness ratios of 3:1 and 16:1 in two examples. Mudstone clasts and plant debris are associated with erosional basal and internal surfaces. Trough cross-stratified sandstones with set thicknesses of 10–30 cm pass up into ripple cross-lamination and overlie predominantly massive basal units. Less common planar cross-stratification is present with sets up to 40 cm thick. Some channel bodies have inclined surfaces associated with an undulose topography on their top surface, and others have sandstone 'wings', which thin laterally into floodplain deposits over 2–5 m.

The channel body at 600 m in the section (Fig. 4) is 8 m thick, thicker than any other in the poorly drained facies assemblage. The base of the channel body has 8 m of erosional relief, with one margin visible, and rests on grey mudstone containing root systems and erect trees. The body contains two superimposed storeys of fine- to medium-grained sandstone, has multiple internal erosion surfaces and abundant fragmental plant material. The channel body is overlain by a thick grey sandstone/mudstone interval that contains roots at some levels, but no coals (above the measured section depicted in Fig. 4).

Coals

Coals are an important component of the poorly drained floodplain assemblage and are thickest in cycles 5 and 6. A thick composite coal (Fig. 4, at 410 m; coal 32 of Logan, 1845) marks the boundary between redbed-dominated cycle 4 and cycles 5–7, dominated by poorly drained floodplain deposits. The composite coals, including the Fundy Seam and overlying coals (Fig. 4, 450 m and 470 m), comprise individual coal seams, 10–56 cm thick, that are separated by

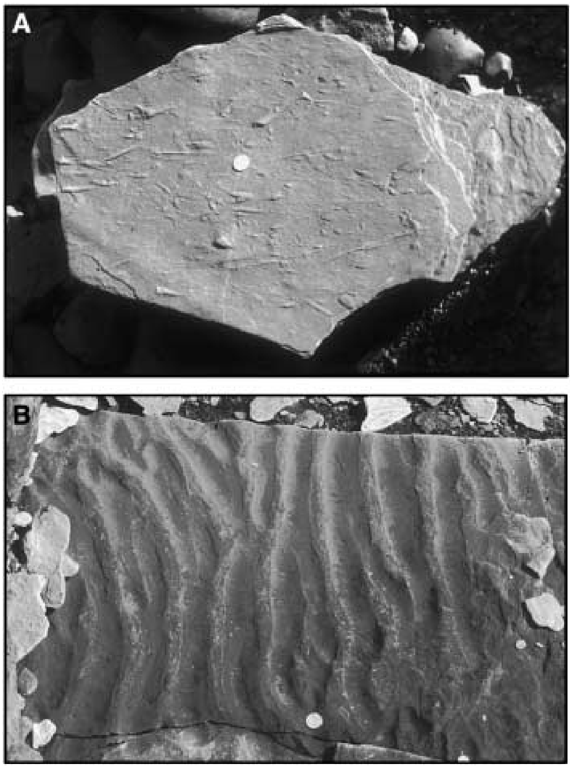

Fig. 9. (A) Groove and tool marks on the base of the sharp-based sandstone beds (cycle 3, 174–180 m). (B) Truncated ripples on top of sharp-based sandstone unit (cycle 3, 174–180 m).

clay layers. These coals are generally vitrinite rich, have high total sulphur (up to 13·7%) and high trace metal contents (Hower *et al.*, 2000). The Upper Fundy Seam (coal 28) is a high vitrinite coal in which arboreous lycopsid spores dominate spore assemblages. Generally, thinner coals are present in cycle 7, a characteristic consistent with the increased dominance of sand-rich lithofacies. The coal horizons become thicker where sand-rich and sand-poor floodplain associations are interbedded towards the top of cycle 7.

Interpretation

The sand-poor subgroup represents deposition in areas distant from major channels or accumulation during a period of low channel activity with a reduction in sand-grade sediment supply. Silt-grade material accumulated during repeated inundation of vegetated overbank areas when the channels were in flood, and the continuous sandstone layers may represent crevasse splay deposits with abrupt, and sometimes erosive, introduction of sand. Disruption by roots has generated some gradational bed boundaries and loss of stratification. Associated small channels are interpreted as crevasse channels. The ostracod-bearing limestones and sparsely fossiliferous siltstones are interpreted as the deposits of localized floodplain lakes. Standing water depths were not great enough to produce the typical open-water facies succession described previously and did not prevent substantial vegetation growth. Local clastic supply must have ceased for brief periods to generate laterally discontinuous limestone beds.

Channel bodies associated with the sand-rich subgroup are interpreted as fluvial channels or larger crevasse channels of low width: thickness ratio. Most were laterally stable with vertical accretion of sand, although some show a component of lateral accretion and the development of bank-attached bar systems. In some cases, channel 'wings' can be traced laterally into vegetated, scour-and-mound layers, indicating

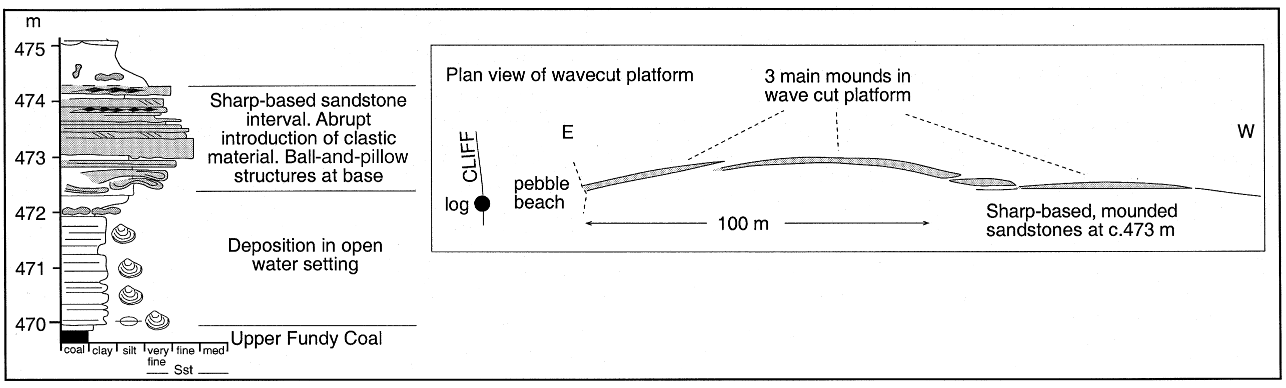

Fig. 10. Aerial view of the wave-cut platform expression of sharp-based, mounded sandstone bodies at 473–474 m and the equivalent cliff section presented as a graphic log. The introduction of sandstone is abrupt, and ball-and-pillow structures are present beneath the first sandstone bed. See text for discussion.

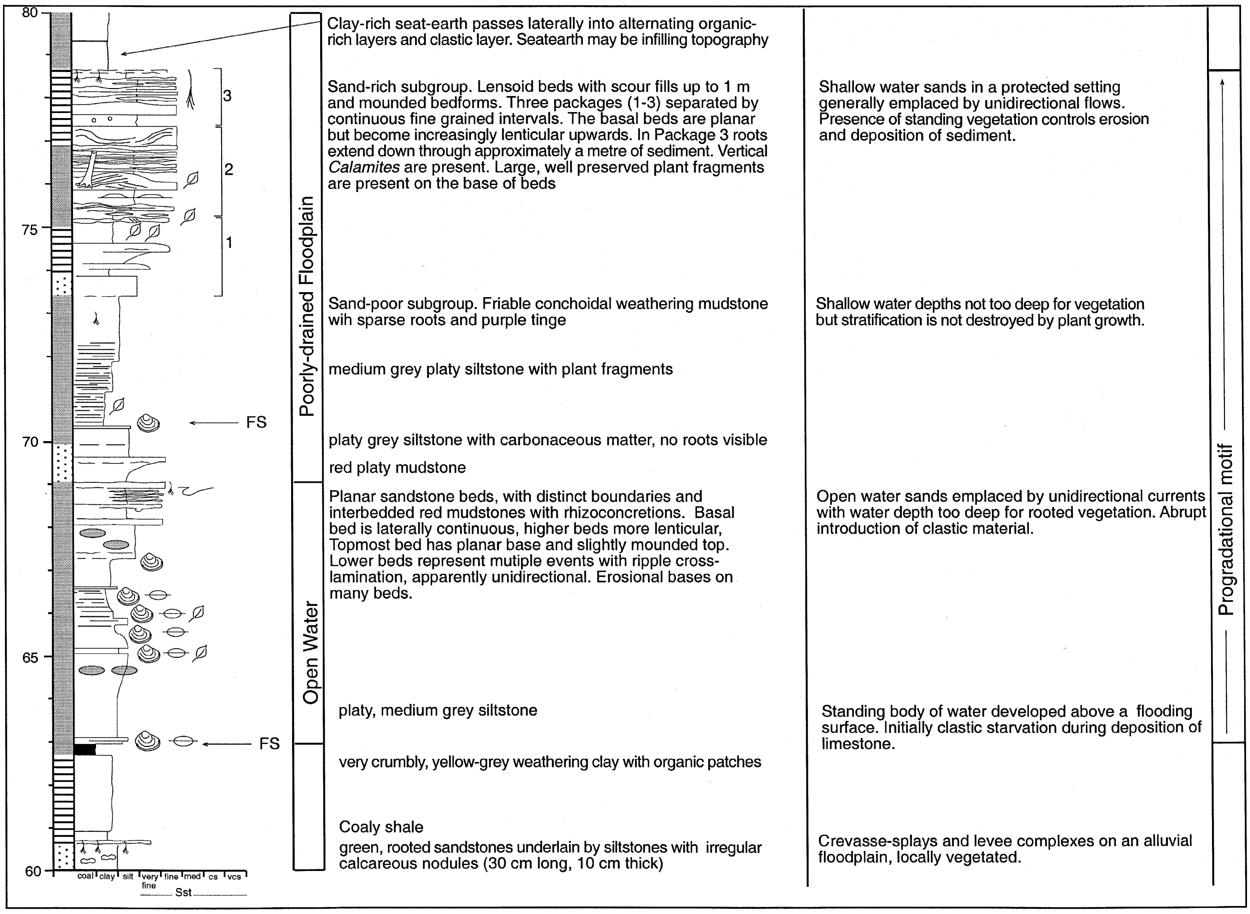

Fig. 11. Sedimentary log through the poorly drained facies assemblage, 60–80 m, cycle 1. See Fig. 7 for legend.

that overbank floods periodically inundated the lycopsid forests.

The channel body at 600 m represents a sand-bed river with periodic flows of strong erosive power, as indicated by the numerous erosion surfaces within storeys. It is the only body in the measured section that could mark an abrupt basinward shift in facies belts, as its fluvial style is more consistent with channel bodies in the well-drained floodplain assemblage than with those from the poorly drained floodplain assemblage within which it lies. However, the channel body is thin (8 m), relatively fine grained and is overlain by poorly drained floodplain deposits rather than the more proximal (well-drained) alluvial facies. Thus, there is no persuasive evidence for a basinward shift in facies at this level.

Sand-rich heterolithic units lie in close proximity to the large channels, which were the main drainage networks. Frequent river flood events scoured the floodplains and transported sand into bordering areas, entombing stands of trees, adjacent to which currents scoured out hollows and deposited mounds (vegetation shadows), resulting in the classic 'fossil forests' of the Joggins section. Unidirectional current indicators indicate fluvial-derived flows. Sedimentary structures preserved within many of these sandstones imply more or less continuous shallow-water cover that allowed some vegetation growth but prevented sufficient colonization to destroy stratification. The scour-and-mound features recorded within the floodplain sediments of the Joggins Formation are similar to modern obstacle marks associated with mature trees observed in the Burdekin River, Australia (Nakayama *et al.*, 2002).

Coals testify to periodic thick peat accumulation, typically as bayfills were drowned. Some precursor peats were formed as rheotrophic mires (Calder, 1994, 1998; Hower *et al.*, 2000). The coal beds at Joggins contain evidence for recurring wildfires, such as fossil charcoal (fusain), which suggests that the peatlands had to tolerate drier periods and were fed by groundwater flow during these conditions (Calder, 1994). The sulphurous character of the coals

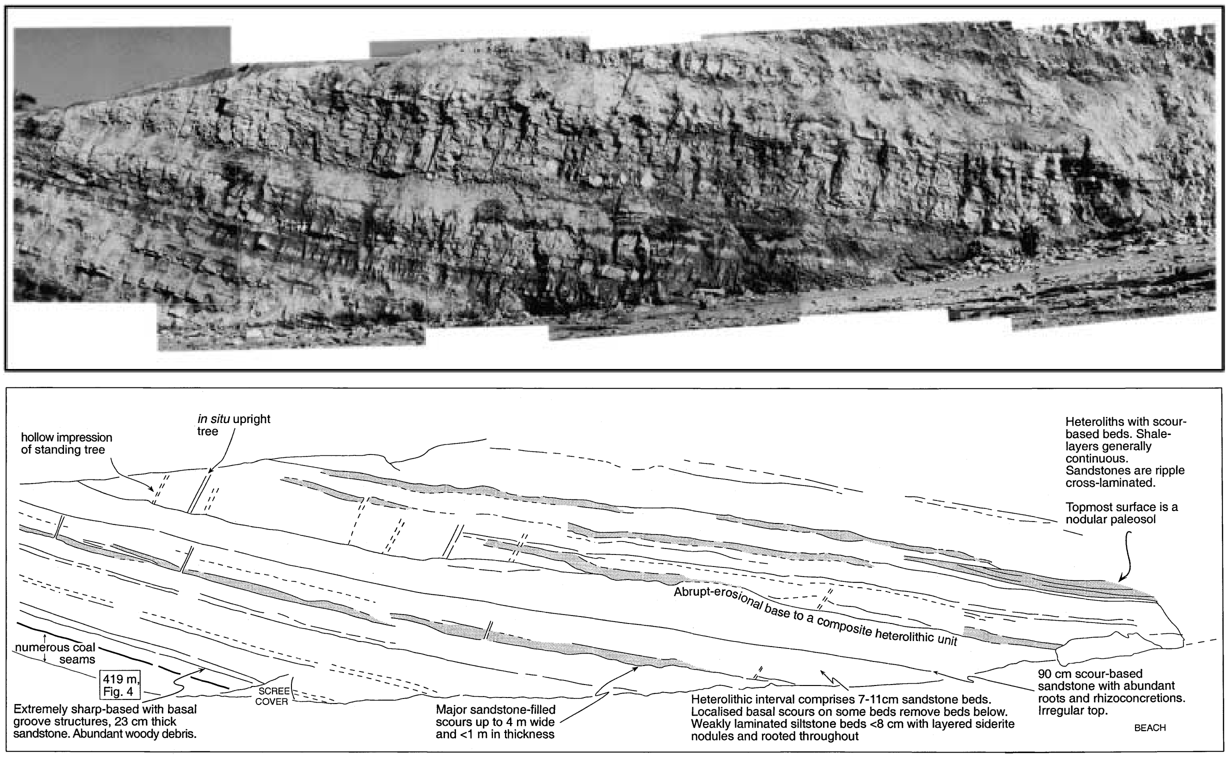

Fig. 12. Cliff exposure of an example of the poorly drained facies assemblage, 405–455 m, including the two main fossil forest horizons.

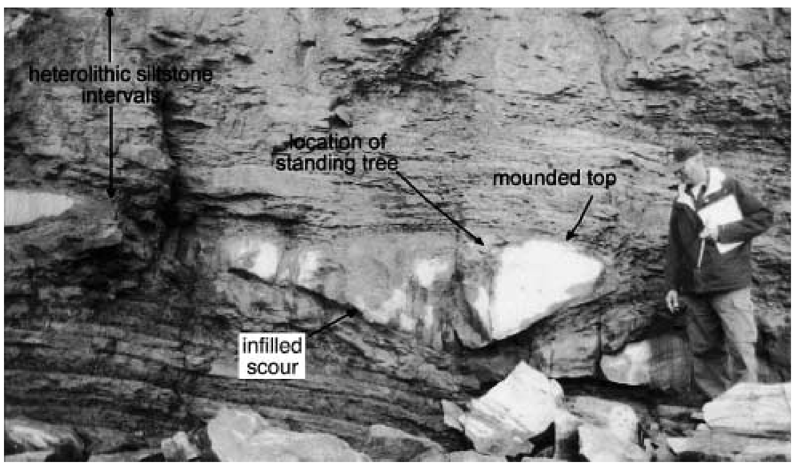

Fig. 13. Scour-and-mound feature around a large tree at 435 m, cycle 5 (equivalent to the upper forest horizon of Fig. 12).

suggests that some swamps were saline influenced (cf. Petersen *et al.*, 1998).

The poorly drained floodplain assemblage is interpreted as a coastal wetland or deltaic plain with shallow lakes that were infilled by channel systems. Similar facies are present on the Mississippi Delta plain (Tye & Coleman, 1989a,b; Koster & Suter, 1993), where abundant lakes on the upper delta plain are filled by minor deltas. A similar tropical wetland system is present in the Upper Nile at 5–9°N (Rzoska, 1974), where an extensive area is submerged seasonally by increased rainfall and overbank spill from rivers in flood. At maximum river-flood levels, only ridges a few metres in height are not submerged. In the dry season, evaporation exceeds water supply, and the area dries out, starting with the margins of the flooded area and progressing towards the main rivers and their associated swamps; some smaller rivers dry up completely. The Upper Nile region has temporary and permanent swamps that expand and contract seasonally. Evidence from the open-water facies assemblage, including sulphurous coals and some fauna, suggests that water table rise and flooding during floodplain deposition could also have been driven by relative sea-level rise as well as by seasonal changes in precipitation.

WELL-DRAINED FLOODPLAIN FACIES ASSEMBLAGE

Description

The well-drained facies assemblage comprises 33% of the measured succession from the base of cycle 1. The key diagnostic criteria are a red colour, absence of coal, common presence of calcareous nodules as opposed to sideritic nodules and fluvial systems that include multichannel styles. Thin poorly drained intervals within well-drained floodplain deposits are identified by their grey-green colour, abundance of carbonized rootlets and presence of sideritic nodules. The red coloration is interpreted as a primary feature because many red strata have the characteristics of oxidized palaeosols and because distinct layers of reworked red siltstone clasts are found locally within the open-water facies assemblage (Fig. 7).

Red siltstones, typically in units several metres thick interbedded with thin sandstones, dominate this facies assemblage. The siltstones have a blocky appearance and contain centimetre-thick grey bands and vertical dark streaks. Calcareous nodules, up to tens of centimetres in size, are exclusive to this facies association; nodules are scattered within siltstones or more rarely form layers, but never approach the density of a petrocalcic horizon. Standing trees are apparently uncommon, but this may be a preservation artifact because trees are preserved as outlines in the siltstone intervals.

Heterolithic packages comprising red blocky siltstone interbedded with thin (2–5 cm) to medium (20–35 cm) bedded sandstone are a subordinate component (Fig. 14). These packages can be up to 12 m thick and comprise 80–90% sandstone (Fig. 15). The sandstone beds generally have undulose, scoured bases, are diffusely stratified internally, and the packages are continuous across the cliff and wave-cut platform. In some cases, packages thin markedly away from associated channel bodies and show inclined surfaces that dip in the direction of tapering. Carbonized rootlets are common at some horizons (Fig. 14). Tetrapod footprints are common on the upper surfaces of these sandstone beds.

Lenticular, single-storey channel bodies 1–1·5 m thick and 2–3 m wide (Fig. 15) erosionally overlie heterolithic sandstone packages. Channels occur within or cut down from the top of packages and comprise mainly fine- to very fine-grained sandstone, passing up into siltstone or heterolithic strata. Low-angle accretion surfaces are a common feature. In several cases, a series of channel bodies is positioned at precisely the same stratigraphic level in the cliff face and shows a semi-regular spacing of ≈ 50 m.

Large, multistorey channels 3–6 m thick with incised margins are prominent in the section below cycle 1 and in cycles 2 and 4. In cycle 4, ‘zones’ of channels occur (Fig. 15 at 290–295 m, and examples at 317 m, 314·5 m, 325 m, 335–340 m and 400–405 m, Fig. 4). The channel body at 311·5–314·5 m is ≈ 2 m thick. The lower storey is 0·6–1·5 m thick and has a heterolithic fill with thin sandstone beds. Planar-laminated beds with primary current lineation pass upwards into beds with ripple cross-lamination. The upper storey has a grooved, erosional base, millimetre-sized plant fragments and a structureless sandstone fill. A second channel erodes into floodplain sediments from a slightly higher stratigraphic level. A channel zone at 317 m in the wave-cut platform comprises four channel bodies (located on Fig. 5). The maximum erosional relief associated with these channels is 6 m, and the fills vary from silt dominated to sand dominated (Fig. 15).

Calamites in growth position was observed within several channel bodies. *Stigmaria* root systems are also present on the margins of some channel bodies. Reptile bones (including the pelvic girdle of a 1·5 m long reptile), gastropods, *Arthropleura* trackways (*Diplichnites*) and large shells of the unionid-like bivalve *Archanodon westoni* are locally found in association with the channel sandstones (296 m, Fig. 14; Calder, 2000). The well-drained floodplain assemblage contains abundant *Cordaites* and a higher proportion of plant material in the form of charcoal than is observed in the grey, poorly drained floodplain assemblage (Falcon-Lang, 1999, 2000).

The lateral equivalents of some channel bodies (e.g. at 317 m and 336 m) are heavily root-penetrated, 50–70 cm thick sandstone intervals with groups of low-relief, scour-based sandstone mounds that pass laterally into isolated mounds. These scour-and-mound features are similar to those described from the poorly drained facies assemblage. Although erect trees are rarely preserved, evidence for standing vegetation associ-

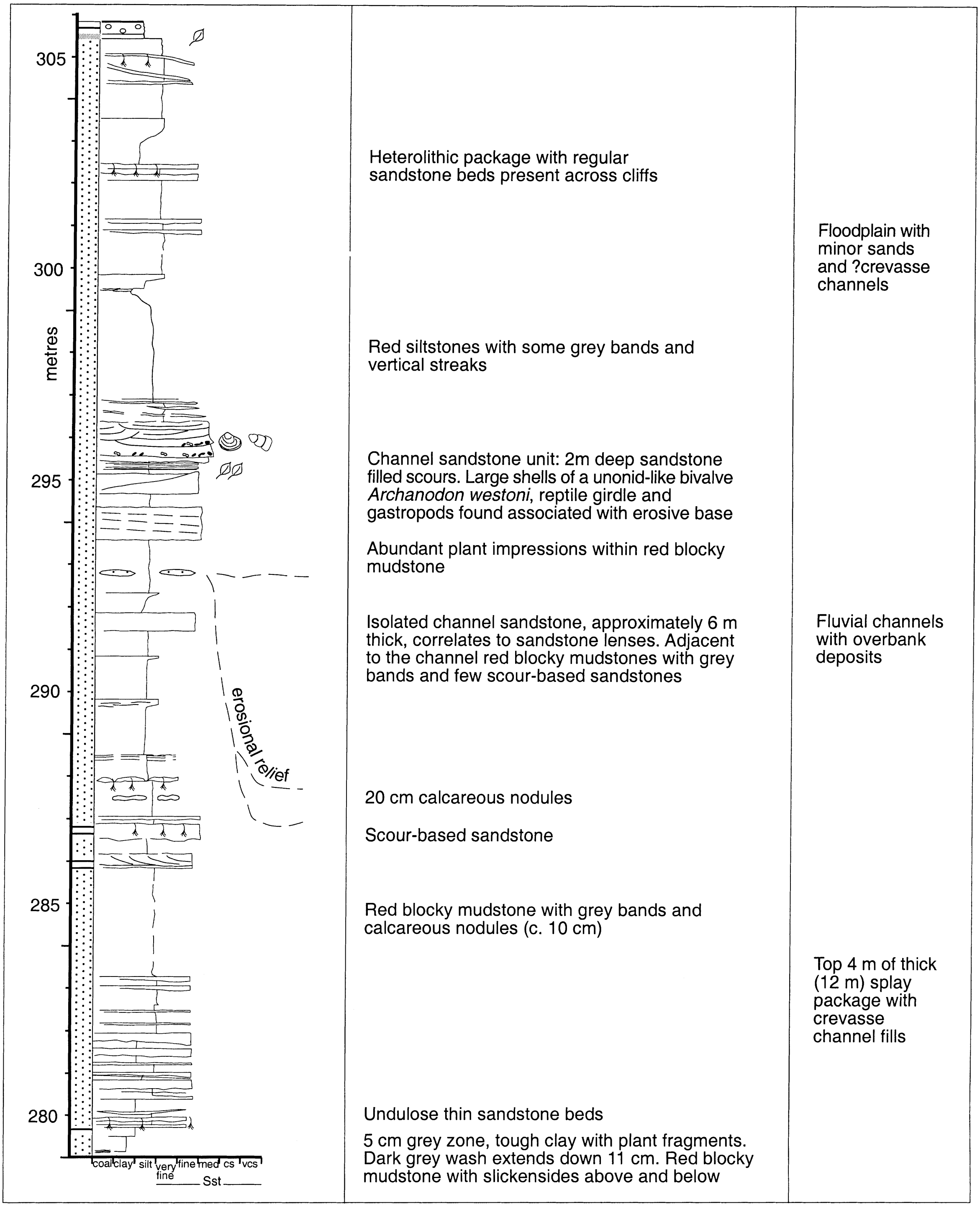

Fig. 14. Sedimentary log through an example of the well-drained facies assemblage illustrating the succession in cycle 4 (279–306 m). See Fig. 7 for legend.

ated with these mounds includes dense root systems, irregular scouring and distorted stratification. Climbing ripple lamination is the predominant sedimentary structure where stratification is visible.

Interpretation

The presence of standing trees in some siltstones implies that water was available for vegetation growth, but the absence of coals

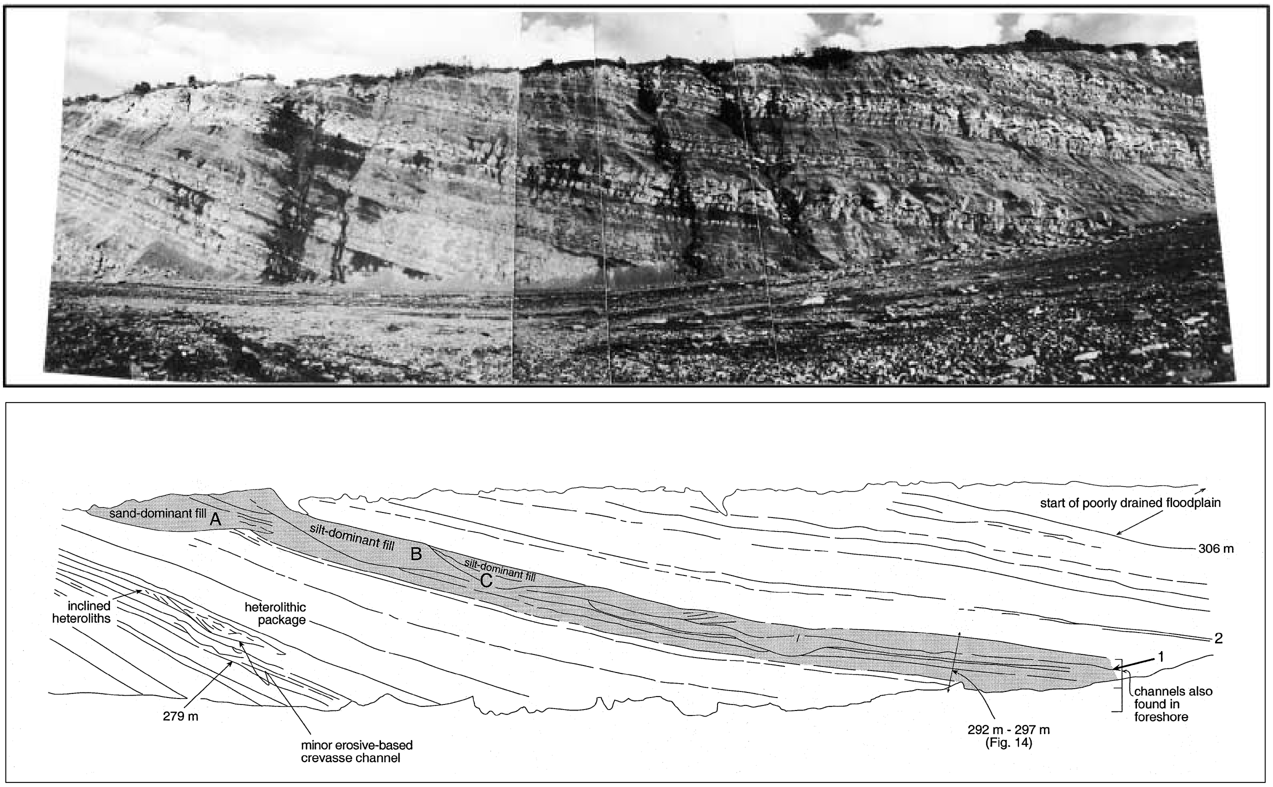

Fig. 15. Cliff exposure of the well-drained facies association illustrating the succession between 279 and 306 m. Note the lateral occurrence of the channels and their contrasting fills (A–C) of both sandstone and siltstone.

implies that the water table remained low throughout deposition of this facies assemblage. The presence of calcareous nodules and the red coloration of the sediment also suggest improved drainage.

The presence of numerous, small channel bodies at the same level suggests the presence of multiple-channel (anastomosed) fluvial systems. The larger, multistorey bodies suggest channel amalgamation in zones where channels were more closely spaced or that channels later reoccupied the same floodplain area. In the redbed intervals below the base of cycle 1 and within cycle 2, multistorey channel sandstone bodies lie within valleys with greater relief than that associated with individual channels; however, these bodies lie entirely within redbeds, and there is no evidence that incision was linked to base-level lowering. The presence of *in situ* vegetation, invertebrates and vertebrate bones and trackways in channel sandstones imply that the channels were important waterholes, perhaps supporting life during drier periods.

The heterolithic packages are interpreted as splay deposits and levees with sediment transported either via the small channels or from sheetfloods overtopping the main fluvial channels. Levee deposits are represented by heterolithic packages (Figs 14 and 15) with low-angle inclined stratification that thins away from channel bodies. Some small single-storey channel bodies associated with heterolithic packages probably represent crevasse channels through which sediment was supplied to the floodplain.

These interpretations are essentially similar to those of Rust *et al.* (1984), who interpreted the younger Springhill Mines Formation, south of the Joggins Formation measured section, as deposits of anastomosed rivers. The alternation of red and green floodplain intervals (especially on a scale of metres to tens of metres in cycle 4) may reflect changes in the climate and groundwater level at the site of deposition. In the UK Westphalian, however, the existence of redbed successions deposited contemporaneously with coal-bearing strata demonstrates that redbeds could form in humid-tropical climates and that variations in drainage were related to both differential subsidence and facies progradation (Besly & Fielding, 1989). The alternation of the red and green intervals at Joggins could have resulted from subtle changes in the subsidence rate, relative to the rate of sediment supply, producing sustained changes in water table levels.

EVIDENCE FOR FLOODING

The Joggins Formation contains several important facies that indicate drowning of the low-lying floodplain (Table 1). Flooding surfaces are defined as horizons where open-water sediments overlie alluvial floodplain sediments and also horizons, marked by colour and textural changes in palaeosols, that reflect movement of the groundwater table. Rising groundwater tables would not necessarily have caused prolonged submergence of the floodplain, but evidence of a significant rise in the groundwater table is considered to be evidence for flooding. All flooding surfaces can be traced from the cliffs across the wave-cut platform, extending for at least 500 m.

Coal/limestone packages with mined coals, for example the Forty Brine coal and associated limestone (Fig. 1), can be traced for tens of kilometres inland (Copeland, 1959) and hence represent relatively extensive flooding events. Therefore, surfaces that underlie coal and fossiliferous limestone/siltstone intervals and constitute cycle boundaries are interpreted as major flooding surfaces (Fig. 4). These coal, fossiliferous limestone and siltstone and platy, plant-rich siltstone intervals represent flooding events that produced open bodies of standing water sufficiently deep to prevent the growth of standing vegetation.

A suite of minor flooding events is also evident (Table 1). Nodular, massive ostracod-rich limestones are present at two levels (128 m, 160 m, Fig. 4) and show intensive colonization by vegetation, including organic-lined roots and larger *Stigmaria* root systems which, along with lateral thickness variations, distinguish these horizons from the limestones described previously. These limestones are interpreted as palustrine deposits formed in localized floodplain lakes. The infill of these small lakes by sediment deposition enabled rapid colonization by plants.

Rising base level is also recorded by three other lithological changes. First, layer-parallel grey-green bands are commonly observed within the well-drained floodplain assemblage where the drab coloration extends into underlying red sediments. These horizons are interpreted to represent a rise in the water table, possibly driven by a base-level rise down depositional dip or by periods of increased precipitation and local ponding, enabling preservation of organic matter. A link to base level is supported in many instances by the progressive increase in spacing of grey horizons upwards within red intervals with distance from the underlying grey packages. Some may represent the organic epipedons of soil horizons. Secondly, pronounced upward changes are noted from red or grey, homogeneous siltstone with an irregular fracture character into grey platy siltstones, similar to those found above limestone horizons, but lacking fauna and flora. Thirdly, thin coals, generally <10 cm thick but always <20 cm, are present throughout the formation and even occur within the redbed-dominated cycle 4 where they are 2–6 cm thick (Fig. 4). These thin coals are not associated with fossiliferous siltstones or limestone, unlike the thicker coal intervals.

The prominence of major flooding lithologies varies through the section. In cycles 1 to the base of cycle 4, limestones are well developed and associated with thin coals (Fig. 4). In cycle 4 (205–410 m), coals are thin (2–6 cm) and limestones rare (330 m; Fig. 4). Fossiliferous limestone and siltstones are interbedded with the well-developed fossil forests in cycles 5 and 6 (400–470 m), and coal seams form composite units up to 1 m thick. Both fauna and coal seams are uncommon in the poorly drained sand-rich floodplain deposits in cycle 7 (470–525 m) but, above 515 m, thin coals and fossiliferous siltstone horizons reappear. The thickest limestones occur in cycles 7 and 8 and, most significantly, no standing vegetation is associated with the sandstone and siltstone deposits overlying these thick limestones. The only coal present probably originated from drifted plants.

PALAEOSOLS

Smith (1991) documented the macro- and micromorphology of palaeosols in five intervals of the Joggins section between Lower Cove and Ragged Reef. Although only one interval lies in this studied section, Smith (1991) noted that his pedogenetic associations are representative of the Joggins section as a whole.

The well-drained floodplain assemblage includes variegated red mudstones up to 1·8 m thick, associated with thin sandstones that show a modest degree of horizonation. Many profiles

Table 1. Summary of the types of flooding surfaces present in the Joggins Formation.

Flooding surface expression	Characteristics	Interpretation	Example in Fig. 4
Major surfaces and beds			
Coal	Thick coal or aggregated coal beds overlain by fossiliferous limestone or fossiliferous shale. Actively mined across the Cumberland Basin	Rheotrophic mires representing the onset of flooding	63 m, 100 m, 174·2 m, 205 m, 470 m, 567 m
Fossiliferous limestone and siltstone	Dark grey-black, laminated limestone with abundant fauna commonly overlain or interstratified with fossiliferous siltstone. Generally sharp contact with underlying coal. Fauna includes ostracods, bivalves (*Curvirimula* and *Naiadites*), gastropods and spirorbids. Rare fish bones, shark spines and agglutinated foraminfera.	Major flooding events leading to development of a standing water body. Restricted clastic sediment supply	63 m, 100 m, 174·2 m, 205 m, 470 m, 567 m
Plant-rich siltstone	Laminated or platy-weathering siltstone contains plant fragments and some fauna, usually present above a coal or fossiliferous limestone/siltstone	Development of a standing water body and continued/ renewal of clastic supply	176·50–177·5 m
Minor surfaces and beds			
Ostracod limestone	Not associated with coal, contains abundant ostracods, other fauna is rare. Abundant plant fragments, organic lined roots and common *Stigmaria*	Palustrine deposit, probably of limited extent compared with the fossiliferous limestones	127 m, 161 m
Grey band	Thin horizons within red siltstones; may have some associated topography, with drab zones extending down into underlying sediment	Rise in groundwater level or brief submergence of floodplain; prevents oxidation of overbank sediments	275 m
Siltstone character change	Abrupt change from homogeneous ('chippy') red or grey siltstone with or without clear roots, to grey, laminated ('platy') siltstone	More sustained rise in groundwater level that may wholly or partially submerge the flooplain	
Coal	Thin, stratigraphically 'isolated' coal, no association with faunal limestone or faunal shale	More sustained rise in groundwater level that may wholly or partially submerge the flooplain	237 m, 242 m, 342 m, 372 m

have a continuous, sharply defined grey colour band near the top, representing an organic epipedon or O horizon, although (as noted above) some may represent oscillations of the water table. Blocky peds increase in size downwards, and drab mottles, locally associated with carbonaceous roots, decrease in abundance downwards; these trends imply a decreased intensity of pedogenesis lower in the profiles. Oriented plasma fabrics (mainly masepic, vosepic and omnisepic fabrics: Brewer, 1976) are present locally. Translocation of clay and other materials to lower levels is indicated by cutans of varied composition (argillans, calcans, ferrans), some in root channels. Microcrystalline calcite nodules are present at lower levels of many profiles, and some contain gastropod and plant fragments, sparite fracture fills and manganiferous coatings. The calcite nodules are scattered in distinct horizons but were not observed to form an intergrown, petrocalcic horizon anywhere in the Joggins section; they thus correspond to the Stage II calcic accumulations of Machette (1985). The variegated mudstone layers pass down gradationally into red mudstones with relict bedding defined by discontinuous siltstone and organic-rich layers. Clay types are mainly illite (locally interstratified with vermiculite and smectite), kaolinite (generally more common in the upper parts of profiles) and minor chlorite. Smith (1991) suggested that the illite and chlorite were inherited from source areas and that illite was modified during soil formation to kaolinite and some 2:1 mixed-layer clays, although the effects of subsequent diagenesis on the clays cannot be ruled out. Smith (1991) identified these palaeosols as alfisol-like soils (Soil Survey Staff, 1975) of moderate maturity, formed under warm, dry and oxidizing conditions. Associated incipient sandy palaeosols have roots but few other indications of pedogenesis, and Smith (1991) classified these as immature soils of entisol type, the development of which had been inhibited by frequent flooding events. No more evolved redbed palaeosols (*sensu* Besly & Fielding, 1989) with haematite concretions, suggesting tropical leaching, were recognized.

The poorly drained facies assemblage and rare pedogenic zones within the open-water facies assemblage are characterized by grey mudstones associated with coals and carbonaceous shales. The mudstones have drab mottles, carbonaceous roots and siderite nodules. Plasma fabrics are mainly unoriented or weakly laminated. Some prominent grey mudstones ('underclays') overlain by coals have a blocky to massive structure and abundant slickensides associated with carbonaceous roots. Siderite and siderite/calcite root casts are common, and some small root traces have manganiferous coatings. Smith (1991) interpreted the mudstones as inceptisol-like soils with organic-rich epipedons. They developed under frequently saturated conditions and a periodically emergent water table, and siderite nodule layers may represent the temporary water table. Coals that overlie the mudstones may represent in part the A horizon of an underlying gley soil, as well as a subsequently formed histosol, and some pedogenetic features of the mudstones may have formed under a peat cover. These poorly drained palaeosol associations may be examples of two superimposed soils formed under conditions of rising groundwater level (Gardner *et al*., 1988). These soils are very similar to immature palaeosols recognized from the UK Westphalian record, where horizonation features were absent and *Stigmaria* roots and siderite nodules were common throughout (Besly & Fielding, 1989). These immature soils were considered as characteristic of incomplete surface drainage and form in water depths of <1 m.

In general, palaeosols in the Joggins measured section are immature and cumulative, resulting in incipient profile development. Soil morphological features suggest formation under warm, relatively humid conditions, with indications of seasonal dryness in redbed intervals. Significantly, Smith (1991) did not identify highly mature palaeosols within the Joggins section. In other Carboniferous successions, mature palaeosols are recognized within generally poorly drained successions (e.g. Percival, 1983). Such palaeosols can represent regionally extensive surfaces (interfluves) that may correlate laterally with valley systems and may be used as evidence for a significant base-level fall (Hampson *et al*., 1997). Interfluve palaeosols initially developed under freely drained conditions may also become gleyed during transgression in response to rising water tables, as observed in Carboniferous palaeosols from the US Appalachian basin (Aitken & Flint, 1996), but this type of modification was not recognized in Joggins Formation palaeosols.

STRATIGRAPHIC ARCHITECTURE

The most distinctive architectural feature of the measured Joggins section is the presence of large-scale cycles, mainly 30–100 m thick, that commence with prominent flooding surfaces marked by coal, fossiliferous limestone/siltstone and plant-rich siltstone (Table 1; Fig. 4). This pattern of cyclic organization commences with the limestone at the base of cycle 1 (60 m position), above which the motif of alternating open-water, poorly drained and well-drained floodplain assemblages is developed. The cycles contain many additional, minor flooding surfaces that divide the cycles into thinner units. The flooding surfaces are sharp but not erosive, and the absence of ravinement surfaces implies low-energy flooding. Wave energy was sufficient to generate wave ripples and occasional hummocky cross-stratification in the open-water facies at cycle bases, although water depths are not known.

Stratal intervals between the flooding surfaces are generally a few metres thick and are parasequences (*sensu* Van Wagoner *et al.*, 1988), representing the filling of water bodies that varied from the relatively deep brackish water bodies of the open-water assemblage to shallow and virtually emergent conditions in the floodplain assemblages. Figures 7, 10, 11 and 14 illustrate examples of each assemblage. Parasequences cannot readily be identified in most of the well-drained floodplain assemblage, in which many of the recorded 'events' represent channel-derived splays linked to transient floods. Cycles 1–3 and 5–8 comprise one or more parasequence sets with predominant progradational and aggradational patterns and minor retrogradational intervals, as shown in the base-level curve in Fig. 16. Cycle 4, 210 m thick, comprises an aggradational succession of predominantly well-drained floodplain strata with relatively few flooding surfaces indicative of sustained base-level rise. A weak retrogradational trend is identified towards the top of cycle 4, where flooding surfaces increase in abundance and become more closely spaced.

Major relief at the base of multistorey systems and the presence of mature interfluve palaeosols are commonly considered to be strong evidence for significant base-level falls and the presence of sequence boundaries (Van Wagoner *et al.*, 1988). Neither feature has been identified in the measured section at Joggins. Channel bodies in the Joggins Formation are <9 m thick, single to multistorey, and their sandstones are fine to medium grained without extrabasinal gravel. In nearly all cases, they can be interpreted as an integral part of the associated floodplain deposits, and there is no evidence that they mark major basinward facies shifts. The one possible exception is the channel body at 600 m but, even here, the evidence is equivocal. Although sharp bases to the sandstone bodies of the open-water assemblage may indicate a modest fall in relative base level (cf. Plint, 1988), other explanations are possible (see interpretation of the open-water facies). Palaeosols throughout the section are cumulative and immature. The 600 m measured

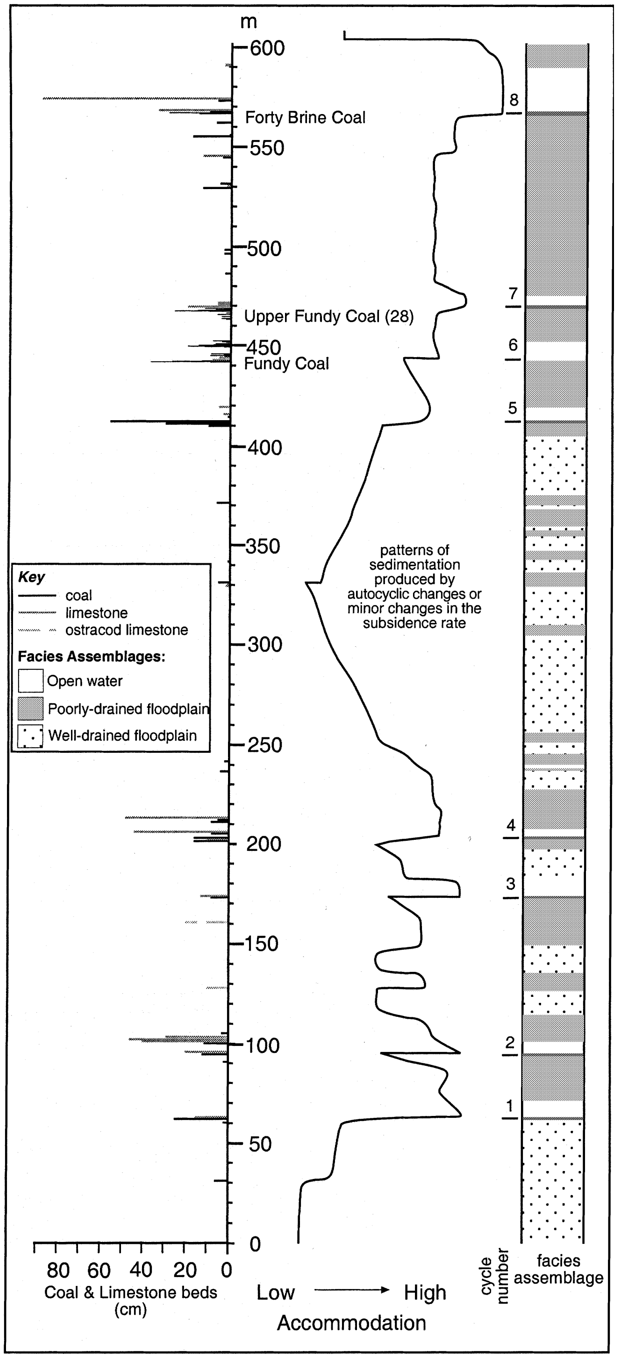

Fig. 16. A curve illustrating changes in the accommodation generation through the 600 m of the Joggins Formation.

Joggins section does not contain sequences of Exxon type, marked by prominent sequence boundaries and divisible into systems tracts. This is more remarkable because the facies spectrum (open water, coastal to alluvial plain) is especially well suited to the development of subaerial unconformities and mature soils as a consequence of base-level change. Instead, the Joggins section illustrates an architectural style dominated by alternate events of base-level rise and infilling through a great stratal thickness, representing the repeated creation of modest amounts of accommodation.

The architectural style observed in the Joggins Formation is interpreted as a tectonic signature that is likely to characterize high-accommodation basins that subsided rapidly along bounding faults. Rapid Namurian to early Westphalian subsidence in the broadly extensional Cumberland Basin generated large amounts of accommodation, and could have prevented the development of subaerial unconformities. Accommodation was probably generated in small increments as the basin floor subsided through motion on the bounding faults, promoting the accumulation of stacked parasequences. High-frequency episodes of activity on fault segments are common in extensional basins (Gawthorpe *et al.*, 1994; Morley *et al.*, 2000) and provide a possible explanation for the Joggins parasequence sets and cycles; unfortunately, no accurate time constraints can currently be applied to these stratigraphic units. Sediment supply to the Cumberland Basin appears to have kept pace with the rapid subsidence rates for significant periods, generally maintaining the Joggins area in a coastal depositional setting. The depositional framework for the Joggins Formation is comparable to the 'accretionary transgression' of Helland-Hansen & Gjelberg (1994), where the rates of sediment supply and accommodation generation are virtually balanced. Helland-Hansen (1995) noted that hiatuses might be uncommon in supply-controlled settings with high subsidence rates.

A similar architectural style has been documented in extensional basins. Gawthorpe *et al.* (1994) noted that tectonic control on subsidence, coupled with structural influence on sediment supply, strongly influenced stratal geometry and facies stacking patterns in Cenozoic basins of Greece. Complex fault and subsidence patterns in footwall and hangingwall areas and in transfer fault zones generated locally varied stratal architecture. However, subsidence rates close to normal faults matched or exceeded the magnitude of average fourth-order glacioeustatic sea-level falls. At these sites, relative sea level continued to rise throughout a eustatic cycle, and only the highest rates of sea-level fall outpaced subsidence to generate incision and sequence boundaries. Progradational to aggradational stacking patterns characterized areas of high sediment supply, and enhanced transgressions characterized areas of low sediment supply. Diminished incision, enhanced transgression and parasequence development have been documented for other high-accommodation settings, including foreland basins (Posamentier & Allen, 1993; Pashin, 1994; Lopez-Blanco *et al.*, 2000; Marzo & Steel, 2000) and subduction-related basins (Naish & Kamp, 1997).

Although the Joggins architectural style suggests a fundamental tectonic signature, glacioeustatic and climatic effects could also have caused relative changes in base level, although deciphering the relative importance of these mechanisms is challenging. High-frequency and high-magnitude sea-level fluctuations are now widely accepted for the icehouse world of the Carboniferous (Crowley & Baum, 1991; Calder, 1994; Hampson *et al.*, 1997). In addition to the modest evidence noted above for marine influence in the Joggins Formation, other lines of evidence suggest links between the wider Maritimes area and the marine realm elsewhere. This evidence includes agglutinated foraminifera in non-saline facies (Gibling & Wightman, 1994), glaucony in Sydney coal measures (Gibling & Nguyen, 1999), widespread high-sulphur coals and some aspects of the biota (Calder, 1998). Base-level rise could have been driven directly by marine flooding across a coastal plain or indirectly as a response of the water table to the rising base level.

Glacial and interglacial cycles would have resulted in significant changes in climate, which both causes and covaries with sea-level change (Blum & Tornqvist, 2000). Changes in climatic regime over time, in addition to tectonic uplift and unroofing of different substrates, generate temporal changes in sediment supply (Leeder *et al.*, 1998). Plant material in the Joggins facies assemblages provides some evidence for climatic fluctuation. As fire frequency is related to drought frequency, the relative abundance of charcoal in the redbeds suggests deposition under a more seasonal, drier climate than the grey units (Falcon-Lang, 2000). Frequent wildfires in the alluvial plain and bordering uplands could have caused a considerable increase in sediment supply to downstream locations. However, charcoal and burnt standing trees (Falcon-Lang, 1999) also occur within the grey, coal-bearing facies, and periodic wildfires probably affected the whole region and may have been related to elevated oxygen levels in the Carboniferous atmosphere (e.g. Berner, 1989). Furthermore, growth rings are not present in woody cordaite material in redbed channel deposits of the Joggins and Springhill Mines formations, suggesting that these plants were not subjected to water stress (Falcon-Lang & Scott, 2000); perhaps they grew in a riparian setting where water was available even during droughts. These observations indicate the difficulty of documenting climatic trends for the Joggins Formation.

The Joggins architectural style contrasts with that of the underlying Boss Point Formation, for reasons that remain unclear. Boss Point multistorey fluvial systems extend laterally for up to 12 km and have an average preserved thickness of 38 m with up to 15 m of basal relief (Plint & Browne, 1994). These low-sinuosity, braided systems were dominated by conglomeratic, trough cross-bedded sandstones with no overall upward fining (Browne & Plint, 1994). They alternate with thick, abruptly based successions of lacustrine deposits. The Boss Point Formation is thus characterized by both incision and flooding events, and accords more closely with an Exxon sequence model. The $\approx$600 m thick, poorly exposed succession between the Boss Point Formation and below cycle 1 within the Joggins Formation consists of alluvial redbeds with isolated medium-grained channel bodies, interpreted as indicating more torrential, seasonal flow. These strata lack open-water and poorly drained floodplain assemblages, and the cyclic nature of the strata is not readily discerned. The remainder of the Joggins Formation (an additional 300 m above the measured section) and the lower part of the Springhill Mines Formation have a similar architectural style to that documented here.

CONCLUSIONS

In the Late Namurian–early Westphalian, Joggins Formation, coal/limestone horizons are interpreted as important flooding surfaces and are used to subdivide the succession into eight cycles. Three main facies assemblages are recognized within these cycles and represent deposition in open-water conditions and on poorly drained and well-drained floodplains. The predominance of flooding surfaces throughout the formation reflects the rapid basin subsidence, which would also account for the development of thick successions of parasequence sets. Progradational and aggradational patterns of sedimentation predominate. Sediment supply was sufficient to balance active subsidence and maintain facies belts close to base level.

Although the stratigraphic architecture reflects a tectonic signature, the high-magnitude/high-frequency (40–100 ka) sea-level fluctuations recognized from temporally equivalent successions in Europe and the USA may have been superimposed on the rapid subsidence of the Cumberland Basin that enhanced periods of sea-level rise and suppressed periods of sea-level fall. Few of the criteria for subaerial unconformities are recognized, and multistorey fluvial sandstone bodies appear to be integral components of the floodplain. The absence of highly mature palaeosols from the Joggins Formation is in accordance with near-continuous accumulation.

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The Pennsylvanian Joggins Formation of Nova Scotia: sedimentological log and stratigraphic framework of the historic fossil cliffs

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ABSTRACT

Carboniferous strata of the famous Joggins fossil cliffs hold a unique place in the history of geology. Made famous by the fossil discoveries of Lyell and Dawson in the mid 1800s, the cliffs continue to yield important information about paleobiology. The Joggins Formation (of probable Langsettian age) has been completely remeasured for the first time since Logan and Dawson's pioneering studies, and a visual log and a map of the foreshore illustrate the 915.5 m of strata along Chignecto Bay. Formation boundaries are formally described, and two informal members are abandoned. The formation is divided into 14 cycles, most of which commence with major transgressions represented by the open-water facies assemblage, some faunal elements of which show a restricted-marine affinity. Higher in the cycles, the re-advance of coastal and alluvial systems yielded poorly and well drained facies assemblages, respectively. The main levels of standing trees, dominated by lycopsids, were entombed where distributary channels brought sand into coastal wetlands. Some trees contain tetrapods and invertebrates, which may have sought refuge or become trapped in hollow trees. Cordaitalean (gymnosperm) forests covered the alluvial plains and basin-margin uplands, and were periodically swept by wildfires. The predominance of flooding surfaces and the apparent absence of lowstand exposure surfaces reflect the rapid subsidence of the Cumberland Basin controlled by active basin-margin faults and salt withdrawal. The cycles may reflect tectonic events, glacioeustatic sea-level fluctuations, and/or variations in sediment flux.

RÉSUMÉ

Les strates carbonifères des célèbres falaises fossilifères de Joggins occupent une place unique au sein de l'histoire de la géologie. Devenues célèbres à la suite des découvertes de fossiles de Lyell et Dawson vers le milieu du 19e siècle, les falaises continuent à fournir des données précieuses au sujet de la paléobiologie. La Formation de Joggins (qui remonte vraisemblablement au Langsettien) a été entièrement remesurée pour la première fois depuis les premières études importantes du secteur réalisées par Logan et Dawson; une description visuelle et une carte de l'estran illustrent les 915,5 mètres de strates le long de la baie Chignectou. L'étude décrit officiellement les limites de la formation et abandonne deux membres officieux. La formation est subdivisée en 14 cycles dont la majorité commencent avec des transgressions importantes représentées par l'assemblage de faciès en eaux libres, dont certains éléments fauniques présentent une affinité marine restreinte. À des niveaux supérieurs des cycles, la récurrence des systèmes côtiers et alluviaux fournit des assemblages de faciès mal drainés et bien drainés, respectivement. Les principaux niveaux d'arbres sur pieds, à prédominance de lycopsides, ont été enfouis dans des secteurs où des canaux tertiaires ont apporté du sable à l'intérieur des terres humides côtières. Certains arbres renferment des tétrapodes et des invertébrés, lesquels pourraient avoir cherché refuge ou s'être retrouvés prisonniers dans des arbres creux. Des forêts cordaitaléennes (gymnospermes) ont couvert les plaines alluviales et les terres hautes de marge de bassin, et ont périodiquement été balayées par des incendies de forêt. La prédominance de surfaces d'inondation et l'absence apparente de surfaces d'affleurement de bas niveau témoignent de la subsidence rapide du bassin de Cumberland, contrôlée par des failles de marge de bassin actives et un retrait du sel. Les cycles pourraient correspondre à des événements tectoniques, à des fluctuations glacio-eustatiques du niveau de la mer ou à des variations du débit de sédiments.

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THE JOGGINS CLIFFS

The Joggins fossil cliffs constitute one of the world's most remarkable and historic stratigraphic sections. The cliffs extend from Lower Cove past Joggins village to McCarron's Creek, bordering a broad tidal platform along Chignecto Bay, where some of the world's highest tides continually erode Carboniferous strata of the Cumberland Basin (Figs. 1, 2). The Joggins Formation comprises only 2.8 km of a 30 km long continuous coastal section that Sir Charles Lyell (1871, p. 410) described as "the finest example in the world of a natural [Carboniferous coal measures] exposure", a view that is still widely accepted.

Early accounts by Jackson and Alger (1828), Brown and Smith (1829), and Gesner (1836) brought the Joggins section to the attention of the world. Lyell visited Joggins during his first visit to North America and was deeply impressed by the spectacular geological features (Lyell 1845; Scott 1998). In the following year, Joggins hosted William Logan, the head of the newly constituted Geological Survey of Canada, who recorded a 14 570 foot (4441 m), virtually continuous section along Chignecto Bay (Logan 1845; Rygel and Shipley 2005).

For the remainder of the century, Lyell, J.W. Dawson and other Victorian luminaries repeatedly visited the cliffs, a particular highlight being the discovery in 1852 of tetrapod bones and land snails within tree trunks (Lyell and Dawson 1853; Dawson 1878, 1882). In many ways, Joggins was to Lyell what the Galapagos Islands were to Darwin (Calder 2003). Lyell's research at Joggins, following the earlier success of "Principles of Geology" (Lyell 1830–1833), was pivotal in establishing the stratigraphic record as an archive of Earth's evolving landscape. Joggins is mentioned several times in Charles Darwin's "Origin of Species" (1859). The cliffs have yielded some of the world's best preserved fossil forests, the earliest known true reptile (*Hylonomus lyelli*), and the first land snail (*Dendropupa vetusta* – referred to as "miserable little dendropupa" by Bishop Sam Wilberforce during the famous British debate on evolution in the 1860s (Wilberforce 1860, p. 244).

Over the past 25 years, the natural laboratory of the Joggins cliffs – renewed constantly by the tides – has experienced a surge of scientific interest. Paleontological research has touched upon the main forested levels and the entombment of standing trees and their contained fossils (Rygel *et al.* 2004; Calder *et al.* in press), wetland and dryland plant assemblages (Falcon-Lang and Scott 2000; Falcon-Lang 2003a,b), charcoal and the wildfire record (Falcon-Lang 1999), and age assessment (Dolby 1991; Utting and Wagner 2005). There have been discoveries of reptiles, bivalves, ostracodes, gastropods and foraminifera, as well as tetrapod trackways and other trace fossils (Solem and Yochelson 1979; Archer *et al.* 1995; Reisz 1997; Hebert and Calder 2004; Falcon-Lang *et al.* 2004a; Tibert and Dewey 2005). Sedimentological research has investigated channel bodies (Rygel *et al.* 2001; Rygel 2005), paleosols (Smith 1991), sequence stratigraphy (Davies and Gibling 2003), and composition of coals and carbonaceous strata (Gibling and Kalkreuth 1991; Hower *et al.* 2000). Scott (2001) and Falcon-Lang *et al.* (2004b) presented general scientific accounts. In 2004, Joggins was proposed for Canada's list of World Heritage nominations (Falcon-Lang and Calder 2004).

Despite the importance of the Joggins cliffs, the only formal stratigraphic log has remained the detailed written descriptions of Logan (1845) and Dawson (1854). Later workers have remeasured short segments, and Ryan and Boehner (1994) recast Logan's log as a simplified graphic log. We have remeasured the cliff and foreshore section (915.5 m thick) from Lower Cove to south of Bell's Brook, the lower 600 m of which was described by Davies and Gibling (2003), and an interval of 145 m higher in the section by Tenière (1998). In Appendix A we present a complete sedimentological log, with a notation of Logan's numbered coals and Dawson's Coal Divisions, and present a map of the foreshore that shows the stratigraphic height in metres above the base of the Joggins Formation, so that historic and future fossil discoveries may be accurately positioned. We also present formal revision to the upper boundary of the Joggins Formation, and review the formation's cyclicity and depositional setting. A companion paper (Calder *et al.* 2005) presents the section at Lower Cove and formally designates the latter strata as the Little River Formation, and in so doing redefines the Joggins Formation. We hope that these publications will encourage further research on this superb and historic section.

STRATIGRAPHIC FRAMEWORK FOR THE JOGGINS FORMATION

Previous research

Ryan *et al.* (1991), Ryan and Boehner (1994) and Calder (1998) summarized the history of stratigraphic nomenclature for the Cumberland Basin, and Calder *et al.* (2005) set out more fully the history of stratigraphic work in the Joggins area. Previous approaches to subdividing the Joggins stratal interval are outlined in Figs. 3 and 4. Despite its magnificence, the coastal exposure provides only a two-dimensional view of the basinal strata, and a full regional understanding is complicated by minimal exposure inland, the presence of Chignecto Bay, and complex facies relationships southward towards the Cobequid Highlands (Fig. 1), which was an active, fault-bounded upland during deposition of the Joggins Formation. In proposing a stratigraphic framework, every researcher since Logan has wrestled with this difficult background.

Logan (1845) divided the Chignecto Bay strata into eight divisions (numbered from the top downwards), placing the predominantly grey, coal-bearing strata of the Joggins cliffs in Division 4. He measured this interval as 2539' 1" (774 m) of grey and red mudstone, sandstone, limestone, coal, carbonaceous shale and minor conglomerate. Logan recognized 45 coal groups (identified with numbers) in Division 4, and recorded an aggregate thickness of 37' 9.5" (11.5 m) of coal and 23' 3" (7.1

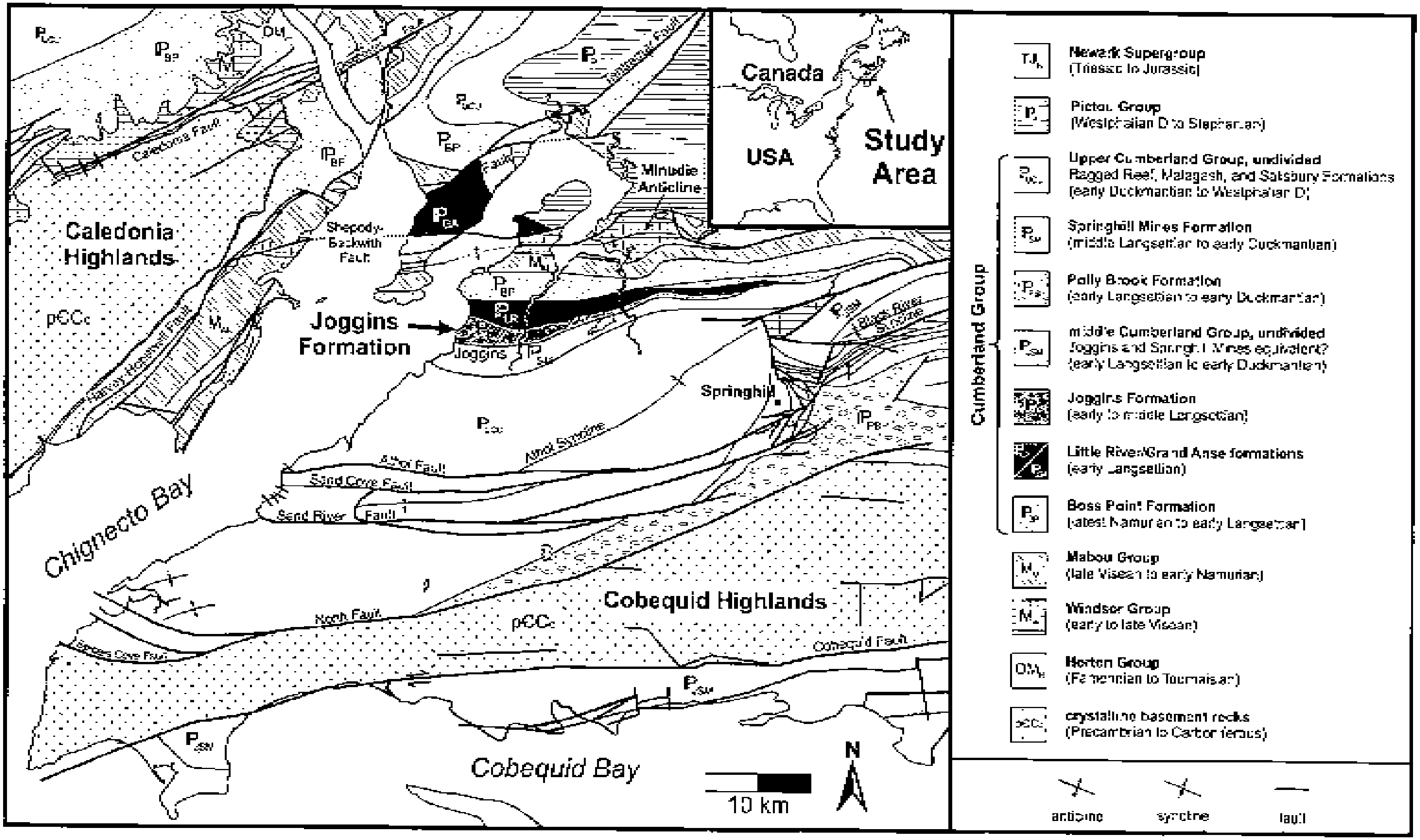


Fig. 1 Geological map of the western Cumberland Basin and adjacent areas showing the distribution of the Joggins Formation and the location of the Joggins section near Joggins village. Modified from Ryan *et al.* (1990), St. Peter (2001), and New Brunswick Department of Natural Resources and Energy (2000).

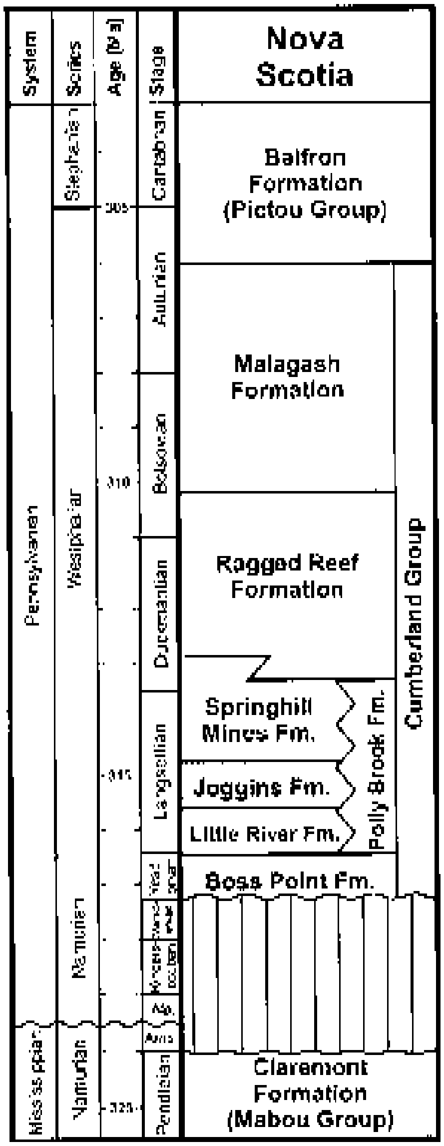


Fig. 2 Stratigraphic position of the Joggins Formation within the Cumberland Group. Modified from Ryan *et al.* (1990) and St. Peter (2001).

m) of limestone in the division. Red, red-green and chocolate shale and sandstone constituted 264 m (34%) of his section, the remainder being grey. In contrast, he noted the absence of coal in the underlying Division 5, which he described as red mudstone and grey and red sandstone, with a few green shale and calcareous nodular horizons. This division, only partially exposed at Lower Cove, was measured at 2082′(635 m) down to the top of "South Reef", a prominent and thick sandstone body within Division 6. Logan's Coal Group 45 lies slightly above the base of Division 4 at Lower Cove, and was described as comprising 10′2″ (3.1 m) of coal, carbonaceous shale and interbedded shale and sandstone, with a basal thin coal 3″ (7.5 cm) thick. These strata are underlain by 5′6″ (1.7 m) of underclay and red shale and sandstone, the base of which marks the base of Division 4. The top of Coal Group 1 marks the top of Division 4 near Joggins village, where a 4′ (1.2 m) limestone rests upon a 1′ (0.3 m) coal. The overlying Division 3 has a lesser proportion of coal (22 seams with only 5′5″ or 1.7 m aggregate thickness), a greater proportion of red beds and, most significantly, no limestone. Division 2 is mainly red sandstone and mudstone.

Subsequent workers used aspects of Logan's classification. Dawson (1854, 1855) divided Division 4 into 27 coal divisions (designated with Roman numerals), and provided more detail for some of Logan's coal groups. Dawson (1868) adopted aspects of British terminology in identifying a Millstone Grit Series and a Middle Coal Formation, a system that was modified by Bell (1912). Bell (1914) subsequently proposed the name "Joggins Formation" for Divisions 5, 4, 3 and part of 2, an interval 6886′ (2099 m) thick, and the name "Shulie Formation" for overlying strata (most of Division 2 and Division 1). Bell discussed the rationale for combining the Division 5 red beds and the Division 4 grey, coal-bearing beds into one formation, inferring that a regional disconformity underlies Division 5 within the Cumberland Basin (although it is not apparent in the coastal

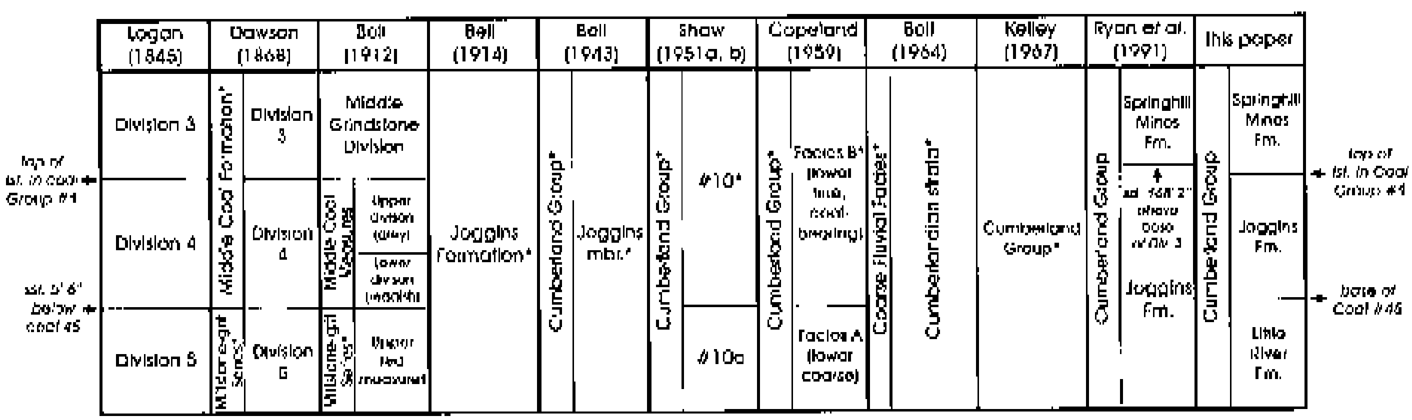


Fig. 3 Comparative stratigraphic chart showing the evolution of nomenclature for the Joggins Formation and associated strata in the Cumberland Basin. Vertical axis is approximately scaled to the thickness of the units. Chart refers only to major stratigraphic revisions that affected subdivision of the coastal section. Asterisks denote units that are partially shown. Modified from Ryan *et al.* (1991).

section). He subsequently retracted the formation names (Bell 1943) due to problems in correlating units inland, arising in part from miscorrelation of the coal-bearing strata of Spicers Cove with those of Division 4 to the north at Joggins. Bell combined the Joggins and Shulie formations as the "Joggins member" of an undivided Cumberland Group. Shaw (1951a,b) mapped coarser and finer rock units within the basin, and assigned the Joggins grey strata to his unit 10, noting that conglomeratic wedges near the Cobequid Highlands thin northward and complicate the basinal stratigraphy. Copeland (1959) followed this approach, and confirmed that coals thin inland within the Joggins-Chignecto coalfield. Belt (1964) referred strata at this level across the region to the "Coarse Clastic Facies", but Kelley (1967) retained the Cumberland Group for the lower part of this interval.

Ryan *et al.* (1991) reinstated the Joggins Formation and presented a formal description with the Joggins cliffs as the type section. Ryan *et al.* (1990) mapped the formation inland, and included Divisions 5, 4 and the basal strata of Division 3 within the reconstituted Joggins Formation, for a total thickness of 1433 m. Both Ryan *et al.* (1991) and Ryan and Boehner (1994) illustrated member boundaries on a column derived from Logan's section (their figs. 5 and 2-13, respectively), but did not elaborate on them in the text. The figures show three informal members: the Little River Bridge member (Division 5), the Coal Mine Point member, and the Bells Brook member (Division 4 and basal strata of Division 3), but these members were not formally defined or shown on the accompanying maps.

In the coastal section, Logan's Division 5/6 boundary was taken to mark the base of the Joggins Formation, and its top was placed at the base of a thick sandstone body that ushers in a more sand-dominated interval at the base of their new Springhill Mines Formation (Ryan *et al.* 1991; Ryan and Boehner 1994). This upper boundary was selected by Ryan *et al.* (1991) who placed the basal 168' 2" (51 m) of Division 3 within the Joggins Formation. This contact has proven difficult to map.

Modifications to Joggins Formation definition at the type section

Remeasurement of the section (Appendix A of this paper, and Appendix A of Calder *et al.* 2005) has led Calder *et al.* (2005, their Appendix C) to redefine the Joggins Formation from the boundaries set out by Ryan *et al.* (1991) (Fig. 4). Below, we describe the boundaries of the revised formation at the coastal type section as they relate to our recent sedimentological investigations.

Formation base and top at the type section

In the absence of a detailed measured section, Ryan *et al.* (1991) included Division 5 within the Joggins Formation based on unconfirmed reports of coals within the red beds. With the advantage of a detailed measured section, Calder *et al.* (2005) reaffirm Logan's observation that Division 5 lacks coal, fossiliferous limestone and grey mudstone. They formally redefine

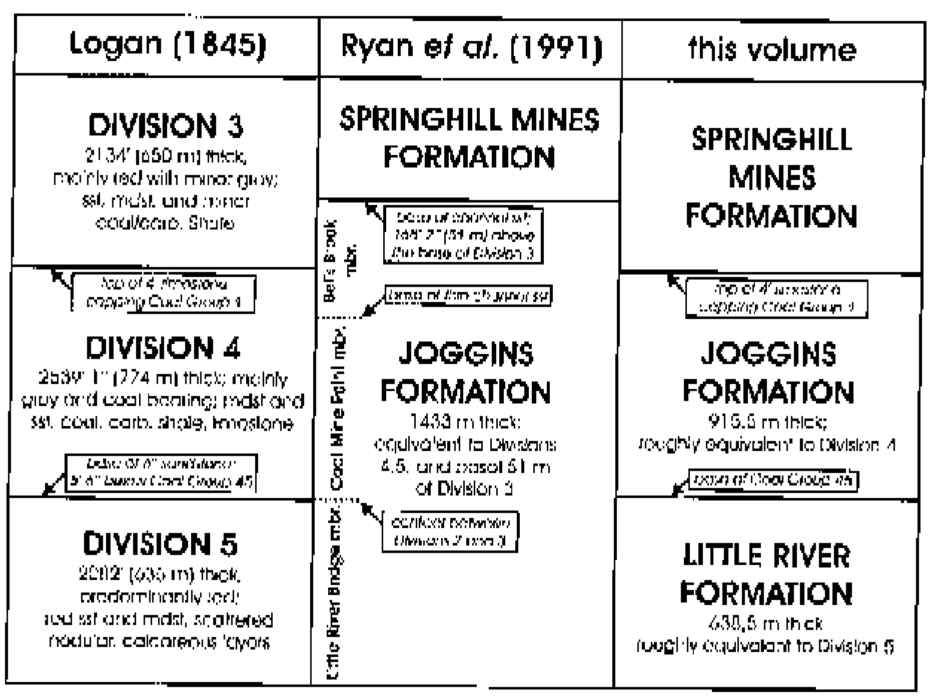


Fig. 4 Definition of Joggins Formation boundaries in the coastal section along Chignecto Bay, as outlined in some key papers. Where strata were originally measured in feet, metric equivalent is shown to nearest metre. sst = sandstone, mdst = mudstone, carb. = carbonaceous.

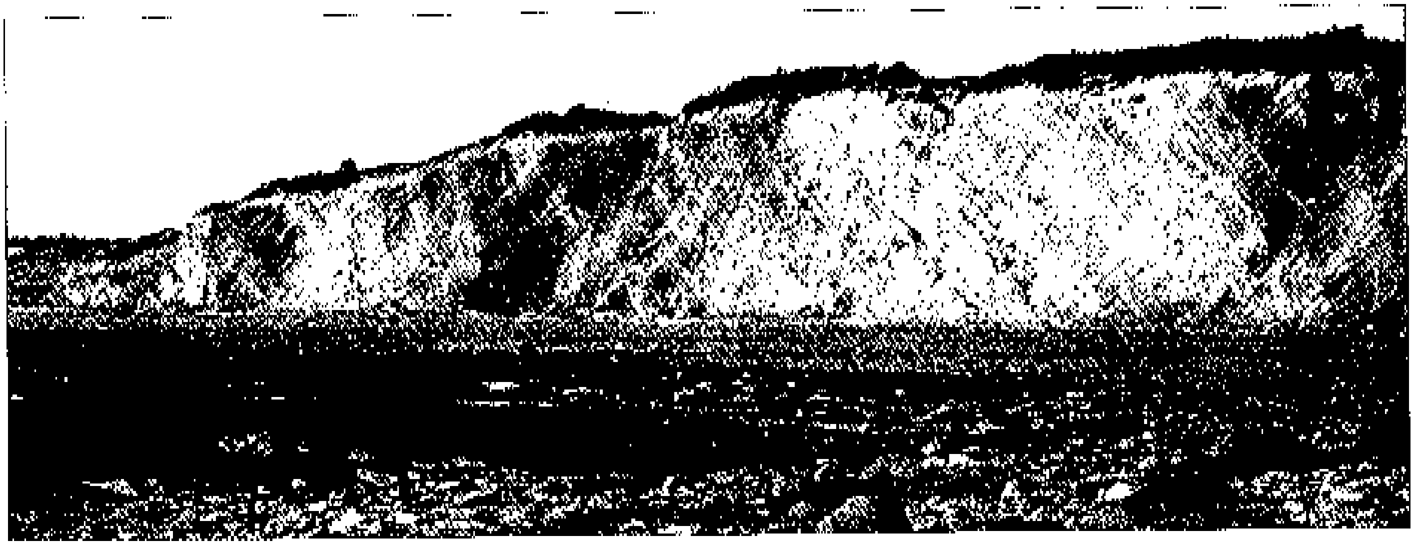


Fig. 5 Basal 250 m of the Joggins Formation south of Lower Cove (cycles 1–4 and basal strata of cycle 5). Formation base is at extreme left. Cliffs are about 20 m high, and dark, seaweed-covered reefs in foreground are lenticular channel sandstones.

Division 5 as the Little River Formation (635.8 m thick) and, in so doing, also redefine the Joggins Formation. The base of the Joggins Formation as reformulated by Calder *et al.* (2005) coincides with the lowermost coal exposed in the section, within Coal Group 45 and 1.7 m above the base of Division 4 as originally defined by Logan (1845). This approach essentially retains Logan's Division 5 as a unit distinct from both the underlying Boss Point Formation and the overlying Joggins Formation and, in consequence clarifies the definition of the Joggins Formation as a coal-bearing unit with co-occurring bivalve-bearing limestones.

The formation top is redesignated at the top of the uppermost limestone unit within coal group 1 south of Bells Brook in keeping with the original definition of Division 4 by Logan (1845), as opposed to the channel-sandstone base at the higher level designated by Ryan *et al.* (1991). This limestone/coal interval is unusually thick, and the limestone is the topmost major calcareous unit in the type (cliff) section. Mining records and mapping (Goudge 1945; Shaw 1951b; Copeland 1959; Ryan *et al.* 1990) show that limestone beds within the interval of mined coal seams of the Joggins Formation (Coals 7–32) extend up to 40 km inland and can be interpreted as basin-wide flooding events (Calder 1994). Falcon-Lang (2003a) noted that these limestones and overlying platy shales yield abundant remains of upland floral elements, confirming that major flooding events inundated most of the basin. In contrast, individual channel bodies have yet to be mapped inland, and our observations in the coastal section (Davies and Gibling 2003; Rygel 2005) indicate that most channel-sandstone bodies are lensoidal and discontinuous. Although thick intervals of coarser and finer strata tend to be mappable within the basin at the formation scale (Shaw 1951b), the lensoidal nature of and relative similarity between channel bodies in the Joggins and Springhill Mines formations makes the uppermost limestone a more useful lithostratigraphic surface.

The Joggins Formation as redefined has a total thickness of 915.5 m. Logan (1845) recorded this interval as 2533' 7" (772 m), a discrepancy likely resulting from the speed at which he measured the section (Rygel and Shipley 2005).

Members

The Coal Mine Point and Bells Brook members of the Joggins Formation were not formally defined by Ryan and Boehner (1994) and are abandoned here. The boundary between them was designated as the top of a sandstone just south of Bells Brook, but this bed is not prominent and there is no indication that it is mappable. Between Lower Cove and Coal Mine Point, Duff and Walton (1973) designated informal lower, middle and upper beds, and Davies and Gibling (2003) and the present authors recognize informal cycles 16 to 212 m thick, the bases of which are located at prominent flooding levels marked by limestone, coal and grey platy shale with siderite nodules (Appendix A). Some coal seams at cycle bases are mappable inland (Goudge 1945; Copeland 1959) and some cycles or groups of cycles could in the future merit member status if they prove to be extensive.

AGE OF THE JOGGINS FORMATION

The formation has been dated on the basis of palynology as late Langsettian (Dolby 1991). Recent investigation and taxonomic revision of the macroflora suggest that the strata are most probably early Langsettian (Utting and Wagner 2005), and the proximity of the Namurian-Westphalian boundary is suggested by the presence of late Namurian floral elements.

THE STRATIGRAPHIC SECTION

The stratigraphic section (Fig. 5; Appendix A) was measured bed-by-bed with centimetre-scale resolution. Although measured at the base of the accessible cliff, the section represents the exposed cliff face more broadly and records lateral changes in thickness of channel bodies and crevasse splays evident at the time of measurement. Figure 6 shows the stratigraphic level in the section (in metres above the base of the Joggins Formation) for distinctive beds that protrude from the adjacent tidal platform as resistant bodies, long known as "reefs". Fine-grained beds, limestones and sharp-based sandstones are generally continuous across the exposure area, but the numerous lensoidal channel bodies exposed only in the foreshore are not represented in the measured section. Considerable difficulty was encountered in measuring an accurate section through the former mining areas on the Joggins Seam due to waste heaps and the removal of the coal seams. We record present exposures in this interval (~800 m to 870 m), leaving Logan's section – which was measured prior to major coal extraction – as a more complete representation. Red and drab intervals are recorded to the left of the column; these colour designations are highly generalized, and drab intervals in particular show wide variation from dark to light grey and green. Most channel sandstones are grey-brown regardless of their association, and their colour is typically shown on the log as similar to the strata above and below.

The section is divided into 14 cycles (Fig. 7), the bases of which are marked by limestone, coal or fossiliferous shale. The cycles are divided in turn into stratal intervals that belong to the open-water, poorly drained floodplain, and well drained floodplain facies assemblages (Davies and Gibling 2003), the main features of which are summarized briefly below. In the cycles, the three assemblages typically succeed each other upwards, although the open-water facies assemblage is not represented in some cycles.

FACIES ASSEMBLAGES AND FOSSIL GROUPS

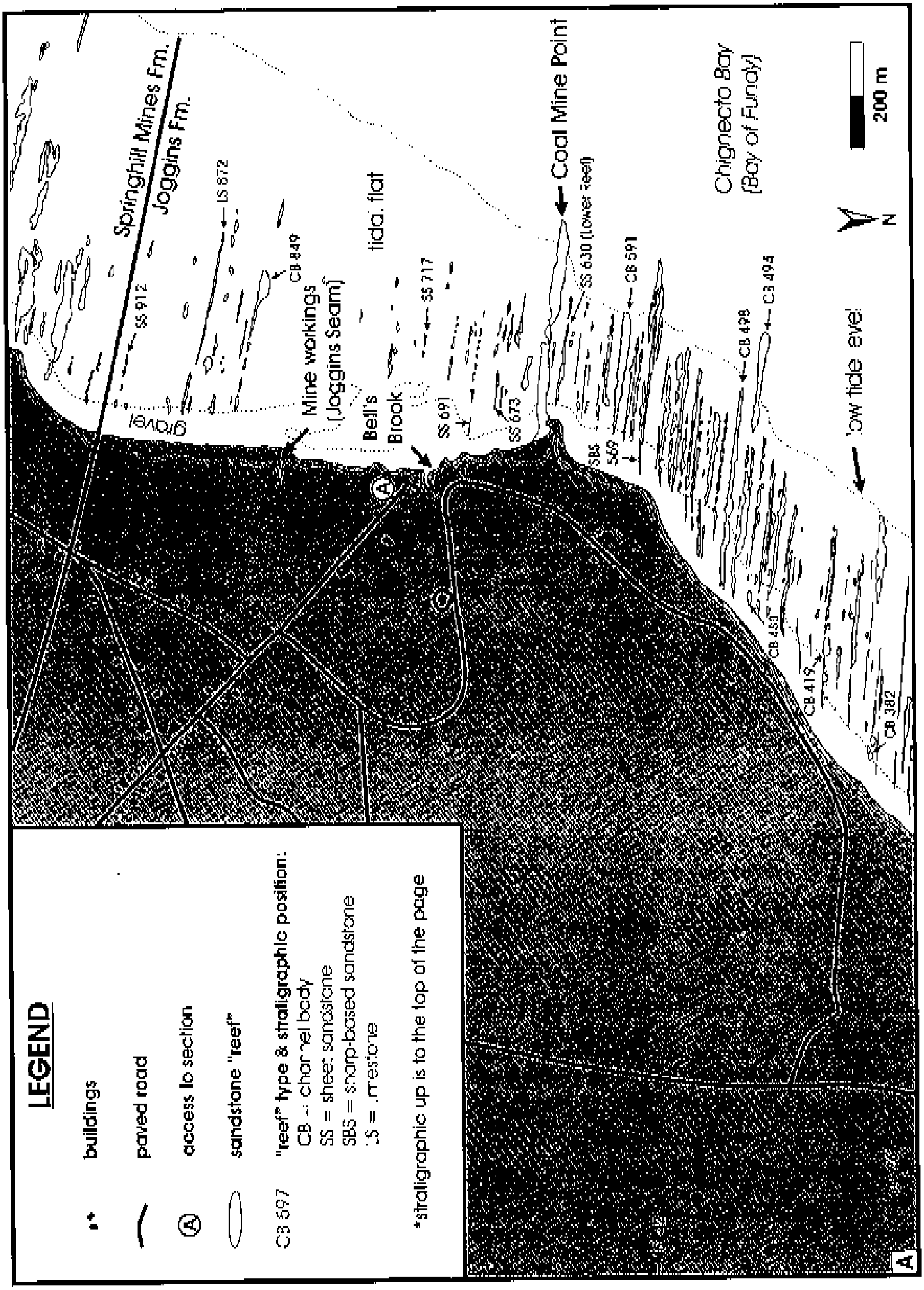
Open-water facies assemblage

This assemblage represents major flooding events, some of which probably inundated most of the western Cumberland Basin. Especially good examples in the lower part of the formation (cycles 2–4) are represented by a thin coal overlain by a dark limestone up to 1 m thick, which is overlain in turn by several metres of grey siltstone capped abruptly or gradationally by sandstone. The limestones are well cemented and stand out on the foreshore. They are locally termed "clam coals" because of their dark colour and the abundance of bivalves with accessory ostracodes, spirorbids, arthropods, disarticulated fish and plant fragments.

The overlying siltstones are laminated and platy weathering, and contain discoidal siderite nodules. The siltstones contain bivalves and ostracodes (generally confined to discrete levels), as well as drifted plant material. Agglutinated foraminifera were obtained from some samples (Archer *et al.* 1995). Capping the siltstones are sharp-based, sheet-like sandstones a few metres thick, which extend across the cliff and foreshore and are characterized by planar bedding and a flaggy appearance. In a few instances, they comprise overlapping mounds up to 100 m in apparent width. The sandstones contain unidirectional ripple cross-lamination, local mud drapes, and lineated plane beds, with wave ripples and rare hummocky cross-stratification indicating wave activity. Trace fossils include delicate grazing and walking traces (Archer *et al.* 1995) and, less commonly, resting traces (for example of limulids). A few channel bodies cut the planar sandstones, with which they are evidently closely associated. The topmost coarser beds contain roots, which mark the re-establishment of subaerial conditions after the initial flooding event.

The assemblage represents the establishment across the basin of a restricted-marine gulf, perhaps similar to the modern Baltic Sea in its partially enclosed nature and variable but generally low salinity (Grasshoff 1975). Open-marine faunal elements have not been observed, but the presence of certain taxa of bivalves, ostracodes, foraminifera and trace fossils suggest at least brackish conditions (Bell 1914; Duff and Walton 1973; Archer *et al.* 1995; Skilliter 2001; Tibert and Dewey 2005). Strontium isotope data from fish material also suggest marine influence (Calder 1998), although mineralogical and geochemical data from some bivalve shells are consistent with a freshwater setting (Brand 1994). During some flooding events at cycle bases, the presence of a basal coal suggests that peat formation initially kept pace with rising water level. When the rate of sea-level rise exceeded that of peat accumulation, the area was transformed into a shallow bay where faunal-concentrate layers accumulated. The upward change to siltstone indicates the renewed advance of the coastal plain as the rate of sea-level rise decreased. Progradation culminated in shallow-water sands that represent thin shorefaces and small delta lobes derived from the associated channels. Wave activity was prominent, but sedimentological evidence for tidal influence is restricted to mud drapes at a few levels (Skilliter 2001).

Drifted lycopsid plants predominate in the basal limestones, whereas overlying siltstones and sandstones contain a mixed suite of drifted gymnosperms (cordaitaleans), sphenopsids (primarily calamiteans), pteridosperms and putative progymnosperms (Falcon-Lang 2003a). The high proportion of progymnosperms and gymnosperms suggests that the basin floor was almost entirely drowned, greatly reducing the area of coastal swamps. Under these conditions, elements of the upland vegetation (Falcon-Lang and Scott 2000) brought to the sea by rivers were preferentially concentrated in the siltstones (an example of the "Neves Effect" of Chaloner 1958). The presence of stigmarian roots within some limestone beds points to near emergent, shallow conditions in some cases, and maximum water depth during deposition of open-water facies was probably only a few metres to a few tens of metres.


LEGEND
buildings
paved road
access to section
sandstone "reef"
CB 597
"reef" type & stratigraphic position:
CB = channel body
SS = sheet sandstone
SBS = sharp-based sandstone
*stratigraphic up is to the top of the page
Springhill Mines Fm.
Joggins Fm.
gravel
SS 912
LS 872
CB 849
Mine workings
(Joggins Seam)
tidal flat
Bell's
Brook
SS 717
SS 691
SS 673
Coal Mine Point
SS 630 (Lower reef)
CB 591
SBS
569
CB 498
CB 494
CB 453
CB 419
CB 382
low tide level
Chignecto Bay
(Bay of Fundy)
N
200 m
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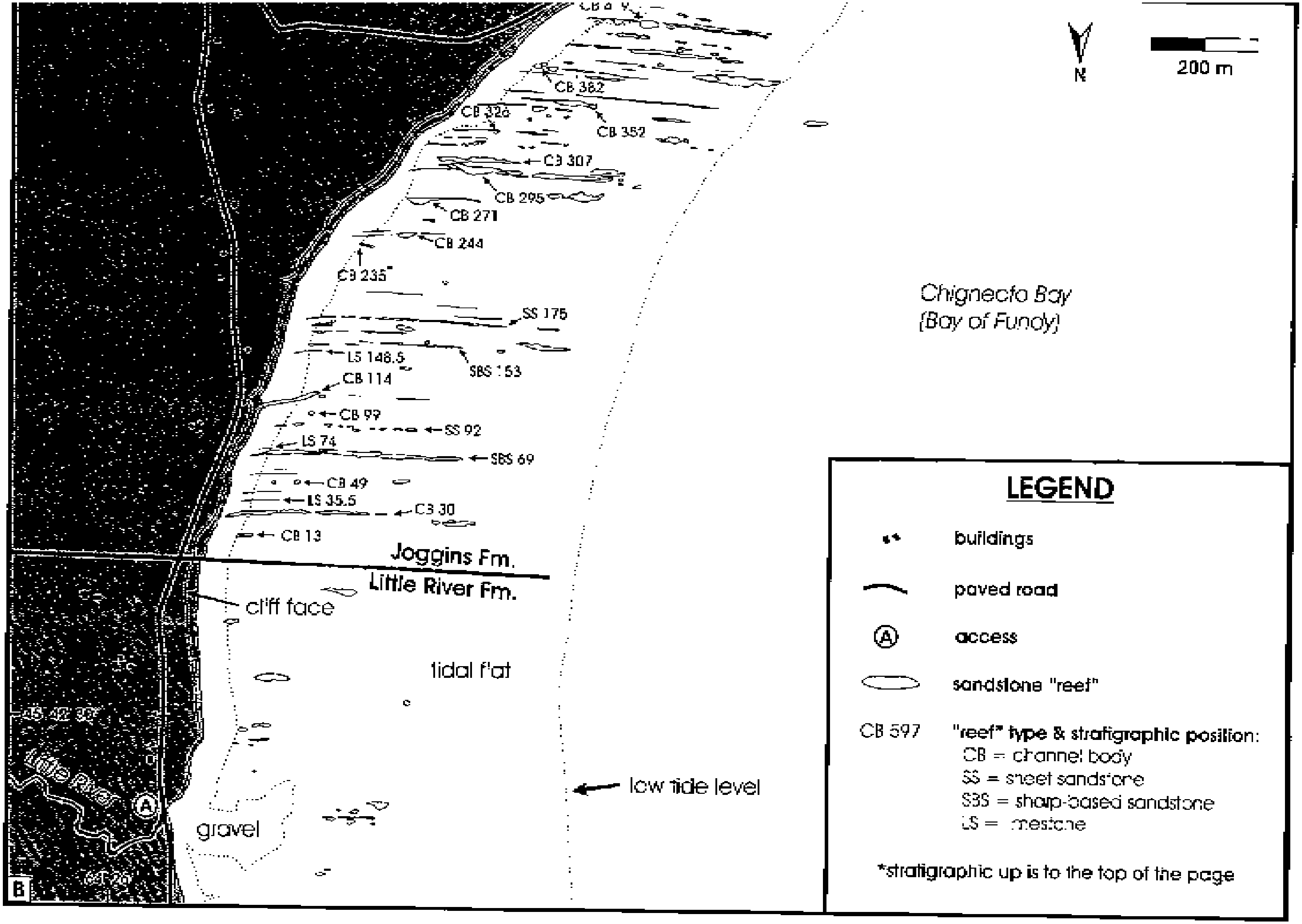

Fig. 6 (Pages 122–123) Outcrop maps of the Joggins Formation exposed on the tidal flat of Chignecto Bay. Both maps are at 1:10 000 scale and show the stratigraphic height in metres above the base of the Joggins Formation corresponding to the top of prominent beds. A. shows the upper part of the formation and B. shows the lower part; there is slight overlap between the two parts of the figure. Coastal topography from airphotos 85314-2 (1:10 000) and A18580-125 (1:15 840), available from the Nova Scotia Department of Housing and Municipal Affairs, Land Information Services Division. To assist with field work, properly scaled maps of the A and B components of this figure (at 100% and 63.13%, respectively) can be printed on overhead transparency film and used as an overlay on the respective parent airphotos.

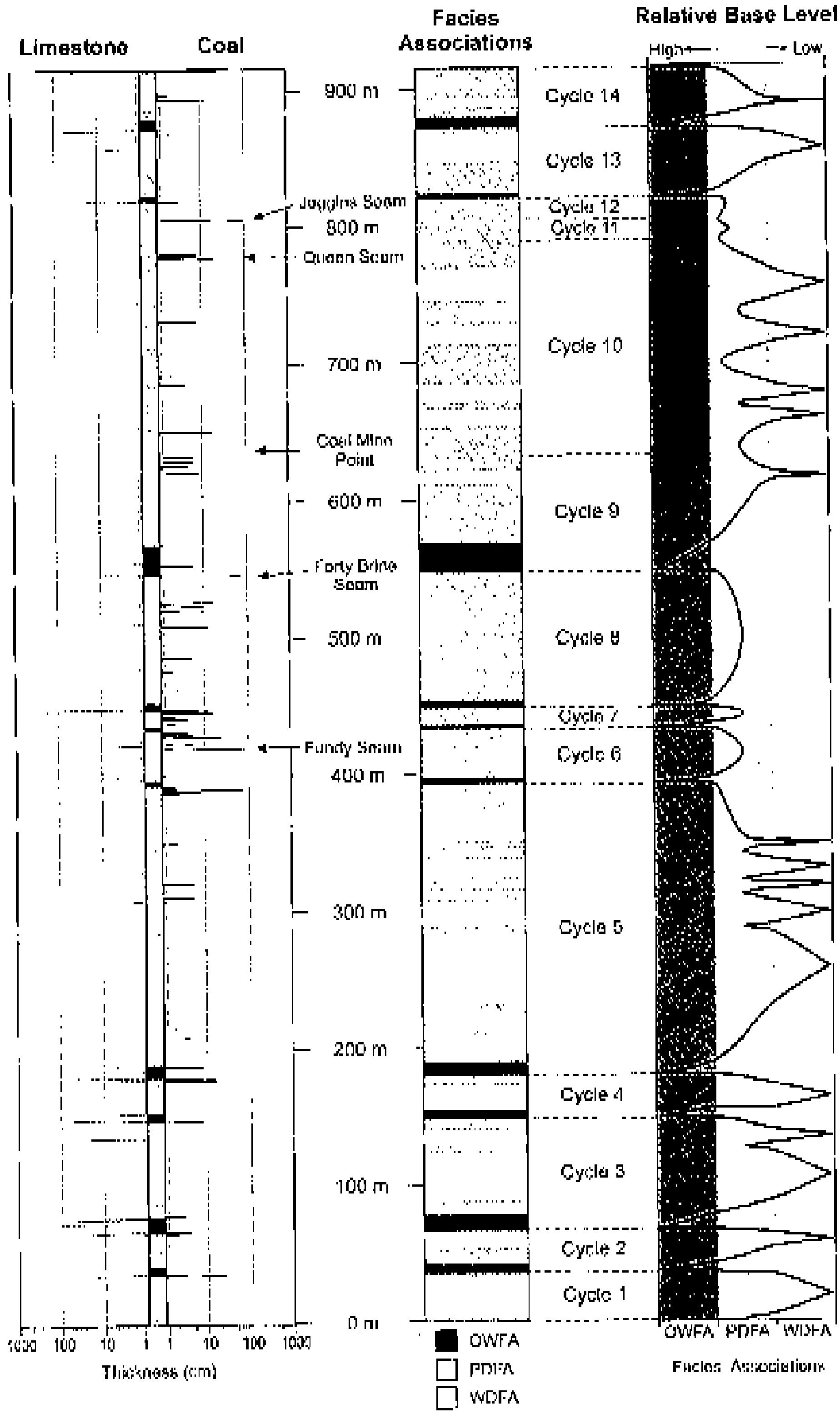

Fig. 7 Summary log for the Joggins Formation, showing cycles, facies assemblages, position and thickness of coal and limestone beds, and relative base-level curve.

Poorly drained floodplain assemblage

Joggins is justifiably famous for its poorly drained floodplain deposits, which contain the spectacular fossil forest horizons. Sandstone and green/grey mudstone (commonly intensively rooted), are accompanied by coal, carbonaceous shale and minor limestone, with siderite nodules. Bivalves and ostracodes are generally less common than in the open-water assemblage. The assemblage includes thin grey carbonaceous shales that separate red beds near cycle tops from coal and limestone at the base of the next cycle.

Especially prominent are sheet-like, heterolithic units of sandstone and mudstone, several metres thick, which extend across the cliffs and foreshore and contain many entombed erect trees. Splendid examples include two forested intervals below the Fundy Seam (404–420 m; Calder *et al.* in press), two intervals just below the Forty Brine Seam (539–546 m) and the lower reef just north of Coal Mine Point (628–630 m). Charles Lyell was struck by the preserved height of the trees, which he estimated to be up to 7.6 m tall (Lyell 1842, 1845). The maximum height observed over the past three decades has been 6 m (Calder *et al.* in press). Vegetation includes abundant lycopsids and sphenopsids in situ (Falcon-Lang 1999; Calder *et al.* in press) with a compression macrofloral record comprising cordaitalean gymnosperms, pteridosperms, ferns and putative progymnosperms (Calder *et al.* in press). Many standing trees are bordered by scour fills of sandstone up to 2 m thick with centroclinal (inward dipping) cross stratification, and suites of large sandy mounds (vegetation shadows) are common (Rygel *et al.* 2004).

Within this assemblage, Lyell and Dawson made their remarkable discovery of fossils within tree trunks, mainly from the lower reef ("Lesser Reef" of Dawson 1882) at Coal Mine Point. The tree-stump fauna is highly diverse, including eleven tetrapod genera, abundant coprolites, and a variety of invertebrates – land snails (*Dendropupa*), millipedes, arthropod fragments, and calcareous shells of the annelid *Spirorbis* (Carroll *et al.* 1972). Charcoal fragments are abundant within and adjacent to some trunks, testifying to wildfires that swept the forests (Falcon-Lang 1999). The organisms may have taken refuge within hollow trees or may have become entombed accidentally, and some fragments may have been swept in by floods (Lyell and Dawson 1853; Carroll *et al.* 1972; Scott 2001).

The heterolithic units are closely associated with narrow channel bodies up to 3 m thick. A few much larger channel bodies are also present in the assemblage. One large channel body at 580 m has incised 9 m through rooted grey mudstone and contains two vertically stacked storeys. The major sandstone "reef" at Coal Mine Point (637–648 m) is a channel body that contains trough cross-beds, scroll-bar forms and lateral accretion surfaces (Rygel 2005). This channel body contains especially spectacular examples of *Diplichnites* (large trackways attributed to the arthropod *Arthropleura*: Ferguson 1975).

Many of the coal groups (marked on the section in Appendix A) lie within this assemblage, which includes the main economic seams of the formerly worked Joggins–Chignecto Coalfield: most notably the Fundy (coal 29a), Forty Brine (coal 20), Kimberly (coal 14), Queen (coal 8) and Joggins (coal 7) seams. The bituminous coals are sulphur-rich (Copeland 1959; Skilliter 2001) with prominent mudstone partings and locally high concentrations of Zn, Pb and As (Hower *et al.* 2000).

The strata were deposited in wetlands akin to those of the modern Mississippi Delta (Coleman and Prior 1980; Tye and Coleman 1989), although the geomorphic form of the coastal system is not known. Small distributary channels traversed the coastal plain and brought sand and mud to the adjacent fresh to brackish bays during repeated flood events, depositing characteristically heterolithic sediment as interdistributary crevasse splays and bay fills. These sedimentation events entombed the standing trees (Calder *et al.* in press) and created scour hollows and vegetation shadows around the trunks (Rygel *et al.* 2004). At the level of the upper Fundy forest (419 m level in Appendix A), thin sandstone sheets can be traced from the margins of channel bodies on the tidal platform into scour fills around standing trees exposed in the cliffs. The forests were affected by wildfires that may have been instrumental in hollowing out the trunks and providing shelter for early tetrapods and other organisms. The channel body at the 580 m level is interpreted as a large distributary channel, based on its incised nature and aggradational style, whereas the Coal Mine Point channel body represents a meandering river that advanced over bayfills, much as the modern Atchafalaya River of Louisiana advanced rapidly once it had filled Atchafalaya Bay (Tye and Coleman 1989). Thin poorly drained intervals at cycle tops represent incipient drowning of the coastal zone prior to the main transgression.

The coals represent planar (groundwater-fed) mires (Hower *et al.* 2000; Calder *et al.* in press) where, for prolonged periods, peat accumulated away from detrital supply, although floods periodically generated muddy partings. Several economic seams cap heterolithic units or channel bodies, suggesting that the precursor peat accumulated in freshwater settings following abandonment of a local distributary. These thick coals may be the updip equivalent of marine flooding events, and the high sulphur levels of many coals suggest that marine, sulphate-rich waters influenced the peats, probably after the mires were drowned by sea-level rise. Many drab mudstones are hydromorphic paleosols that formed under variable redoxymorphic conditions, and red and red/grey mottled intervals testify to episodes of soil formation under oxidizing conditions (Smith 1991). The 595–612 m interval of cycle 9 contains stratified red and grey mudstone without coal or invertebrate fossils, suggesting that oxidized mud was washed into clastic-dominated lakes.

Well drained floodplain assemblage

This predominantly red bed assemblage comprises red mudstone and sandstone, with minor grey mudstone, rare coal and ostracode-bearing limestone. Although not highly fossiliferous, these strata have recently yielded some unusual fossil discoveries (Hebert and Calder 2004), as outlined below. Cycle 4 contains an especially thick red bed interval.

Channel bodies are narrow and up to 6 m thick with an aggradational style of filling, and in places several bodies lie at the same stratigraphic level in the cliffs (Rygel 2005). Most are associated with heterolithic sheets of sandstone and mudstone that typically thin away from the channel bodies and represent levee and crevasse splay complexes. The channels are filled with grey and red sandstone and mudstone, with local conglomerates composed of reworked carbonate (paleosol) fragments. Within cycles 1 and 3, some large channel bodies contain smaller channel fills, suggesting that the bodies are small dryland valleys. The red muds are poorly stratified and contain scattered calcareous nodules, although petrocalcic horizons were not observed.

Standing trees are restricted to poorly preserved stump casts, and narrow hollow fills with abundant underlying roots marking the former positions of trees, since decayed (Rygel *et al.* 2004). Charcoal and other floral remains in channel bodies are dominated by cordaitaleans, with minor pteridosperms, sphenopsids and lycopsids – the minor constituents typically confined to channel-margin situations (Falcon-Lang 1999, 2003b; Falcon-Lang and Scott 2000). One channel body at 270–274 m, known informally as the "Hebert beds", contains abundant charcoal as well as tetrapod material, shells up to 23 cm long of the unionid bivalve *Archanodon*, and land snails (*Dendropupa*) (Falcon-Lang *et al.* 2004a; Hebert and Calder 2004). Other channel bodies have yielded large arthropod trackways *(Diplichnites)*.

The assemblage represents the alluvial plain of a seasonal dryland traversed by suites of narrow channels that probably had an anastomosing planform (Rygel 2005), as indicated by multiple, narrow channels at similar levels connected by sheet sandstones ("ribbon tiers" of Kraus and Wells 1999). The setting may have resembled that of the Channel Country of Australia with its dryland anastomosing systems and water holes (Gibling *et al.* 1998); Rust *et al.* (1984) also drew on the Channel Country in interpreting the overlying Springhill Mines Formation. The red floodplain muds are immature, cumulative paleosols that formed under a humid seasonal climate (Smith 1991). The abundance of cordaitalean charcoal in some dryland channels suggests that the seasonally dry floodplains were covered with a fire-prone and ecologically stressed assemblage dominated by gymnosperms (Falcon-Lang 2003b; Falcon-Lang *et al.* 2004a). Riparian (channel-margin) settings permitted the local growth of vegetation more akin to the wetlands, and wildfires were common, perhaps promoted by elevated levels of atmospheric oxygen (Robinson 1991). The unusual biota preserved within the "Hebert beds" suggest that the parent channels provided intermittent water holes where organisms continued to flourish during seasonal low-stage flow or more prolonged droughts (Falcon-Lang *et al.* 2004a).

FORMATION-SCALE TRENDS

Cyclic patterns

The 14 cycles recognized in the 915.5 m of the Joggins Formation range in thickness from 16 to 212 m, averaging 65 m. Nine cycles are 16 to 52 m thick, three are 52 to 99 m thick, and the remaining two are 158 m and 212 m thick, respectively. Facies distribution was used to construct a relative base-level curve for the formation (Davies and Gibling 2003; Fig. 7). Unfortunately, the present lack of firm biostratigraphic boundaries and absolute dates for the section precludes the determination of cycle durations and accumulation rates.

Relatively straightforward facies patterns are evident in cycles 1 to 4 and in the basal part of cycle 5. These intervals show a systematic upward succession from open-water facies, which mark major transgressions, to poorly drained and well drained facies, marking regressions. At some levels, thin occurrences of poorly drained facies below open-water intervals herald the base of the next cycle, denoting the onset of base-level rise. Limestones and platy siltstones are prominent, coals are thin and mainly underlie limestones, and the prominent sharp-based sandstones that cap open-water deposits contain many trace fossils. Cycle 5 constitutes the most prolonged period of red bed accumulation, with alternate periods of poorly and well drained conditions and some thin coals in the upper 80 m.

The most marked and sustained lithological change within the formation is the relatively abrupt change from well drained to poorly drained floodplain deposits at the base of cycle 6 (Fig. 7), with a suite of prominent coals; future mapping inland may provide justification for identification of a member boundary at this level. Cycles 6 to 8 are of moderate thickness, and usher in a period when the area was dominated by coastal wetlands (represented by the poorly drained assemblage), with only thin intervals of open-water deposits. Coals are numerous and thick, and many of the most prominent fossil forests are found in this interval (Calder *et al.* in press). Limestones are generally scarce, apart from a thick bed at the base of cycle 8. Cycle 9 commences with a well developed occurrence of open-water facies above the Forty Brine Seam (Skilliter 2001), with limestones, mud drapes, trace fossils (Archer *et al.* 1995), and a large distributary channel body, passing upward into probable lacustrine deposits of stratified red and grey beds.

Cycle 10 (158 m thick) marks the start of a 200 m interval of alternate poorly drained and well drained deposits without open-water sections and limestones (cycles 10–12). Prominent sets of fossiliferous carbonaceous shales (cycle 10) or thick coals (Queen and Joggins seams, cycles 11 and 12) mark cycle bases, but several thin coals delineate minor transgressions within the numbered cycles. Limestones mark the base of cycles 13 and 14 and the Joggins / Springhill Mines formation contact.

Following the abrupt onset of wetland conditions at its base, the Joggins Formation records a punctuated set of advances and retreats of the coastal zone (Fig. 7). A long term balance seems to have been maintained between accommodation creation and sediment supply, such that the study area remained close to the coastal zone for much of Joggins Formation time, with periods of more sustained open-water, wetland or dryland conditions. Thick limestones and thick coals tend to be mutually exclusive (Fig. 7): thin coals underlie many limestones, but thick coals rarely have limestone caps, the most notable exception being the Forty Brine Seam (coal 20). This pattern probably reflects variations in the magnitude and rate of base-level rise. Large base-level rises would tend to flood much of the Cumberland Basin, resulting in reduced sediment flux to open-water areas and the accumulation of fossil-concentrate limestone. Rapid base-level rise would tend to outpace the rate of peat accumulation, resulting in thin peats only. In contrast, thick peats (coals) probably accumulated where modest or slow base-level rise caused prolonged freshwater ponding inland of transgressive shorelines (Kosters and Suter 1993). A rheotrophic (groundwater-influenced), planar character is the hallmark of the coals of the Joggins Formation (Hower *et al.* 2000; Calder *et al.* in press).

Sand accumulated preferentially in the poorly drained floodplain assemblage, where coastal bays formed repositories for coarse detritus. In these areas, sand deposition was strongly focused into sheets, scour fills and vegetation shadows where forested landscapes slowed overtopping flood waters (Rygel *et al.* 2004). In contrast, shoreface and delta-lobe sands of the open-water assemblage are relatively thin, and dryland alluvial plains of the well drained assemblage include thick mud intervals, with sands restricted to small channels, levees and splays.

Sequence stratigraphy

Many Carboniferous cycles (or cyclothems) reflect sea-level fluctuations in the order of tens of metres in amplitude caused by the accumulation and melting of ice sheets in high southern latitudes (Crowley and Baum 1991; Maynard and Leeder 1992; Soreghan and Giles 1999). Glacioeustasy in Carboniferous basins has commonly generated stacked Exxon-type sequences with prominent sequence boundaries, valley fills, maximum flooding surfaces and systems tracts (Hampson *et al.* 1999; Gibling *et al.* 2004). Such expressions of glacioeustasy may be modified under conditions of unusually rapid subsidence, as at Joggins, where the record of sea-level fall may be suppressed and the record of sea level rise may be strongly augmented, rendering the basin susceptible to basin-wide flooding events marked by fauna-rich horizons. At Joggins in the western Cumberland Basin, rapid subsidence reflects the extensional basin setting, coupled with active withdrawal of Windsor salt (Waldron and Rygel 2005). In consequence, the Joggins cycles display what we consider to be a "tectonically controlled architecture" characterized by multiple flooding surfaces (Davies and Gibling 2003), including coal and fossiliferous limestone at cycle bases that mark important episodes of sea-level rise. The overlying strata lack clear evidence for sea-level fall such as profound valley incision or well developed paleosols, although sharp-based shoreface and delta-lobe sandstones may reflect in part modest falls of sea-level (similar to those documented by Plint 1988). Large channel bodies appear to represent distributary channels and meandering rivers within a coastal plain setting, rather than recording profound basinward facies shifts that could have emplaced proximal (braided or low-sinuosity) river deposits over marine deposits. Small valley fills in cycles 2 and 3 appear to lie within red bed intervals, and need not imply major basinward shifts of facies belts linked to base-level lowering. The Joggins cycles may record glacial-interglacial transitions manifested in an equatorial setting, periods of varied subsidence rate as faults moved and salt migrated, variations in sediment flux, or combinations of all three. However, regardless of the ultimate cause of the cycles, their unusual architectural features are inferred to reflect extremely rapid subsidence, in accord with observations in other high-subsidence settings worldwide (Davies and Gibling 2003).

In the absence of sequence boundaries, the Joggins cycles can be categorized as parasequence sets, in which the predominant coastal-plain facies are composed of numerous thin parasequences and bounded by flooding surfaces marked by limestones, coals and carbonaceous shales. Thin drab intervals at cycle tops mark retrogradational parasequence sets that culminated in profound flooding at the start of the overlying cycle. As coastal rivers re-advanced, thick progradational parasequence sets accumulated where tropical wetland deposits filled marine embayments, until a dryland alluvial plain was established. Thereafter, alluvial red beds accumulated, flooding surfaces become fewer and less prominent, and trends of pro-, retro- or aggradation are difficult to establish.

Because subsidence was so rapid, a remarkably complete record of environments and the organisms that inhabited them is preserved in the Joggins cycles. In particular, prolonged periods of wetland conditions, during which sedimentation kept pace with subsidence, promoted the repeated generation and burial of forests at many levels (Waldron and Rygel 2005).

CONCLUSIONS

The Joggins Formation in the famous fossil cliffs along Chignecto Bay, Nova Scotia, has been completely remeasured for the first time since the mid 1800s. We present a visual log of 915.5 m of strata and describe revised formation boundaries (formalized in Calder *et al.* 2005). The formation comprises stacked transgressive–regressive cycles that typically commence with open-water facies with a restricted-marine fauna, overlain by prograding coastal and alluvial deposits. The main levels of standing trees, predominantly lycopsids, were entombed where distributary channels brought sand into coastal wetlands, and some trees contain tetrapod and invertebrate fossils. Fire-prone cordaitalean (gymnosperm) forests covered the alluvial plains and basin-margin uplands. The cycles may reflect tectonic or glacioeustatic events, or variations in sediment flux. Within the cycles, the predominance of flooding surfaces and the apparent absence of lowstand exposure surfaces reflect rapid subsidence of the Cumberland Basin, controlled by active basin-margin faults and salt withdrawal.

Joggins is an unusual geological locality, and the many scientists, university and school groups, and enthusiastic members of the public who visit the cliffs each year bear testimony to the enduring fascination of this special site. We offer here an illustrated log and foreshore map of the Joggins Formation, along with a brief summary of especially interesting features of the strata, to encourage continued interest in the rocks and fossils. Given the huge and frequently overwhelming amount of rock on display, we hope that the log will serve as a simple guide to visitors with some knowledge of geology, as well as allowing specialists to mark precisely the locations of new fossil discoveries. As Lyell and Dawson realized more than 150 years ago, Joggins is all about ancient landscapes inhabited by remarkable plants and animals, for the fossils are at their most compelling when we can imagine them in the environments where they lived more than 300 million years ago.

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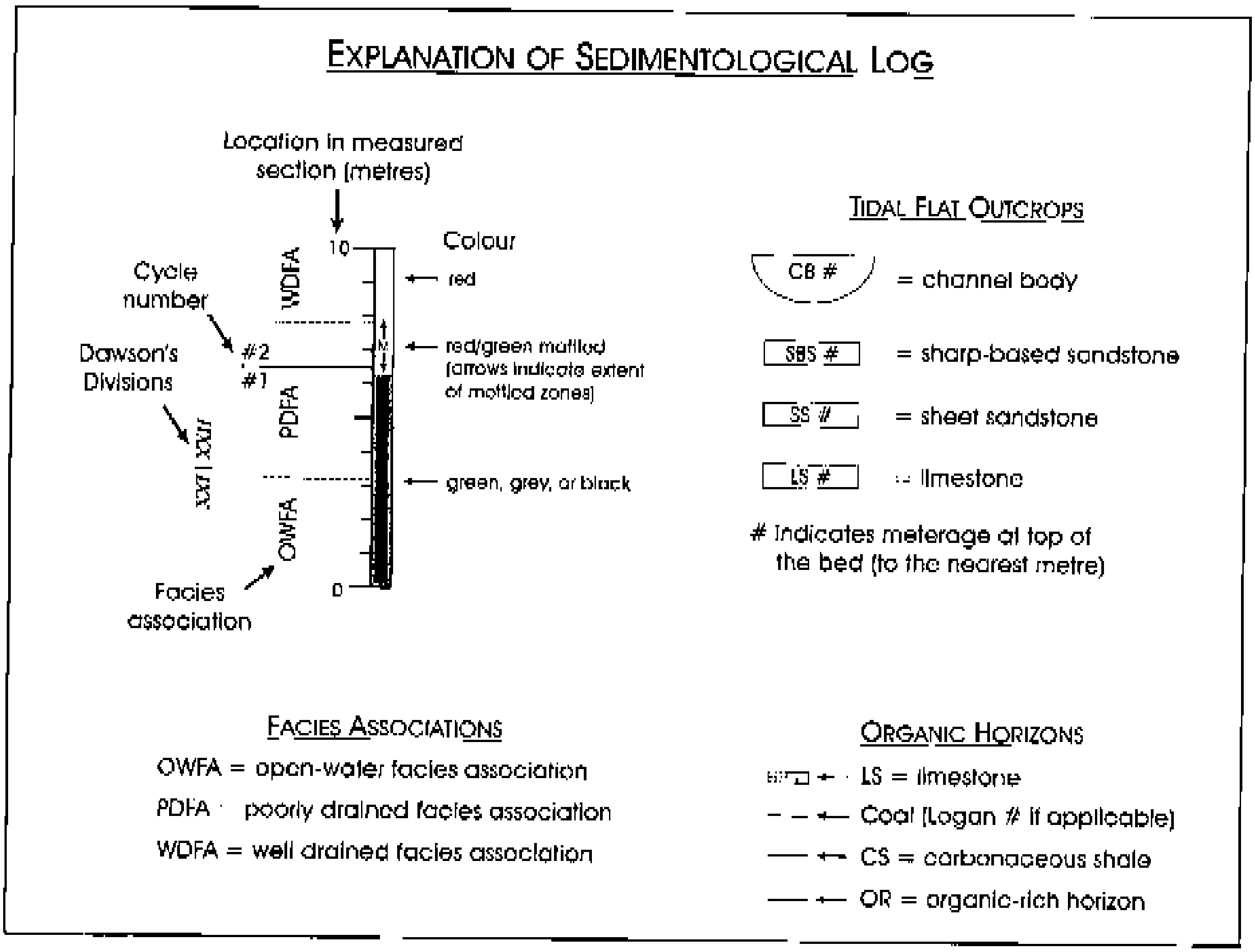
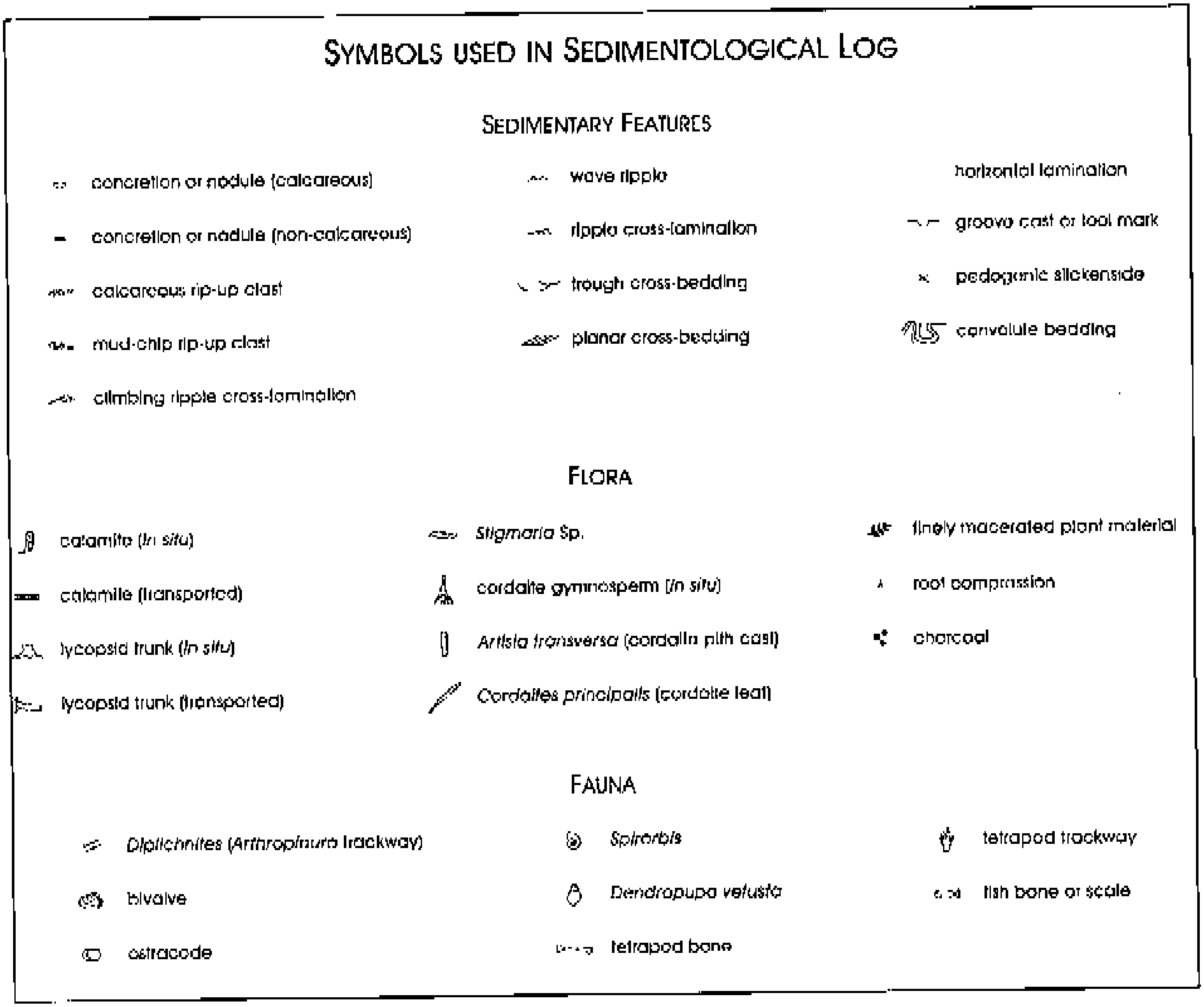
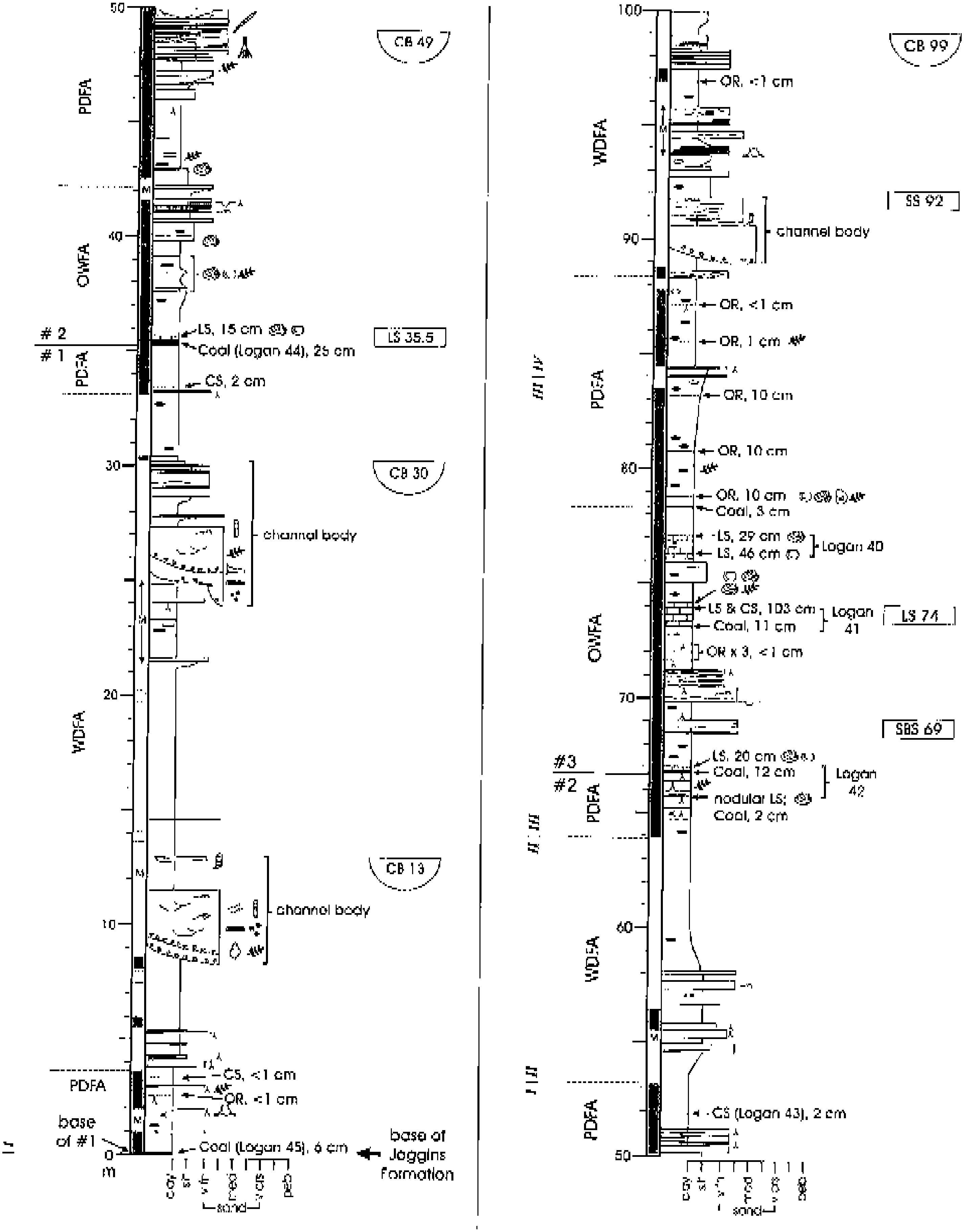
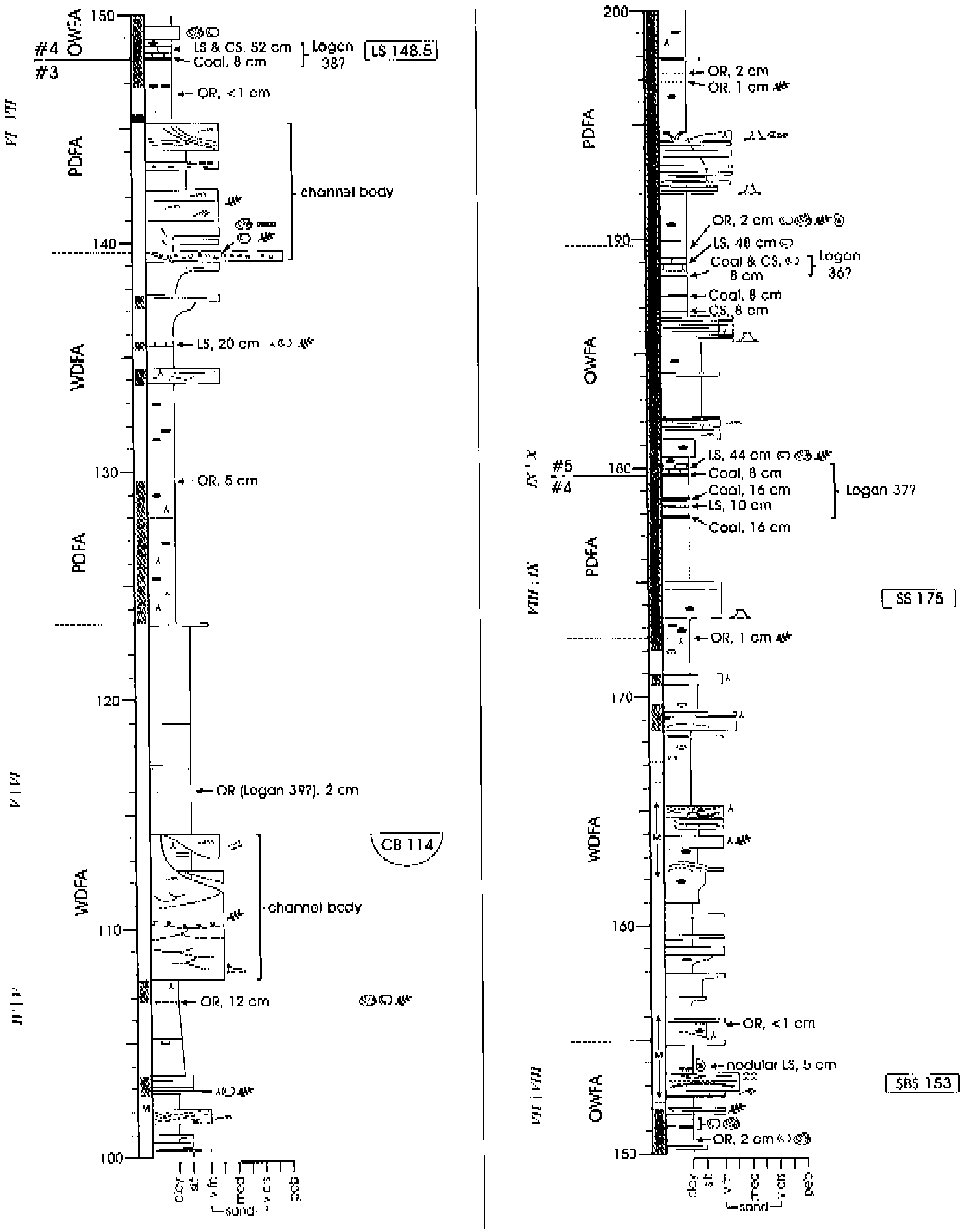
APPENDIX A

Measured section of the Joggins Formation from Lower Cove to south of Bell's Brook.

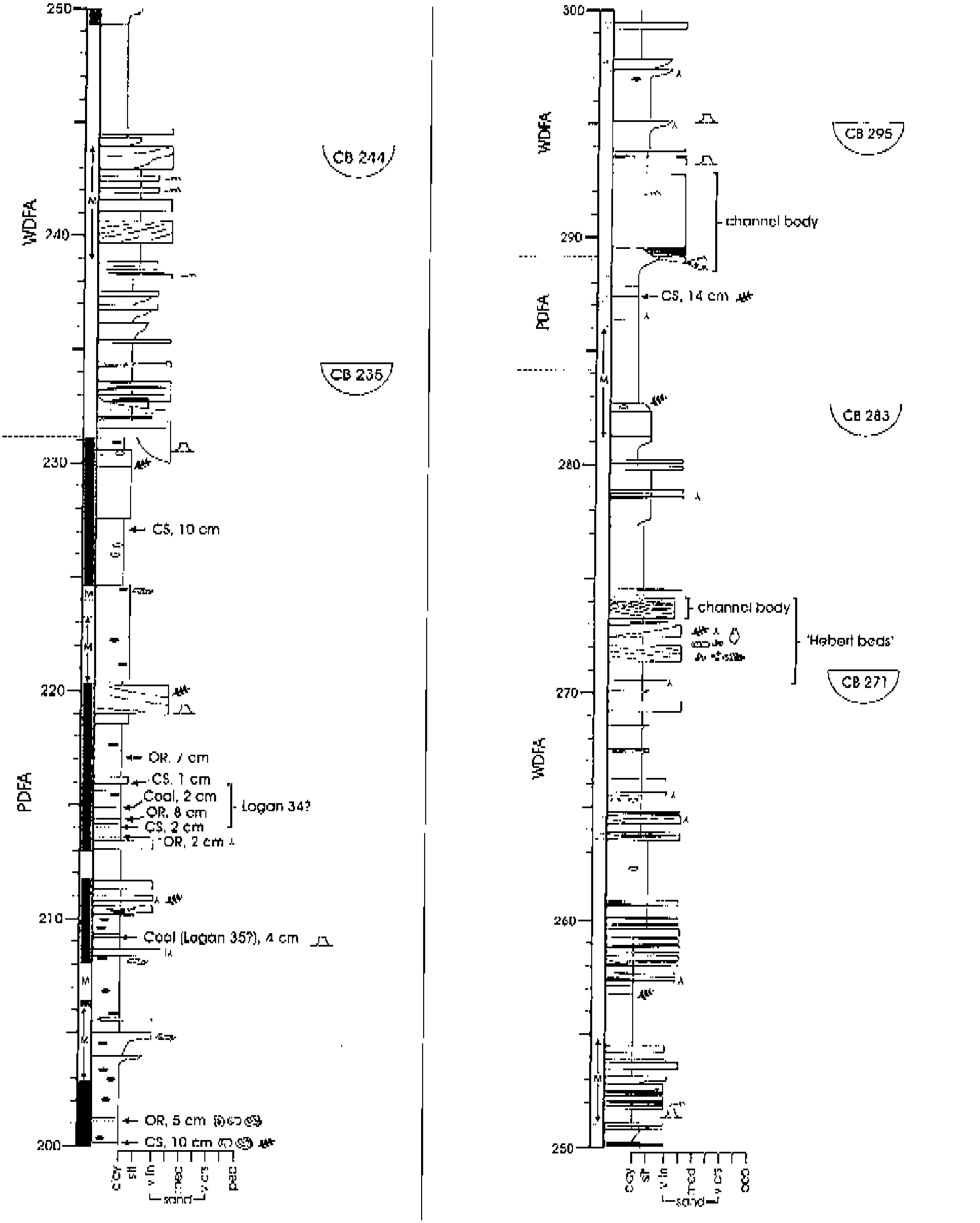


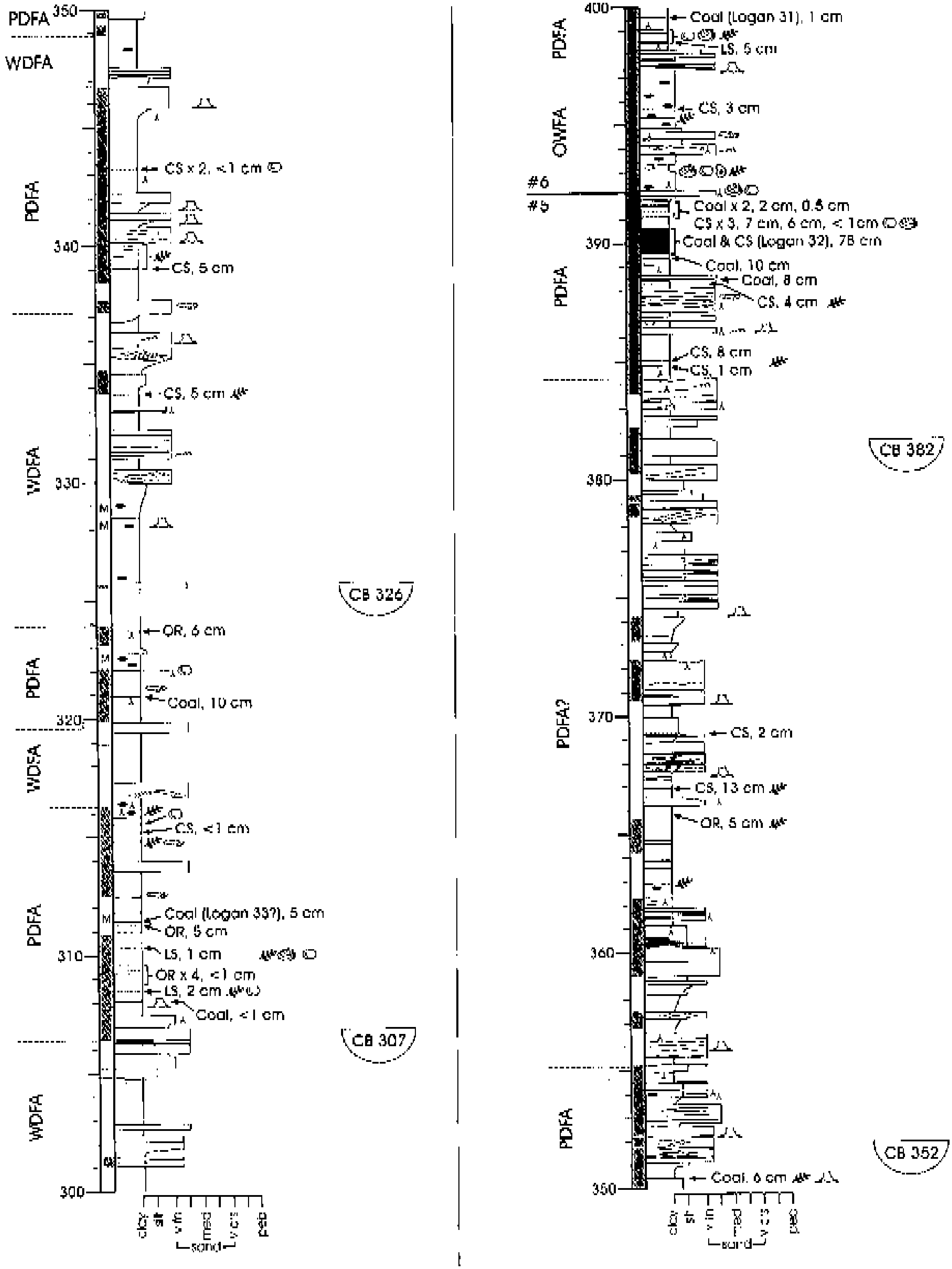

Symbols used in Sedimentological Log
Sedimentary Features
concretion or nodule (calcareous)
concretion or nodule (non-calcareous)
calcareous rip-up clast
mud-chip rip-up clast
climbing ripple cross-lamination
wave ripple
ripple cross-lamination
trough cross-bedding
planar cross-bedding
horizontal lamination
groove cast or tool mark
pedogenic slickenside
convolute bedding
Flora
calamite (in situ)
calamite (transported)
lycopsid trunk (in situ)
lycopsid trunk (transported)
Stigmaria sp.
cordaite gymnosperm (in situ)
Artisia transversa (cordaitn pith cast)
Cordaites principalis (cordaite leaf)
finely macerated plant material
root compression
charcoal
Fauna
Diplichnites (Arthropleura trackway)
bivalve
ostracode
Spirorbis
Dendropupa vetusta
tetrapod bone
tetrapod trackway
fish bone or scale


CB 49
PDFA
OWFA
LS, 15 cm
2
1
Coal (Logan 44), 25 cm
LS 35.5
PDFA
CS, 2 cm
CB 30
channel body
WDFA
CB 13
channel body
PDFA
CS, <1 cm
OR, <1 cm
base of #1
Coal (Logan 45), 6 cm
base of Joggins Formation
0 m
10
20
30
40
50
cay
slt
v.fn
med
v.crs
peb
sand
CB 99
OR, <1 cm
WDFA
SS 92
channel body
OR, <1 cm
OR, 1 cm
PDFA
OR, 10 cm
OR, 10 cm
OR, 10 cm
Coal, 3 cm
LS, 29 cm
LS, 46 cm
Logan 40
LS & CS, 103 cm
Coal, 11 cm
Logan 41
LS 74
OWFA
OR x 3, <1 cm
SBS 69
#3
#2
LS, 20 cm
Coal, 12 cm
nodular LS;
Coal, 2 cm
Logan 42
PDFA
WDFA
CS (Logan 43), 2 cm
PDFA
50
60
70
80
90
100
sand

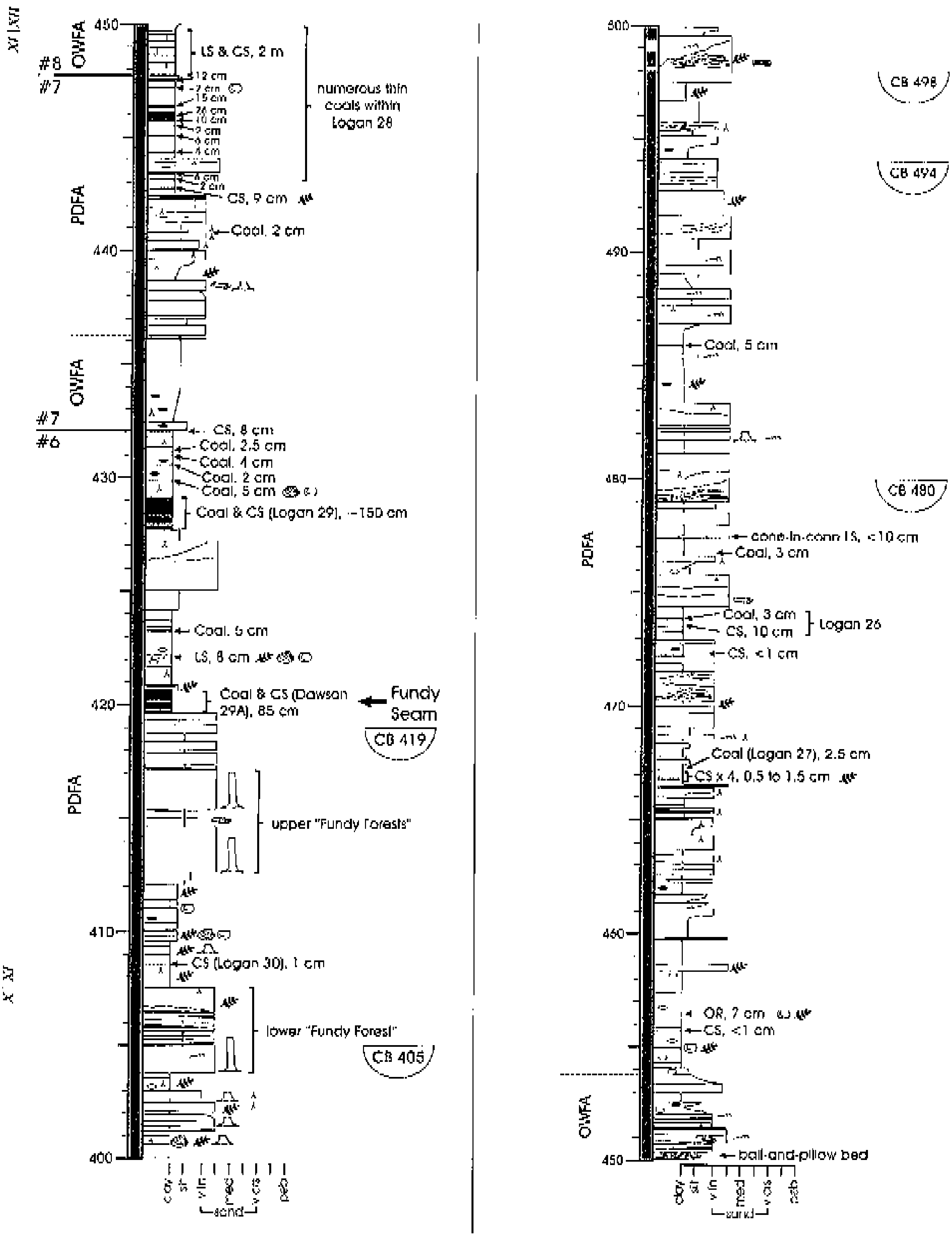


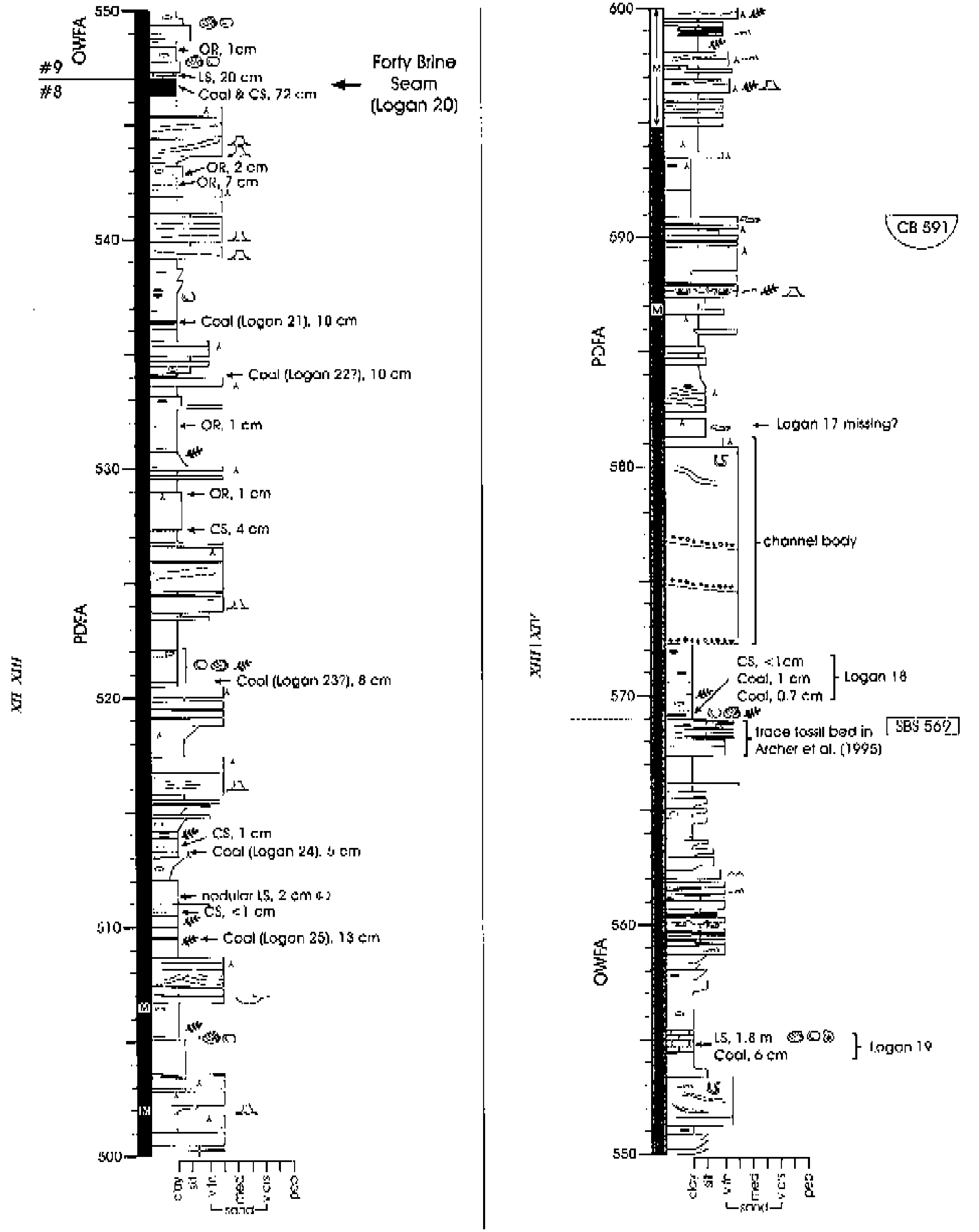
OWFA
#4
#3
LS & CS, 52 cm
Coal, 8 cm
Logan 38?
LS 148.5
OR, <1 cm
PDFA
channel body
LS, 20 cm
WDFA
OR, 5 cm
PDFA
OR (Logan 39?), 2 cm
CB 114
WDFA
channel body
OR, 12 cm
clay
silt
v fn
med
v cs
peb
sand
150
140
130
120
110
100
PDFA
OR, 2 cm
OR, 1 cm
OR, 2 cm
LS, 40 cm
Coal & CS, 8 cm
Logan 36?
Coal, 8 cm
CS, 8 cm
OWFA
LS, 44 cm
#5
#4
Coal, 8 cm
Coal, 16 cm
LS, 10 cm
Coal, 16 cm
Logan 37?
PDFA
SS 175
OR, 1 cm
WDFA
OR, <1 cm
nodular LS, 5 cm
SBS 153
OWFA
OR, 2 cm
200
190
180
170
160
150


250
240
230
220
210
200
WDFA
PDFA
CB 244
CB 235
CS, 10 cm
OR, 7 cm
CS, 1 cm
Coal, 2 cm
OR, 8 cm
CS, 2 cm
OR, 2 cm
Logan 34?
Coal (Logan 35?), 4 cm
OR, 5 cm
CS, 10 cm
clay
silt
v fn
med
v crs
peb
sand
300
290
280
270
260
250
WDFA
PDFA
WDFA
CB 295
channel body
CS, 14 cm
CB 283
channel body
'Hebert beds'
CB 271
clay
silt
v fn
med
v crs
peb
sand

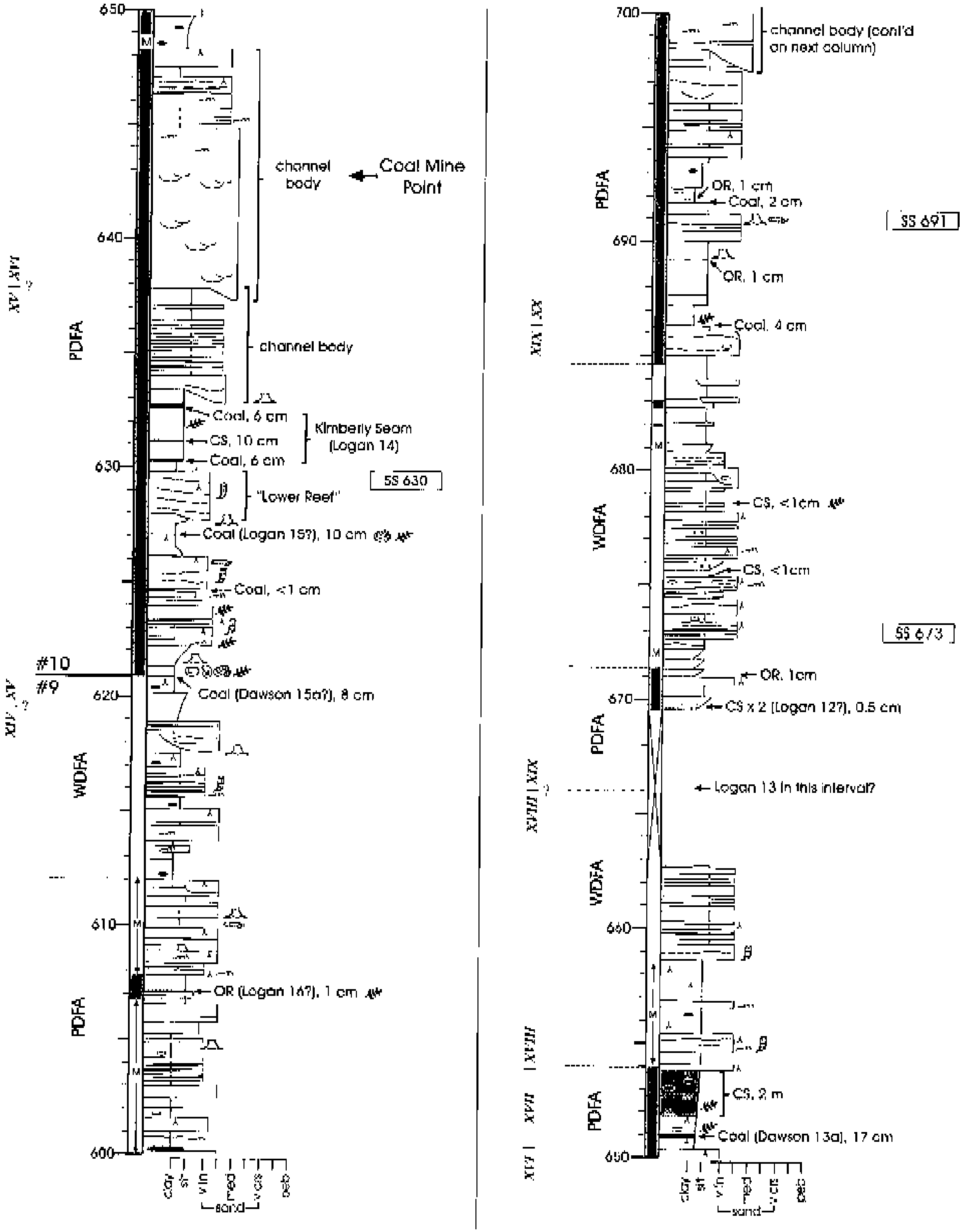


PDFA
350
WDFA
CS x 2, <1 cm
PDFA
340
CS, 5 cm
CS, 5 cm
WDFA
330
CB 326
OR, 6 cm
PDFA
Coal, 10 cm
320
WDFA
CS, <1 cm
Coal (Logan 33?), 5 cm
OR, 5 cm
PDFA
310
LS, 1 cm
OR x 4, <1 cm
LS, 2 cm
Coal, <1 cm
CB 307
WDFA
300
clay
silt
v fn
med
v crs
peb
sand
400
Coal (Logan 31), 1 cm
PDFA
LS, 5 cm
CS, 3 cm
OWFA
#6
#5
Coal x 2, 2 cm, 0.5 cm
CS x 3, 7 cm, 6 cm, < 1cm
390
Coal & CS (Logan 32), 78 cm
Coal, 10 cm
Coal, 8 cm
PDFA
CS, 4 cm
CS, 8 cm
CS, 1 cm
CB 382
380
370
PDFA?
CS, 2 cm
CS, 13 cm
OR, 5 cm
360
PDFA
CB 352
Coal, 6 cm
350
clay
silt
v fn
med
v crs
peb
sand

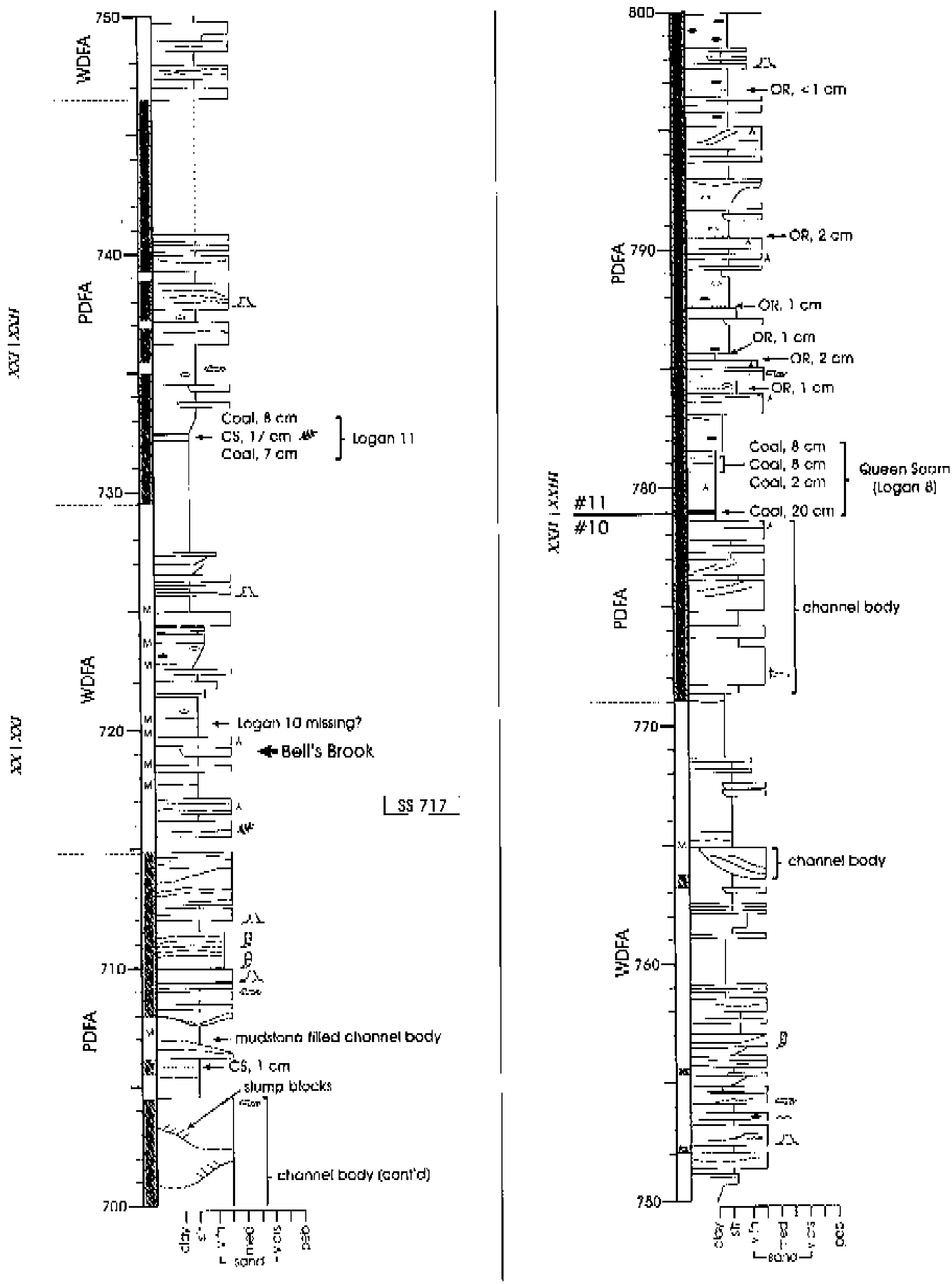

XI | XII
450
OWFA
#8
#7
LS & CS, 2 m
12 cm
~7 cm
15 cm
26 cm
10 cm
2 cm
6 cm
4 cm
4 cm
2 cm
numerous thin coals within Logan 28
CS, 9 cm
PDFA
Coal, 2 cm
440
OWFA
#7
#6
CS, 8 cm
Coal, 2.5 cm
Coal, 4 cm
Coal, 2 cm
Coal, 5 cm
430
Coal & CS (Logan 29), ~150 cm
Coal, 5 cm
LS, 8 cm
Coal & CS (Dawson 29A), 85 cm
Fundy Seam
420
CB 419
PDFA
upper "Fundy Forests"
410
CS (Logan 30), 1 cm
lower "Fundy Forest"
CB 405
X | XI
400
clay
silt
v fin
med
v crs
peb
sand
500
CB 498
CB 494
490
Coal, 5 cm
480
CB 480
cone-in-cone LS, <10 cm
Coal, 3 cm
PDFA
Coal, 3 cm
CS, 10 cm
Logan 26
CS, <1 cm
470
Coal (Logan 27), 2.5 cm
CS x 4, 0.5 to 1.5 cm
460
OR, 2 cm
CS, <1 cm
OWFA
450
ball-and-pillow bed
clay
silt
v fin
med
v crs
peb
sand



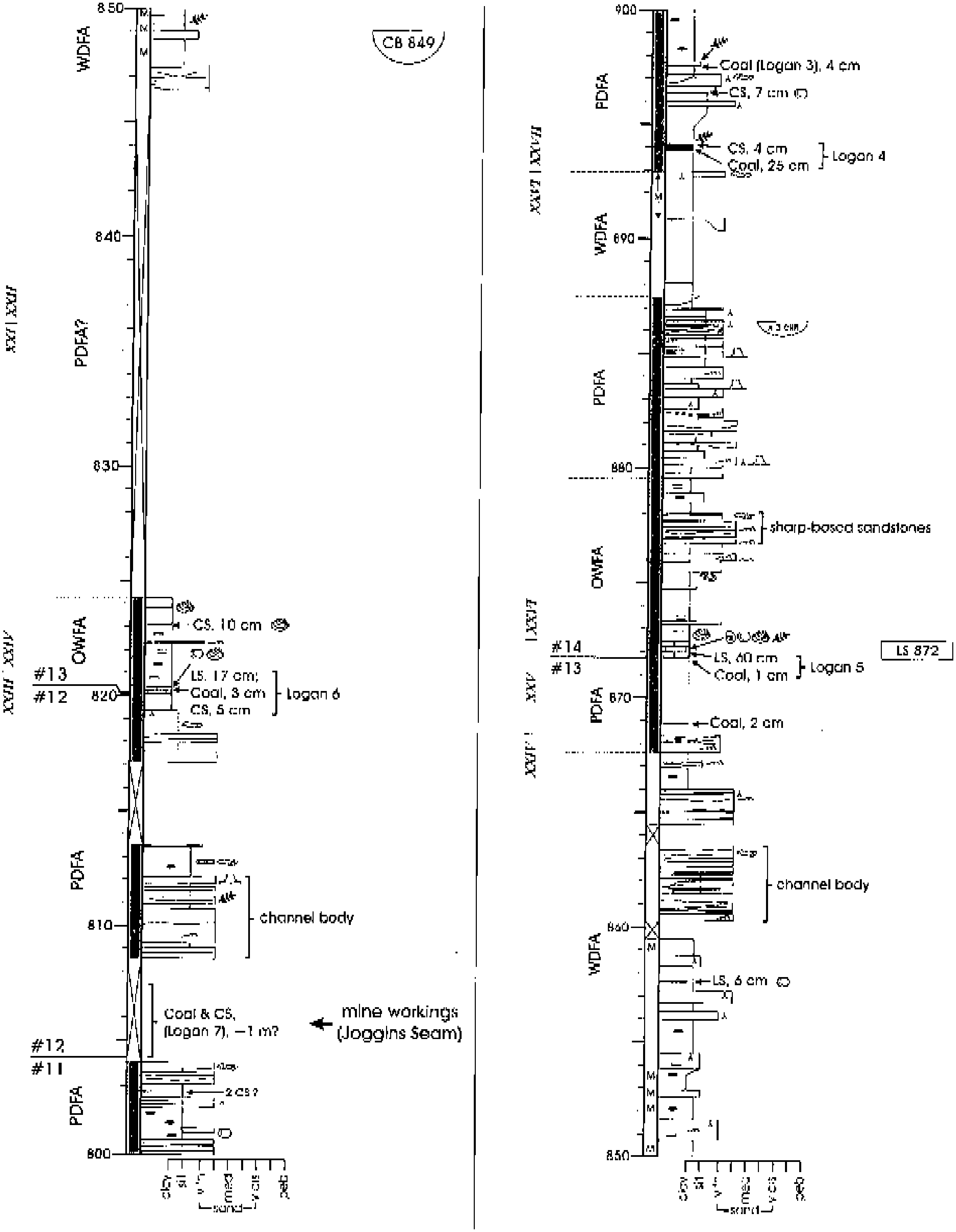
OWFA
#9
#8
OR, 1cm
LS, 20 cm
Coal & CS, 72 cm
Forty Brine Seam (Logan 20)
OR, 2 cm
OR, 7 cm
Coal (Logan 21), 10 cm
Coal (Logan 22?), 10 cm
OR, 1 cm
OR, 1 cm
CS, 4 cm
PDFA
Coal (Logan 23?), 8 cm
CS, 1 cm
Coal (Logan 24), 5 cm
nodular LS, 2 cm
CS, <1 cm
Coal (Logan 25), 13 cm
550
540
530
520
510
500
clay
silt
v.fn
med
v.crs
peb
sand
600
590
580
570
560
550
CB 591
PDFA
Logan 17 missing?
channel body
CS, <1cm
Coal, 1 cm
Coal, 0.7 cm
Logan 18
trace fossil bed in Archer et al. (1995)
SBS 569
OWFA
LS, 1.8 m
Coal, 6 cm
Logan 19

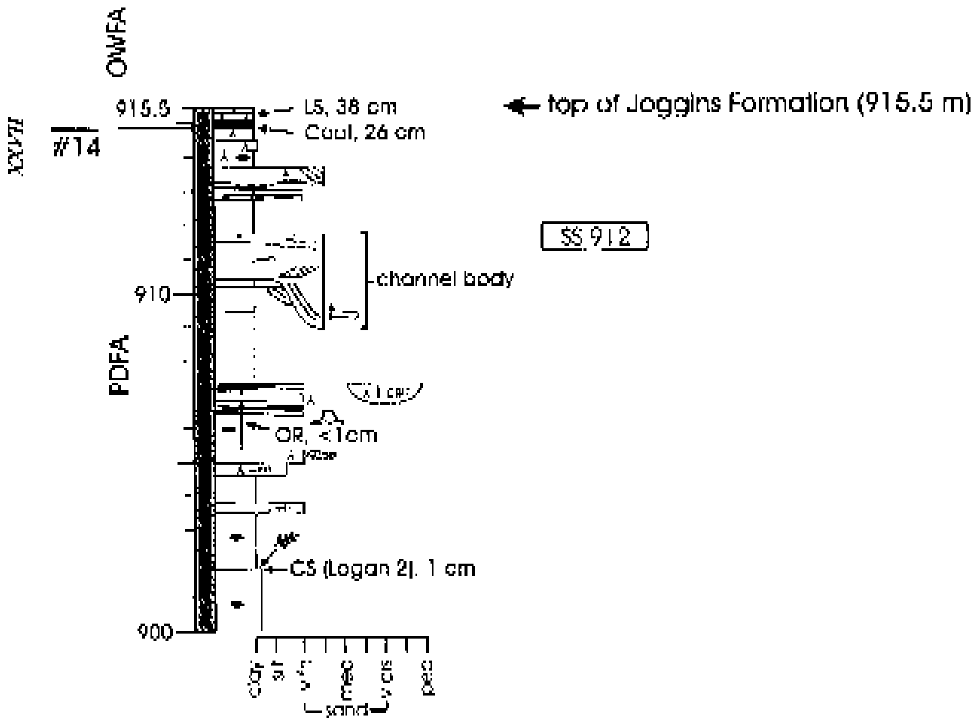


650
640
630
620
610
600
XV | XVI ?
PDFA
XIV | XV ?
WDFA
PDFA
#10
#9
M
channel body
Coal Mine Point
channel body
Coal, 6 cm
CS, 10 cm
Coal, 6 cm
Kimberly Seam (Logan 14)
SS 630
"Lower Reef"
Coal (Logan 15?), 10 cm
Coal, <1 cm
Coal (Dawson 15a?), 8 cm
OR (Logan 16?), 1 cm
clay
silt
v fn
med
v crs
peb
sand
700
690
680
670
660
650
channel body (cont'd on next column)
PDFA
OR, 1 cm
Coal, 2 cm
SS 691
OR, 1 cm
Coal, 4 cm
XIX | XX
WDFA
CS, <1cm
CS, <1cm
SS 673
OR, 1cm
CS x 2 (Logan 12?), 0.5 cm
PDFA
XVIII | XIX ?
Logan 13 in this interval?
WDFA
XVIII
XVII
XVI
PDFA
CS, 2 m
Coal (Dawson 13a), 17 cm



750
740
730
720
710
700
WDFA
PDFA
WDFA
PDFA
XXI | XXII
XX | XXI
Coal, 8 cm
CS, 17 cm
Coal, 7 cm
Logan 11
Logan 10 missing?
Bell's Brook
SS 717
mudstone filled channel body
CS, 1 cm
slump blocks
channel body (cont'd)
clay
silt
v.fn
med
v.crs
peb
sand
800
790
780
770
760
750
PDFA
PDFA
WDFA
OR, <1 cm
OR, 2 cm
OR, 1 cm
OR, 1 cm
OR, 2 cm
OR, 1 cm
Coal, 8 cm
Coal, 8 cm
Coal, 2 cm
Coal, 20 cm
Queen Seam
(Logan 8)
#11
#10
XXII | XXIII
channel body
channel body
clay
silt
v.fn
med
v.crs
peb
sand


CB 849
WDFA
PDFA?
OWFA
PDFA
#13
#12
#12
#11
CS, 10 cm
LS, 17 cm;
Coal, 3 cm
CS, 5 cm
Logan 6
channel body
Coal & CS,
(Logan 7), ~1 m?
mine workings
(Joggins Seam)
2 CS ?
850
840
830
820
810
800
clay
silt
v fn
med
v crs
peb
sand
900
890
880
870
860
850
Coal (Logan 3), 4 cm
CS, 7 cm
CS, 4 cm
Coal, 25 cm
Logan 4
sharp-based sandstones
#14
#13
LS, 60 cm
Coal, 1 cm
Logan 5
LS 872
Coal, 2 cm
channel body
LS, 6 cm



OWFA
PDFA
XXVII
#14
915.5
910
900
LS, 38 cm
Coal, 26 cm
top of Joggins Formation (915.5 m)
SS 912
channel body
OR, <1cm
CS (Logan 2), 1 cm
clay
silt
v fn
med
v crs
peb
sand

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NATURAL GEOMORPHIC VARIABILITY RECORDED IN A HIGH-ACCOMMODATION SETTING: FLUVIAL ARCHITECTURE OF THE PENNSYLVANIAN JOGGINS FORMATION OF ATLANTIC CANADA

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ABSTRACT: **The varied form and architecture of suites of channel bodies is a product of the intrinsic geomorphic variability of the drainage network as well as extrinsic factors such as climate, eustasy, and tectonics. We investigated the balance between intrinsic and extrinsic controls on the basis of eighty two fluvial-channel bodies in the Pennsylvanian Joggins Formation, which is superbly exposed along the Bay of Fundy in Nova Scotia, Atlantic Canada. Based on their internal architecture and three-dimensional form, these channel bodies were divided into fixed, meandering, and multistory types, and each type is present in both coastal wetland and inland floodplain facies associations. Although the facies associations are organized into cyclic packages that probably represent relative changes in base level, the channel-body types are not positioned systematically within the cycles. Apart from a small group of unusually deep meandering channels within the wetland deposits, comparison of paleochannel depth and width/depth shows that active channels throughout the formation were similar in size and shape. The multistory bodies are small channel belts or valley fills that do not appear to record the basinward advance of facies belts but rather are genetically linked with the associated floodplain deposits. These observations suggest that the varied form of the Joggins channel bodies largely reflects the geomorphic variability of the original drainage network, with the largest, meandering channels in the coastal zone. Preservation of a representative drainage network was probably facilitated by rapid subsidence on bounding faults, enhanced by high-frequency, low-magnitude subsidence events caused by salt withdrawal. The effect of extrinsic factors on channel type and geometry appears to have been modest in this high-subsidence setting.**

INTRODUCTION

Understanding the external form and internal architecture of fluvial-channel bodies is crucial in order to fully exploit their potential as hydrocarbon reservoirs, aquifers, hosts for economic mineral deposits, and sites for carbon sequestration. In interpreting suites of channel deposits, a key question is whether their varied form and architecture mainly represents the original geomorphic variability of drainage networks across a landscape at a given time (Tye 2004), or whether it mainly represents fluctuations in forcing factors such as climate, eustasy, and tectonics, the effects of which are linked to accommodation, sediment supply, and the equilibrium profile of the rivers. Some studies have inferred a link between accommodation and channel-body form (Shanley and McCabe 1993, 1994; Van Wagoner 1995), but relatively few studies have drawn upon datasets comprehensive enough to explore this linkage (Adams and Bhattacharya 2005). Additionally, the form of channel bodies may be governed by local factors such as bank strength and aggradational events, especially in inland alluvial settings (Gibling 2006).

Although outcrop-based studies have the potential to help resolve the relative importance of inherent geomorphic variability and external controls, collection of the necessary data is typically hampered by limited exposure or subsurface control, insufficient paleoflow data, and inadequate constraints on the aspect ratio (width/thickness) of channel bodies. Instantaneous channel dimensions are also difficult to determine in complex channel deposits. Three-dimensional seismic data are rapidly advancing our ability to visualize fluvial deposits in the subsurface (Posamentier 2001; Carter 2003), but presently such studies cannot image many of the small-scale architectural features seen in outcrop.

The present study documents the geometry and architecture of 82 channel bodies in a coastal exposure of the Pennsylvanian Joggins Formation, which was deposited in the Cumberland Basin of Nova Scotia. These channel bodies crop out in an almost completely exposed and accessible coastal area, and they can be positioned within a detailed measured section, which allows their geometry and architecture to be linked precisely with their position within stacked transgressive–regressive cycles (parasequence sets). The size and quality of this dataset permits a comparison of dimensions and aspect ratios for different types of channel body, as well as for the depth of the parent channels, across inland and coastal paleogeomorphic settings. The results suggest that, although forcing factors undoubtedly influenced the system, Joggins channel bodies collectively represent much of the range of variation of the original drainage network, which is unusually well preserved in a basin where rapid subsidence along bounding faults was enhanced by salt withdrawal at depth.

GEOLOGICAL SETTING

The Pennsylvanian Joggins Formation was deposited within the Cumberland Basin of Nova Scotia, a fault-bounded depocenter within the regional Maritimes Basin of Atlantic Canada (Davies and Gibling

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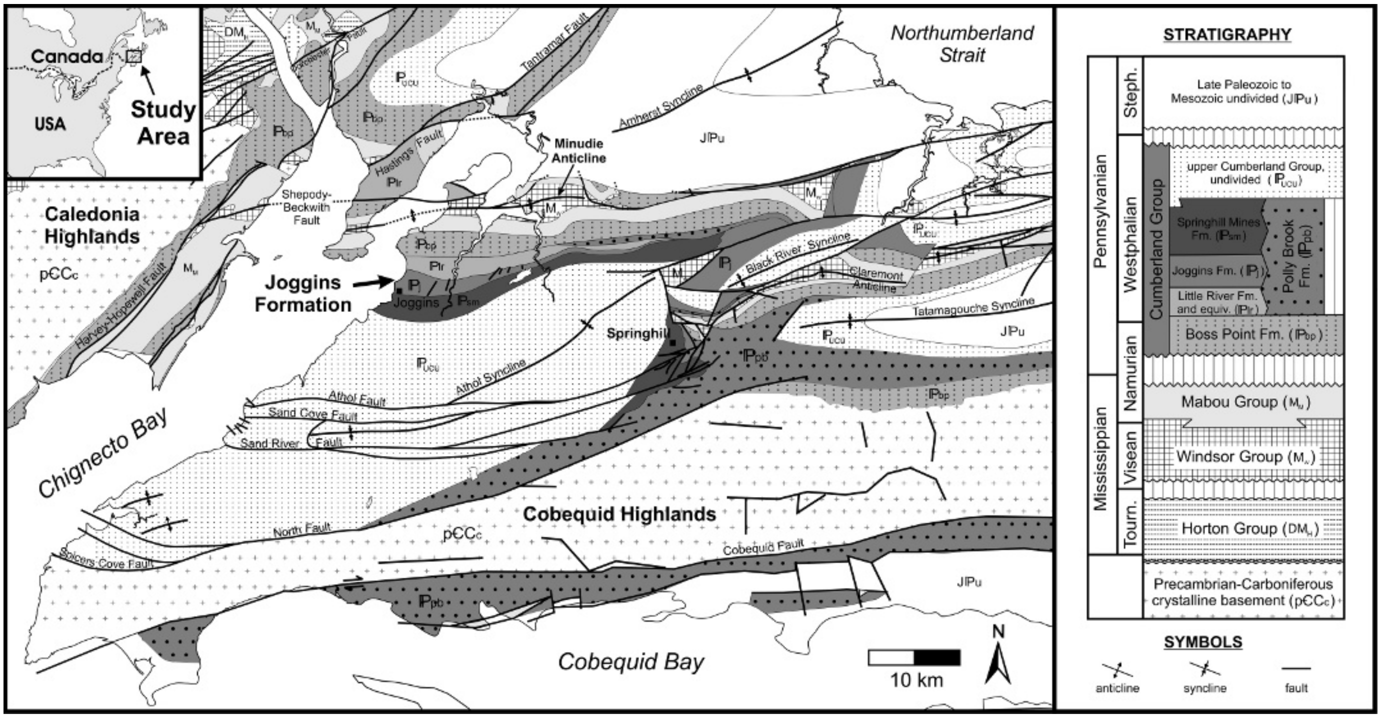


FIG. 1.—Geologic map of the western Cumberland Basin (Ryan et al. 1990; Keppie 2000; New Brunswick Department of Natural Resources and Energy 2000; St. Peter 2001).

2003; Davies et al. 2005). A poorly constrained and complex history of dip-slip and strike-slip motion facilitated the accumulation of 8 km of Carboniferous strata in the basin (Nance 1987; Browne and Plint 1994).

The Joggins Formation is preserved on the northern limb of the Athol Syncline, the dominant structural feature of the western Cumberland Basin (Fig. 1). This 25-km-wide by 75-km-long syncline is bounded by the Caledonia and Cobequid Highlands massifs to the south and west, the salt-cored Minudie Anticline to the north, and two unnamed salt diapirs to the east (Calder 1994). Thinning of stratal units against these salt structures indicates that halokinesis was syndepositional and contributed greatly to the creation of local accommodation in the Athol Syncline, particularly in the early Pennsylvanian (Waldron and Rygel 2005). Although age control is poor, the 915.5-m-thick Joggins Formation (Figs. 2, 3) was likely deposited during ~ 1 My in the early Langsettian (Menning et al. 2000; Utting and Wagner 2005). This phase of subsidence in the Cumberland Basin ranks among the most rapid recorded in Pennsylvanian coalfields (Calder 1991). Constantly hewn and renewed by the world's highest tides, the Joggins Formation is continuously exposed in a gently dipping coastal section with sea cliffs 20 m high and an intertidal zone up to 500 m wide (Fig. 2).

Facies Associations, Cycles, and Sequence Stratigraphy.

Joggins Formation strata have been divided into three facies associations and fourteen cycles (Figs. 2, 3; Davies and Gibling 2003; Davies et al. 2005). Cycles range from 16 to 212 m in thickness and may record Milankovitch-scale glacioeustatic fluctuations within a rapidly subsiding basin (Davies and Gibling 2003; Falcon-Lang 2003a). Understanding the magnitude and signature of climate change in the Joggins Formation has proven to be problematic because paleosols are immature, cumulative alluvial types (Smith 1991; Davies and Gibling 2003) of little paleoclimatic significance, and because the lack of correlative sections precludes disentangling topographic and climatic variations in drainage conditions. Although climate change likely occurred during deposition of these cyclic strata, obvious signatures of climate change probably have been masked by the rapid subsidence and changes in relative sea level that affected this area in the Pennsylvanian.

A typical cycle (Fig. 4) commences with a pronounced flooding event, as recorded by the fresh to brackish facies of the open-water (OW) association. This association represents only 9% of the formation, but the flooding events covered much of the basin, as indicated by floral evidence (Falcon-Lang 2003a) and the lateral extent of flooding surfaces (Copeland 1959; Calder 1991). At these times, the basin was at least periodically marine influenced (Archer et al. 1995; Skilliter 2001). These incursions probably entered the basin from the northeast (Gibling et al. 1992), and facies belts likely extend no farther than a few tens of kilometers in any direction (the adjacent highlands are ~ 60 km apart).

The poorly drained floodplain (PDF) association represents wetlands that flourished in coastal areas with high water tables, as well as locally inland. This association constitutes 56% of the formation, and comprises drab-colored mudrock, channel and sheet sandstones, coal, and thin lacustrine limestones (Davies and Gibling 2003; Davies et al. 2005). The thickest PDF deposits formed during progradation of the floodplain after a cycle-bounding flood event, but thinner, retrogradational and aggradational occurrences are present locally.

The well drained floodplain (WDF) association represents a floodplain that was above the water table for at least part of the year. Well drained deposits make up 31% of the formation, and comprise red mudrock, channel and sheet sandstones, and rare (thin) limestones and carbonaceous shale (Davies and Gibling 2003; Davies et al. 2005). The WDF probably represents progradational and aggradational phases of dryland floodplain sedimentation.

Based on the measured section (Davies et al. 2005) and aerial photographs of the coastal exposure (Fig. 2), floodplain deposits in the well drained and poorly drained floodplain successions contain similar proportions of sheet sandstone (25% and 24%, respectively) and have comparable numbers of channel bodies per unit thickness (13.0 and 8.7


LEGEND
11
Cycle number and approximate extent
96
stratigraphic position of sandstone channel bodies
A
access
*stratigraphic up is to the top of the page
N
200 m
Springhill Mines Fm.
Joggins Fm.
14
13
12
11
10
9
8
7
6
5
4
3
2
1
849
705
Coal Mine Point (648)
611
619
598
581
591
553
569
535
541A,B
499A,B
498
494C
480
464
465A
470
465B
419
419.5
405
398
384
382
383
386
326
348
352
328
314
320B
307
302
295
293B
291
271
244
235A,B
167A,B
114
99
splay adjacent to 92
49A,B
30
13
45° 42'
cliff face
Joggins Fm.
Little River Fm
tidal flat
low tide level
64° 26'
Chignecto Bay (Bay of Fundy)

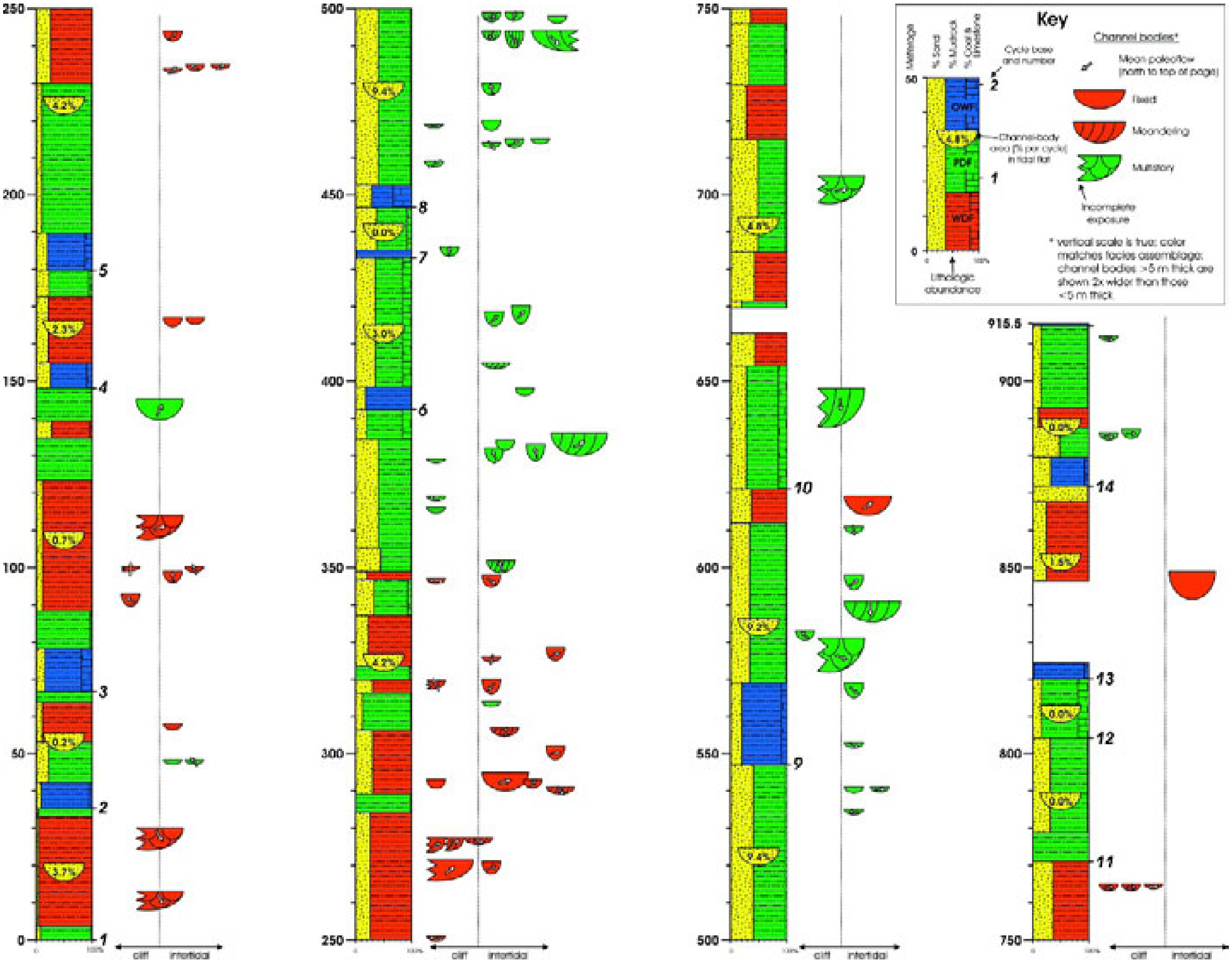


FIG. 3.—Summary log of the Joggins Formation showing meterage, cycles, channel-body location, types, and paleoflow (based on detailed measured section in Davies et al. 2005). OW = open-water association, PDF = poorly drained floodplain association, WDF = well drained floodplain association.

bodies per 100 m, respectively). Airphoto analysis of outcrop surface areas also shows that channel bodies make up 3.5% of the Joggins Formation, a significantly lesser value than the 9.7% estimated from the measured section.

Davies and Gibling (2003) noted that rapid subsidence and sedimentation rates during deposition of the Joggins Formation precluded the development of well developed paleosols or unconformities that could be used to subdivide this unit into unconformity-bounded sequences. Instead, they described the formation as having a ''tectonic architecture,'' wherein cycles bounded by flooding surfaces represent stacked parasequence sets with predominantly progradational and aggradational sedimentation patterns. Water depths probably never exceeded a few meters, but limestones or laminated shales may represent regionally extensive maximum flooding phases that bound depositional sequences. A similar transgression-dominated architecture has been described from other rapidly subsiding coastal-alluvial successions (Amorosi et al. 1999; Amorosi and Milli 2001), although the extreme sedimentation and subsidence rates at Joggins appear to have precluded the development of transgressive surfaces of erosion.

Changing facies associations likely represent changes in the water table and/or relative base level, but the small size of the basin combined with a delicate balance between sediment supply and sedimentation rates (Davies and Gibling 2003; Waldron and Rygel 2005) appears to have kept this portion of the floodplain remarkably close to base level and probably within a few kilometers of the shoreline.

DATASET AND METHODS

Eighty-two channel bodies ≥ 1 m thick are exposed in cliff and accessible intertidal exposures (Figs. 2, 3). Each is identified with

←

FIG. 2.—Labeled airphoto showing the coastal exposure of the Joggins Formation at its type section; labels designate cycles and the stratigraphic position of prominent channel bodies exposed in intertidal outcrops (labels are the same as those in Fig. 3). The image is a mosaic created from air photographs A18580-125 (1:15,840) and 85314-3 (1:10,000), reprinted with permission of the Nova Scotia Department of Housing and Municipal Affairs, Land Information Services Division.

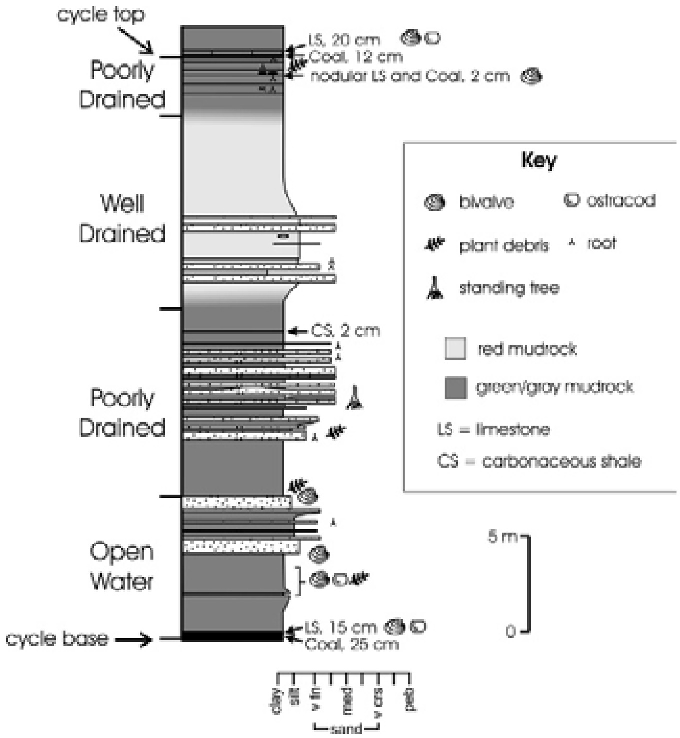


FIG. 4.— Facies succession and sedimentology of cycle 2, a representative Joggins cycle.

a number that corresponds to the meterage at its uppermost level (Figs. 2, 3); multiple channels at a given horizon are also designated with letters (alphabetically from cliff top to low-tide level). The composition, architecture, and geometry of the channel bodies were described using the terminology provided in Table 1. Large vegetation-induced sedimentary structures are similar in size to small channel bodies, but these structures can be distinguished by their internal architecture and close association with standing vegetation (Rygel et al. 2004).

Paleoflow indicators were present and measurable in 67 of the 82 channel bodies. The EZ-ROSE program of Baas (2000) was used to conduct statistical analysis and construct rose diagrams. Mean paleoflow values for each channel body (Fig. 3) were calculated by averaging measurements from the most reliable flow indicators available, mainly channel-margin orientation, trough cross-beds, and ripple cross-lamination. True widths of these 67 bodies were calculated trigonometrically using the apparent width and the paleoflow direction. Despite the superb exposure, true width (and thus W/T) values could only be calculated for 54 channel bodies, and reported W/T values for the remaining 28 bodies are minima or maxima due to incomplete exposure or lack of paleoflow data, respectively. Detailed information about channel body type, geometry, location, and paleoflow are provided in Appendix 1, available from the JSR Data Archive (see Acknowledgments section).

The maximum bankfull depth (D) of the parent channels was calculated by decompacting the thickness of single-story channel bodies, untruncated channel elements, and abandoned channel fills by 10% (Bridge and Mackey 1993). The maximum width of fixed-channel elements is assumed to represent bankfull channel width (W_b). For bodies that experienced significant lateral migration, W_b was calculated as 3/2 the width of lateral accretion surfaces when measured perpendicular to paleoflow (Allen 1965).

Width and thickness were plotted on log-log diagrams, with a best-fit trendline fitted to points with W/T values. Geometric parameters were analyzed for variance using single factor Analysis of Variance (ANOVA) tests in Microsoft Excel©. Both ANOVA and t-tests produce the same probability value (*p* value), but the ANOVA test has the capacity to analyze more than two populations simultaneously in a single test (Moore 1994). In all cases where a statistically significant *p* value is reported, the accompanying *F* value (a measure of the distance between distributions) was greater than the critical value needed for statistical validity. Terminology for architectural elements and bounding surfaces is from Miall (1996), and terms for channel-body geometry and classification are based on Gibling (2006).

Classification of Channel Bodies

The channel bodies are divided into three types, each of which is represented in both well drained and poorly drained associations (Table 1; Fig. 5). The majority of channel bodies are of fixed type ($n = 63$) and are relatively thin and narrow (ribbons to narrow sheets) with prominent incised margins; almost all comprise a single story. Where the fills include lateral-accretion sets, successive inclined strata onlap the basal, concave-up erosional surface (fifth-order channel-bounding surface) at progressively higher levels (Table 1), indicating that the rate of migration of bank-attached bars outpaced the rate of bank retreat and that lateral migration was of limited extent.

A few channel bodies are of *meandering* type ($n = 14$), consisting of a single story with more extensive lateral-accretion sets that onlap flat-lying channel bases. They are broader than the fixed types (mostly narrow sheets) but of similar thickness, and they may represent local reaches where rates of bank retreat and bar advance were in balance for a prolonged period. Fixed-channel and meandering-channel bodies are incised through floodplain deposits from the same level at numerous horizons, suggesting that they may have formed part of avulsive, anabranching, or distributary crevasse systems within sandy overbank deposits. A few meandering-channel bodies in coastal deposits are considerably thicker with laterally amalgamated stories (multilateral bodies), indicating that they represent major trunk drainages rather than local meandering reaches in tributary and distributary systems.

Five *multistory* bodies are relatively thick but appear narrow because only one margin was observed; if completely exposed, these bodies would probably form narrow to broad sheets. These slightly incised, multistory bodies are bounded by sixth-order (channel-belt bounding) surfaces and formed from the amalgamation of smaller channel elements—a situation similar to the channel belt ("simple valley") deposits described by Holbrook (2001).

FIXED-CHANNEL BODIES

Well Drained Floodplain

Description.—Twenty-nine fixed-channel bodies occur in the well drained association (Table 2). These bodies are up to 7.5 m thick with W/T less than 14.3 (Fig. 6A). Channel bases are concave up, cut into the underlying floodplain sediments, and some channel bodies pass laterally into sandy wings whereas others terminate abruptly against mudstone. Although most bodies contain only a single story, two examples have two stacked stories. Multiple (2–3) fixed channels incise from the same horizon at five different levels (Fig. 7), and fixed-channel and meandering-channel bodies incise from the same level at two horizons.

Sandy bedforms and downstream-accretion and lateral-accretion barforms are the most common architectural elements (271, 271.5, and 274A in Fig. 8); fourth-order, inclined erosion surfaces commonly cut through the channel fill to define these bar forms. Laminated to massive mudrock forms beds within lateral-accretion sets and at body tops, with local plugs near the terminal ends of lateral-accretion deposits. Stems and finely comminuted fragments of calamites and other dryland plants (Falcon-Lang 2003b) are abundant throughout channel fills.

TABLE 1.—*Nomenclature used to describe the channel bodies of the Joggins Formation, based on Thomas et al. (1987), Miall (1996), and Gibling (2006).*

Alluvial Lithofacies

Gp	Planar cross-bedded gravel	Sl	Low-angle-laminated sandstone
St	Trough cross-bedded sandstone	Fl	Laminated mudrock
Sp	Planar cross-bedded sandstone	Fm	Massive mudrock
Sr	Ripple cross-laminated sandstone	Fr	Rooted mudrock
Scr	Climbing ripple-cross laminated sandstone	IS	Inclined Strata
Sh	Horizontally laminated sandstone	IHS	Inclined Heterolithic Strata
Sm	Massive sandstone		

Architectural Elements

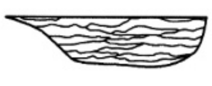
CH	Channel (predominantly sandstone)	GB	Gravel bar or bedform
AF	Abandoned channel fill (mudrock)	DA	Downstream-accretion macroform
LA	Lateral-accretion macroform	SB	Sandy bedform

Bounding Surfaces

6^{th} order	Channel-belt bounding	3^{rd} order	Macroform reactivation and growth
5^{th} order	Channel-element bounding	2^{nd} order	Coset bounding
4^{th} order	Macroform bounding	1^{st} order	Set bounding

Channel Body Width (W)		Channel Body Thickness (T)		Channel Body W/T	
100-1000 m	Medium	5-15 m	Medium	100-1000	Broad Sheets
10-100 m	Narrow	1-5 m	Thin	15-100	Narrow Sheets
1-10 m	Very Narrow			5-15	Broad Ribbons
				<5	Narrow Ribbons

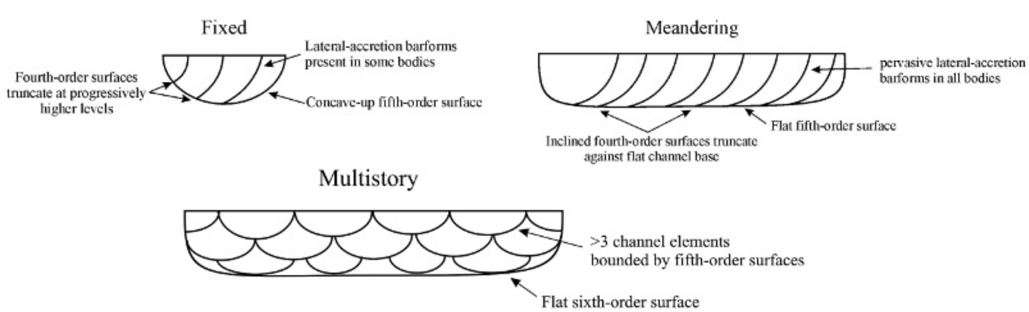
Internal Organization



Erosion-dominated: Poorly preserved channels, numerous erosion surfaces

Succession Dominated: Nearly complete channels, only modest erosion of upper beds

Channel-Body Type



Interpretation.—The WDF fixed bodies are narrow to broad ribbons (Fig. 5; Table 1, 2) with average W/T values of 5.9. Active channels responsible for these deposits were 1.3 to 8.3 m deep and had width/depth (W/D) values of 2.3 to 13.0. Fixed-channel bodies that are cut into muddy overbank deposits (Figs. 5, 7, 8) but are not associated with thick wings are interpreted as the deposits of stable, through-going rivers. Bank-attached bars are present locally, but cutbank migration was generally not an important process. The presence of multiple channels at exactly the same level (Fig. 7) and ribbon-like geometries suggest that these fixed-channel bodies likely record rapidly avulsing and/or anastomosed

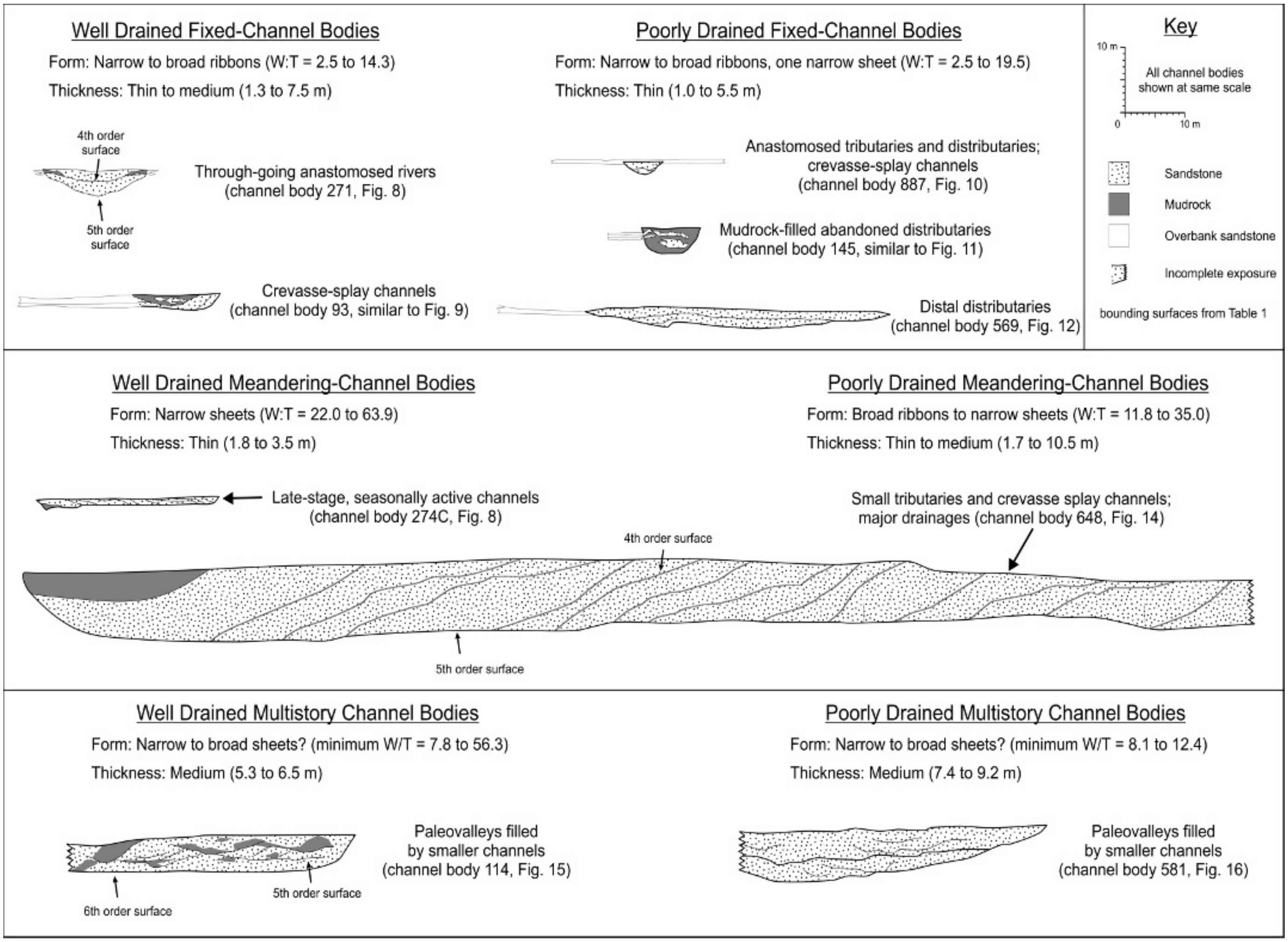


FIG. 5.—Summary diagram showing the three types of channel bodies present in the Joggins Formation. Channel bodies are at the same scale and have been drafted to show a cross-sectional view that is perpendicular to the mean flow direction and corrected for tectonic dip. Examples from each facies association and distinctive subtypes are shown; bounding surface orders are labeled one example of each channel-body type.

drainages—channel morphologies ideally suited to transport large amounts of sediment across a low-gradient plain or into a rapidly subsiding basin (Nanson and Huang 1998; Makaske 2001).

Fixed-channel bodies that lie within sandy overbank sheets (Fig. 9) are interpreted as crevasse channels within overbank deposits. Several such bodies incised from the same level provide compelling evidence that these channel body–overbank packages represent ‘‘tiers’’ formed as a network of crevasse channels spread across the floodplain (Kraus and Wells 1999).

Poorly Drained Floodplain

Description.—Thirty fixed-channel bodies occur within poorly drained strata (Table 2), and are up to 5.5 m thick with W/T up to 19.5 (Fig. 6A). As in the well-drained association, channel bases are concave up and almost all bodies comprise a single story. The exceptions are channel body 886 (Fig. 10), which has three vertically stacked stories, and channel bodies 382 and 384, which have minor overlap with one another (Fig. 11). Multiple fixed-channel bodies incise from the same level at four horizons, and a fixed-channel and a meandering-channel body cut down from 499 m. Fill organization, macroforms, and lithofacies are also similar for the two facies associations (Table 2; Fig. 10). Nearly all sandstone-filled channel bodies pass into sandy wings; thin coals and mounded levee deposits flank channel bodies locally (Fig. 10). Stems and finely comminuted fragments of lycopsids and other wetland floral elements (Falcon-Lang 2003a) are abundant throughout channel fills.

Two fixed-channel bodies with predominantly mudrock fills are present at 145 and 382 m, just below cycle-bounding flooding surfaces (Fig. 11). The fine-grained fill of these single-story bodies is predominantly organized into lateral-accretion deposits. The base of channel body 145 is lined with a lag of mud clasts, and bivalve and ostracod shells.

Channel bodies 553 and 569 occur at the transition between open-water and poorly drained conditions (Fig. 12). These bodies are up to 4.3 m thick and contain downstream-accretion and sandy barforms, both of which are locally cut by third-order erosion surfaces. These channel bodies cut and/or grade into planar-based, distal mouth-bar deposits emplaced by floods or hyperpycnal flows, with wave reworking (Davies and Gibling 2003). Soft-sediment deformation obscures bedding locally, and the uppermost surfaces of the channel bodies contain the stigmarian roots of lycopsid trees.

Interpretation.—The bodies are thin, narrow to broad ribbons, with one narrow sheet (W/T 19.5). The parent channels were 1.1 to 6.1 m deep

TABLE 2.—*Characteristics of fixed-channel bodies in the Joggins Formation.*

		Poorly Drained Floodplain		
	Well Drained Floodplain	Sandstone-filled	Mudrock-filled	Distal Distributaries
Total Number	29	30	2	2
Thickness	1.2 to 7.5 m (2.8 m mean)	1.0 to 4.8 m (2.2 m mean)	4.0 and 5.5 m	1.5 and 4.3 m
True W/T	2.5 to 14.3 (6.1 mean)	2.5 to 19.5 (5.9 mean)	11.3 and 2.0	11.3 and 13.5
Other W/T	Min: 1.6 to 4.8 (n = 3) Max: 7.8 to 14.1 (n = 4)	Maximum: 2.7 to 20.0 (n = 10)	NA	NA
Channel Base	Concave-up fifth-order surface	Concave-up fifth-order surface	Concave-up fifth-order surface	Concave-up fifth-order surface
Stories	1; two examples have 2	Generally 1, minor overlap in several others	1	1
Fill Organization	asymmetric, concentric, and horizontal	asymmetric, concentric, and horizontal	Horizontal	horizontal
Macroforms	SB, DA, LA, AF	SB, DA, LA AF	AF with minor SB	SB and DA
Grain Size	Fine- to medium-grained sandstone (FS and MS, respectively); mudrock and pebble-sized intraformational conglomerate (IFC) locally	FS to MS; mudrock and pebble-sized IFC locally	Mudrock with FS, MS, and pebble-sized IFC locally	Fine- to medium-grained sandstone; mudrock locally
Common Lithofacies	Sr, St, Sl, Sh, Fl and Fm	Sr, Sm, St, Sl, Sh, Fl and Fm	Fl, Fm, Sr, Scr	St, Sr, Scr
Paleochannel Depth	1.3 to 8.3 m (3.3 m mean)		1.1 to 6.1 m (2.4 m mean)	
Paleochannel W/D	2.3 to 13.0 (5.6 mean)		1.8 to 17.8 (5.7 mean)	
Modern Analogues	Channel Country of Australia (Gibling et al. 1998); crevasse channels in the Northern Plains of Australia (Schumm et al. 1996; Tooth 1999).	Magdalena and Columbia Rivers (Smith and Putnam 1980; Smith and Smith 1980; Smith 1986); Saskatchewan River (Pérez-Arlucea and Smith 1999; Morozova and Smith 2000); Atchafalaya Delta of Louisiana (van Heerden and Roberts 1988)	Barwon and South Alligator Rivers (Taylor and Woodyer 1978; Woodyer et al. 1979; Woodroffe et al. 1989)	mouth bar-crevasse channel couplets in the Mississippi River (Coleman et al. 1964; Elliott 1974) and others described by Olariu and Bhattacharya (2006)
Ancient Analogues	Cutler Formation (Eberth and Miall, 1991); Springhill Mines Formation (Rust et al., 1984); Willwood Formation (Kraus and Gwinn 1997)	Paleo-Mississippi and Rhine-Meuse systems (Törnqvist 1993; Törnqvist et al. 1993; Aslan and Autin 1999); Dakota Formation (Kirschbaum and McCabe 1992); St. Mary's River Formation (Nadon 1994); Willwood and St. Mary's River Formations (Nadon 1994; Kraus and Gwinn 1997).	Upper Cretaceous Units in Alberta (Eberth 1996)	Olsen's (1993) channel-mouth complexes; Fielding's (1984) medial crevasse splay/minor delta

with W/D between 1.8 and 17.8 (Fig. 13). Lateral-accretion barforms locally built into the channels without significant channel widening. The few multistory fixed-channel bodies present in the Joggins Formation record reoccupation of existing channels (Makaske et al. 2002).

Like their WDF counterparts, these sandstone-filled bodies have low W/T values (6.5 mean), have multiple channels incising from exactly the same level, and exhibit many characteristics of anastomosed or avulsive river deposits (Makaske 2001). Nearly all the bodies are associated with sandy overbank deposits, and it is difficult to distinguish through-going drainages from distributary or crevasse systems. Larger bodies probably represent through-going networks similar to those described from the Cumberland Marshes or Magdalena River, whereas the smaller channel bodies likely represent smaller distributary or crevasse-splay channels (Table 2).

Given their proximity to a cycle-bounding flood event, the two mudrock-filled bodies are interpreted as deltaic distributary channels formed during a retrogradational phase of floodplain sedimentation. The abnormally fine-grained fill may reflect an anomalous absence of sand-size bedload, or, more likely, the channel body represents a failed avulsion (Guccione et al. 1999) that occurred during a transgressive phase when accommodation was rapidly generated. Eberth (1996) described similar fluvial deposits from Upper Cretaceous units in southern Alberta and attributed their fine-grained fill to rising sea level and limited connection to inland drainages.

Channel bodies 553 and 569 are associated with mouth-bar deposits and are interpreted as terminal distributary channels derived from larger trunk channels (Olariu and Bhattacharya 2006). These bodies record the most basinward extent of channelized flow at the transition to open-water conditions and appear similar to deposits in Australia and Greenland (Table 2).

Comparison of Fixed-Channel Bodies

Comparison of the geometric information for the 29 WDF and 34 PDF fixed-channel bodies (Fig. 6A) shows that the thickness and W/T values for these populations are indistinguishable from one another ($p = 0.17$ and 0.59, respectively). PDF and WDF paleochannel dimensions (D and W/D; Fig. 13) are also indistinguishable because their dimensions are essentially those of the preserved channel body.

MEANDERING-CHANNEL BODIES

Well Drained Floodplain

Description.—Five meandering-channel bodies occur in well drained floodplain deposits within cycle 5 (Table 3). They are up to 3.5 m thick with W/T of 22 to 64 (Fig. 6B). The bodies are generally single story with flat channel bases. A meandering-channel body and a fixed-channel body both incise from the 370 m level.

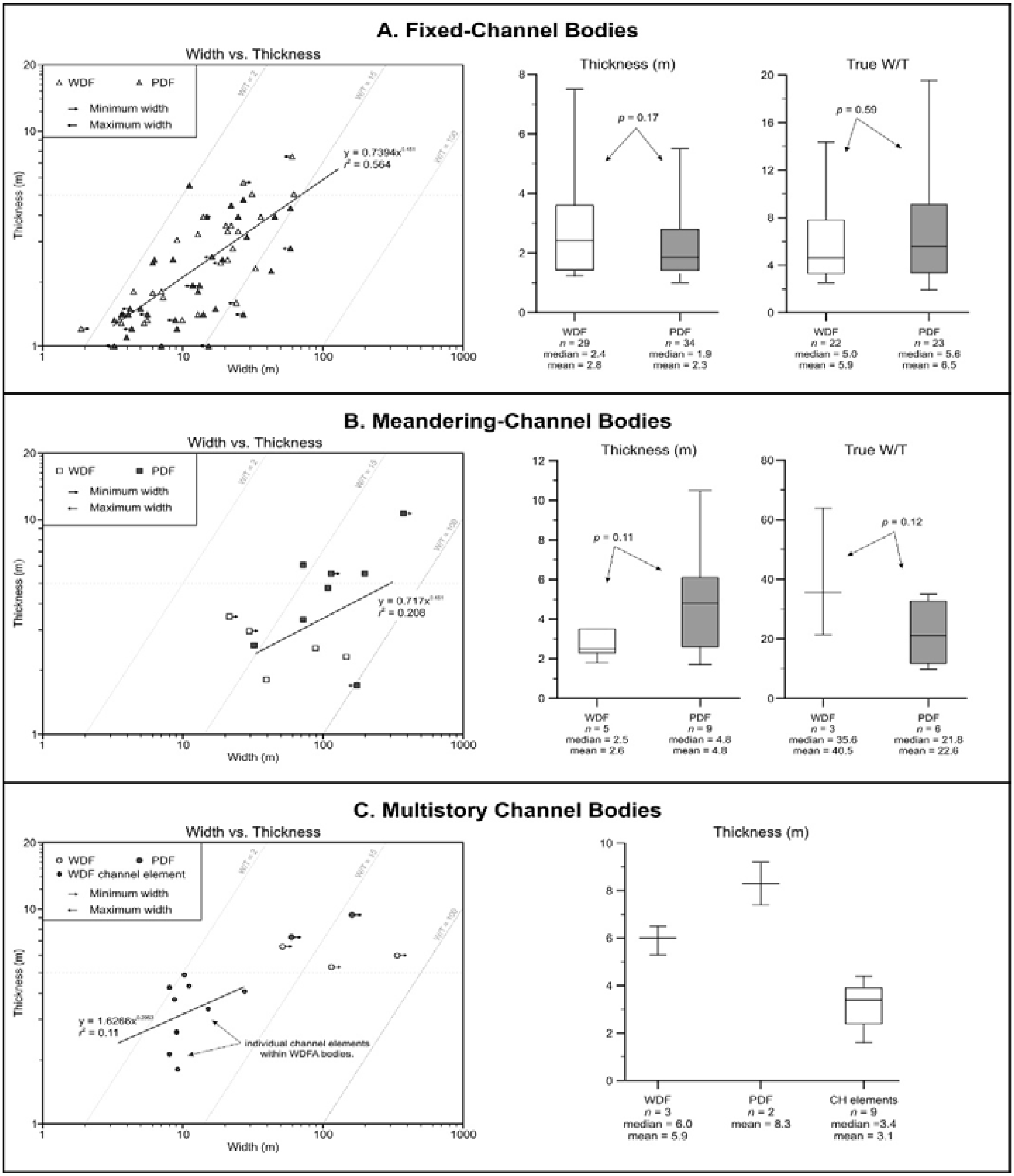


FIG. 6.— Log-log width/thickness (W/T) plots for the three different types of channel bodies in the Joggins Formation. Thickness and W/T information is also presented as box diagrams labeled with the results of the statistical analyses. Following convention, the box defines the area between the 25th and 75th percentiles and the center line represents the median. For populations with less than 4 points, the box is omitted and the center line represents the median ($n = 3$) or mean ($n = 2$).

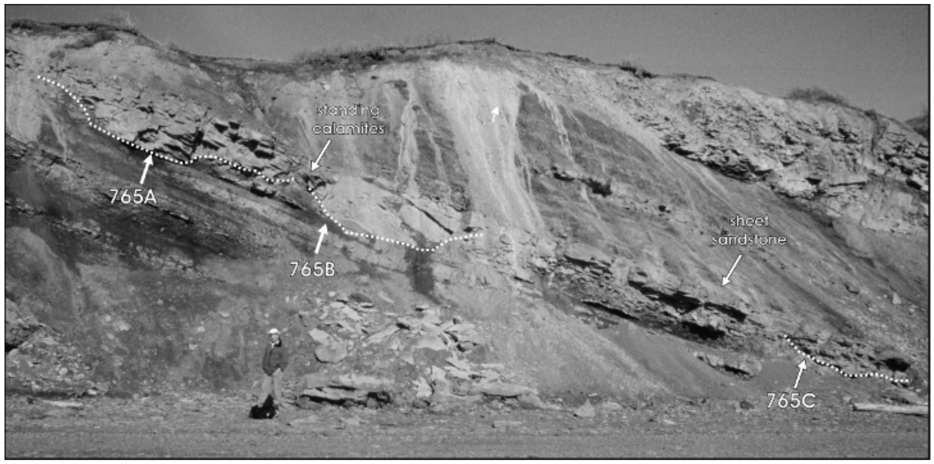


FIG. 7.—Photo of multiple fixed-channel bodies at 765 m in the measured section (well drained floodplain facies association). Person for scale.

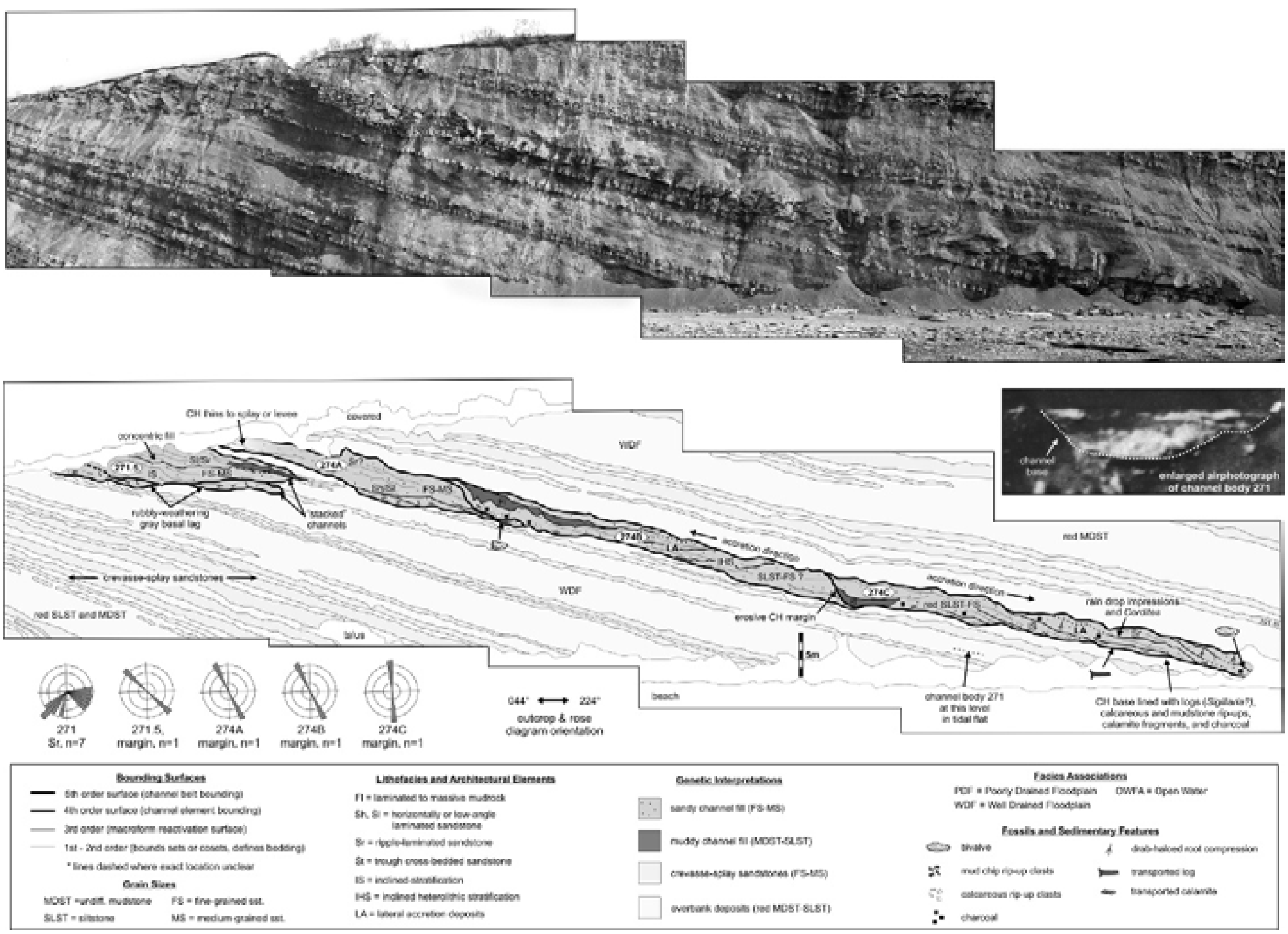


FIG. 8.—Photograph and interpretive tracing of fixed-channel (271, 271.5, 274) and meandering-channel (274B-C) bodies within the well drained facies association of cycle 5. Circled numbers indicate the stratigraphic position of each channel body. Enlarged airphoto of channel body 271 presented at the same scale as the photograph. Fixed-channel bodies encased predominantly by mudrock are interpreted as the deposits of a through-going anastomosed system. Modified from Falcon-Lang et al. (2004).

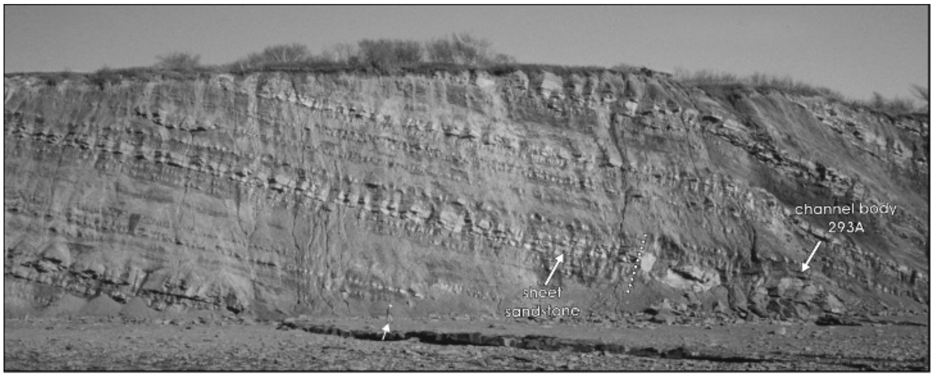


FIG. 9.—Photograph of channel body 293A, a fixed channel within the well drained facies association of cycle 5. The thick, sandy overbank deposits associated with this channel body suggest that it was a short-lived crevasse-splay channel. Person for scale (above lowermost arrow).

Channel bodies are composed almost entirely of inclined stratification and inclined heterolithic stratification that constitute lateral-accretion barforms (Figs. 5, 8). These beds are commonly cut by subparallel, third- and fourth-order surfaces that extend 15 to 30 m laterally and are traceable throughout the thickness of the channel body. Sandy bedforms and downstream-accretion barforms are present locally. In some bodies, massive mudrock fills discrete channel elements near the channel margin. Erosion surfaces are commonly lined by lags of mud clasts, and channel bodies 274B and C contain reworked carbonate rhizoconcretions. Drab-haloed root compressions, raindrop impressions, and mud cracks are present within some bodies. Plant fragments are common, and tetrapod remains, unionoid bivalves, and dryland vegetation were obtained from channel body 274C (Fig. 8; Falcon-Lang et al. 2004; Hebert and Calder 2004).

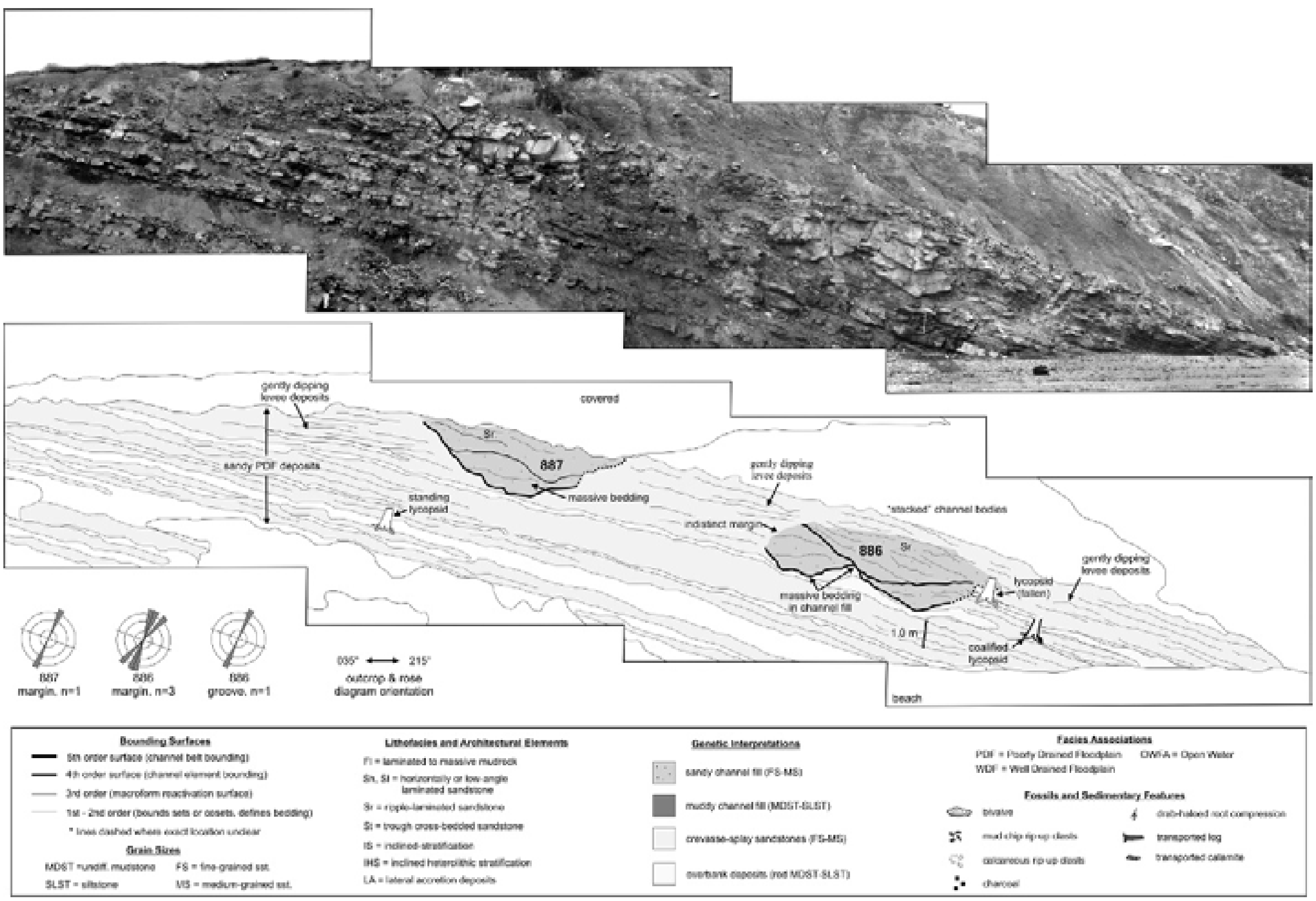


FIG. 10.— Photograph and interpretive tracing of sandstone-filled, fixed-channel bodies 886 and 887, which occur within the poorly drained facies association of cycle 14.

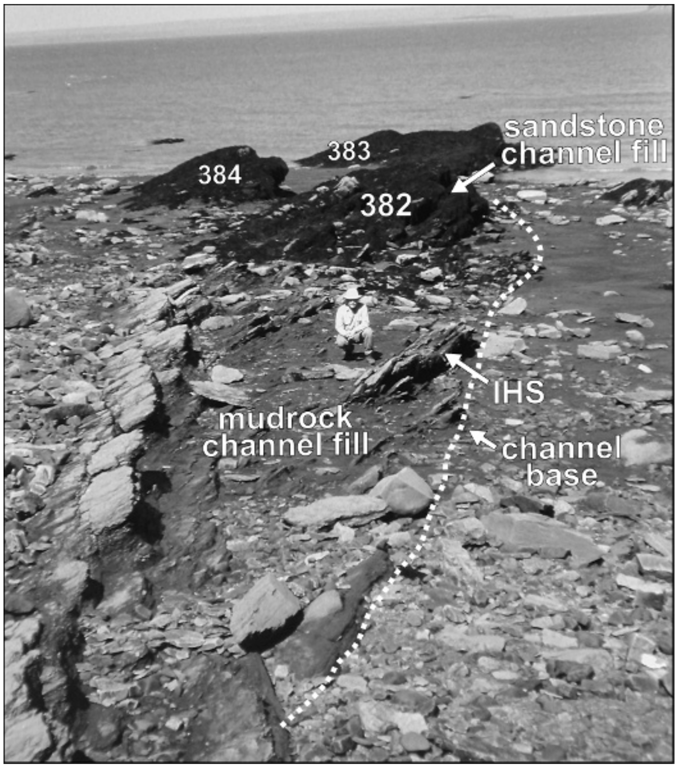


FIG. 11.— Photograph showing channel body 382, a mudrock-filled, fixed-channel body within the poorly drained strata of cycle 5. Channel bodies 383 and 384 are visible in the background. Person for scale.

Interpretation.—The meandering-channel bodies are narrow sheets. Active channels were up to 3.9 m deep with W/D between 7.0 and 9.6 (Table 3; Fig. 13). The close association between fixed-channel and meandering-channel bodies at the 320 m level suggests that local drainage networks included both fixed and meandering reaches. Desiccation indicators suggest that some meandering channels were only seasonally active and may have been late-stage channels similar to those described by Schumm et al. (1996) and Gibling et al. (1998).

Poorly Drained Floodplain

Description.—Nine meandering-channel bodies occur in poorly drained strata (Fig. 6B, Table 3). These bodies are 2.6 to 10.5 m thick and have W/T of 11.8 to 35.0 (Table 3). Three meandering-channel bodies cut down from 494 m, and a meandering-channel and a fixed-channel body cut down from the 499 m level. As with WDF bodies, the basal surfaces are flat-lying and the bodies are filled largely with heterolithic deposits formed by lateral accretion (Fig. 14), with some downstream-accretion and sandy barforms. A 2.9-m-thick abandonment fill in the cliff exposure of Coal Mine Point (channel body 648; Fig. 14) is filled with ripple cross-laminated sandstone and massive mudrock. Fourth-order erosion surfaces lined with mud clasts and plant debris are common throughout.

Interpretation.—The bodies are narrow sheets to broad ribbons (Fig. 5). The active channels that created them were 1.9 to 11.6 m deep with W/D of 6.3 to 7.1 (Fig. 13). The presence of multiple channel bodies at two levels suggests that these channels may have formed part of a multichannel network similar to that of the Rhine–Meuse Delta—a system with coeval fixed-channel and meandering-channel bodies (Törnqvist 1993).

"Coal Mine Point" is a 10.5-m-thick, meandering-channel body (channel body 648; Figs. 5, 14) with a channel that was at least 30% deeper than all other channels recorded on the Joggins floodplain. This large river probably represents a higher order stream and may represent a mobile trunk drainage.

Comparison of Meandering-Channel Bodies

Geometric information for the 5 WDF and 9 PDF meandering-channel bodies (Fig. 6B) shows that, although some PDF channel bodies are much thicker than WDF channels (10.5 m and 3.5 m maximum thickness, respectively), the two populations are statistically indistinguishable ($p = 0.11$). Although W/T values for WDF bodies (40.5 mean) are much greater than for PDF bodies (22.6 mean), the populations do not appear to be distinct ($p = 0.12$); this seeming discrepancy is probably an artifact of small sample size. Channel-body width does not increase significantly with channel-body depth ($r^2 = 0.208$), although two of the largest channel bodies are incompletely exposed (648 and 494C).

Because these channel bodies are one story high, decompacted values of thickness represent paleochannel depths and were similarly indistinguishable ($p = 0.11$). Unlike fixed-channel bodies, the instantaneous width of meandering paleochannels was much smaller than the resulting deposits (Fig. 13), and the two W/D values from the WDF bodies (7.0 and 9.6) match well with the two values from PDF bodies (6.3 and 7.1).

The similarity of paleochannel W/D values and relatively low channel-body W/T values indicates that there is an overlap in form and process between meandering-channel and fixed-channel body types. This continuum in channel-body geometry probably records meandering reaches in predominantly fixed systems where individual channels widened and perhaps became more sinuous—a phenomenon described

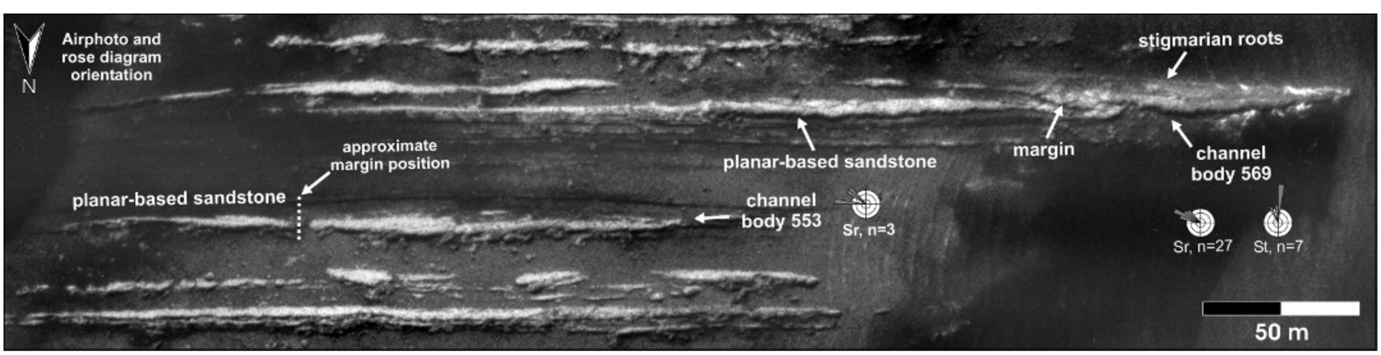
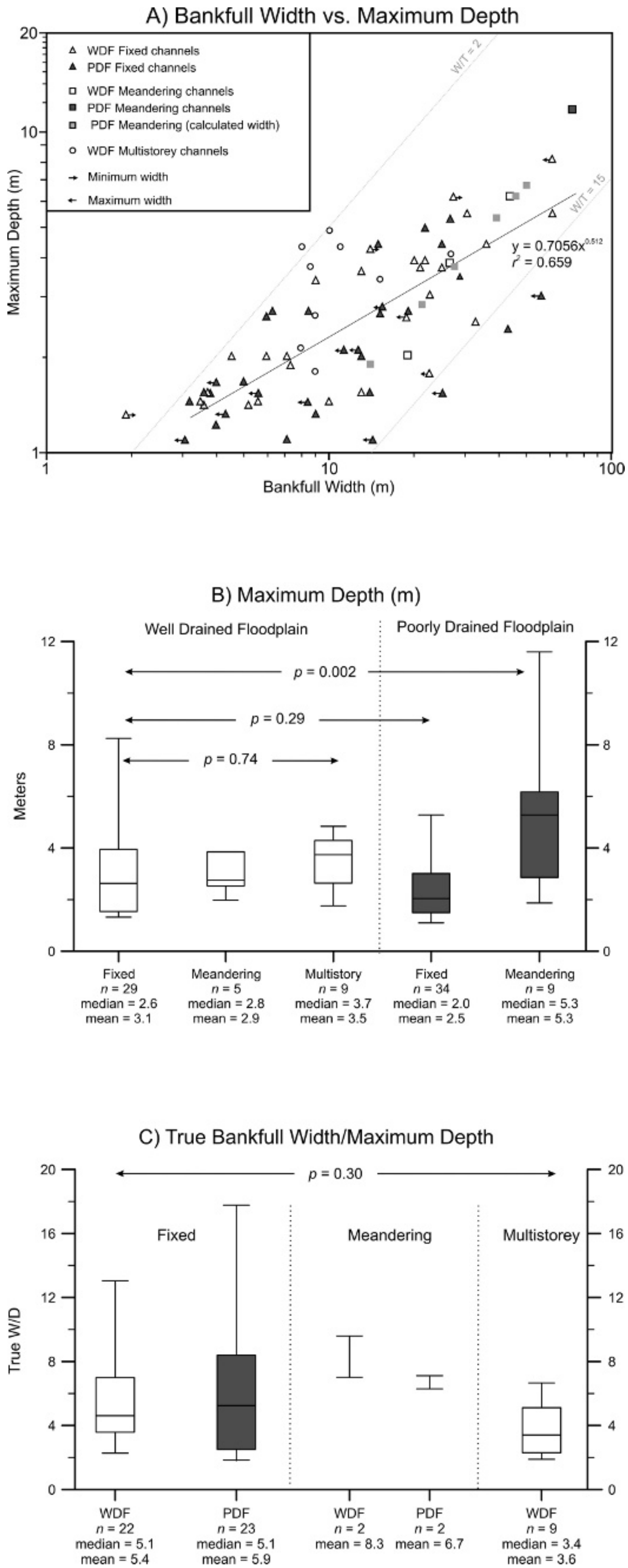


FIG. 12.—Labeled airphoto showing two fixed, distal distributaries within cycle 9 (image is an enlarged portion of Fig. 2). These bodies are encased within strata of the open-water facies association and represent the most basinward extent of the poorly drained facies association.



from both modern anastomosed systems and ancient fixed-channel deposits (Table 3).

MULTISTORY CHANNEL BODIES

Well Drained Floodplain

Description.—Three multistory channel bodies up to 6.5 m thick occur in well drained strata (Fig. 5; Table 4). These bodies are incompletely exposed and have minimum W/T ratios of between 7.8 and 56.3 (Fig. 6C). Flat-lying basal surfaces have small erosional steps with up to 0.5 m of relief. The channel bodies pass laterally into thin (< 1 m thick) sandy wings that extend ~ 250 m into the adjacent floodplain sediments; channel-bounding surfaces do not trace into well developed paleosols or erosion surfaces in overbank areas.

Internally, multistory channel bodies are divided into three or more stories by concave-up fifth order surfaces (Fig. 15). The stories are relatively completely preserved ("succession-dominated" bodies of Gibling 2006), with relatively minor erosion beneath adjacent and overlying stories (Table 1). Nine completely preserved stories range from 1.6 to 4.4 m thick and have W/T between 2.1 and 7.3. Lateral-accretion and downstream-accretion barforms are the most abundant architectural elements, with gravelly and sandy bedforms and abandonment fills locally. Channel body 114 has slump blocks that record failure of the adjacent muddy channel deposits (Fig. 15). The channel fills contain sandstone and red or green clayey siltstone, with lags of pedogenic carbonate nodules and/or mud clasts on erosion surfaces. Floral remains within these bodies are dominated by a dryland assemblage (Falcon-Lang 2003b) consisting of pteridosperms, cordaites, and sphenopsids, the latter being rooted within lateral-accretion deposits within channel body 13.

Interpretation.—These partially exposed bodies have minimum W/T ratios of 8 to 56 (broad ribbons to narrow sheets), and the entire bodies probably represent narrow to broad sheets. Active channels averaged 3.5 m deep with W/D of 3.6 (Fig. 13) and were much smaller than the valleys that they filled (5.9 m mean depth, probably > 350 m wide). The presence of lateral-accretion deposits, mudrock abandonment fills, and downstream-accretion barforms suggests that channel planforms ranged from fixed to meandering. *In situ* vegetation suggests seasonal flow, and fragmented floral associations are consistent with a seasonally dry, well drained alluvial plain and could have been locally derived. The overall size of these bodies and the architecture of sandstone intervals resemble those of the lower Niobrara River of Nebraska (Ethridge et al. 1999; Skelly et al. 2003), but the presence of heterolithic lateral-accretion deposits indicates that mobile channels were also present (Olsen 1988; Bristow 1999).

Although the composite nature of these bodies means that technically they represent paleovalleys (Dalrymple et al. 1994), they do not occur in predictable positions within cycles, nor does every cycle contain a multistory body (cycle 1 contains two multistory bodies). Consequently, it is not clear that they represent stratigraphically significant surfaces, and they cannot be used to define unconformity-bounded sequences or to confidently identify falls in relative sea level. Indeed, it is equally plausible that these bodies formed in response to climate change or local tectonism (Type 2 paleovalleys of Dalrymple et al. 1994). These bodies are similar to Holbrook's (2001) "simple" paleovalley fills, which are multistory channel-belt deposits that do not represent sequence boundaries.

←
FIG. 13.— Paleochannel depth (D), bankfull width (W), and W/D information presented as a log-log plot and box diagrams. Results of the statistical analyses are shown on the box diagrams.

TABLE 3.— *Characteristics of meandering-channel bodies in the Joggins Formation.*

	Well Drained Facies Association	Poorly Drained Facies Association
Number	5	9
Thickness	1.8 to 3.5 m (2.6 m mean)	2.6 to 10.5 (4.8 m mean)
True W/T	22.0 to 63.9 (40.5 mean)	11.8 to 35.0 (22.6 mean)
Other W/T	Minimum: 5.8 and 9.3	Minimum: 22.0 and 38.4 Maximum: 94
Channel Base	Flat fifth-order surface	Flat fifth-order surface
Stories	Generally one, but 274B and C are multilateral (but described individually)	Generally one; 648 is multilateral
Fill Organization	Single accretion direction defined by dipping fourth-order surfaces	Single accretion direction defined by dipping fourth order surfaces
Macroforms	LA, SB, DA, and rare AF	LA, SB, DA, and rare AF
Grain Size	FS to MS; mudrock and pebble-sized IFC locally	FS to MS; mudrock and pebble-sized IFC locally
Common Lithofacies	Sr, St, Sl, Fl and Fm	St, Sr, Sl, Sh, Fl and Fm
Paleochannel Depth	2.0 to 3.9 m (2.9 mean)	1.9 to 11.6 m (2.4 mean)
Paleochannel W/D	7.0 and 9.6 (n = 2)	6.3 and 7.1 (n = 2)
Modern Analogues	Waterholes in the Channel Country of Australia (Gibling et al. 1998; Falcon-Lang et al. 2004)	Rhine-Meuse Delta (Törnqvist 1993, 1994; Törnqvist et al. 1993)
Ancient Analogues	Clear Fork Group (Edwards et al. 1983)	Scalby Formation (Alexander 1992); Morien Group (Gibling and Rust 1987)

Poorly Drained Floodplain

Description.—Two multistory channel bodies occur in the poorly drained facies association at 581 and 705 m (Fig. 5, Table 4). The channel bodies are 9.2 and 7.4 m thick and have minimum W/T of 12.4 and 8.1, respectively. Flat basal surfaces and well defined margins give these channel bodies a shape and geometry similar to their WDF equivalents. Sandy overbank deposits less than 1.5 m thick extend several tens of meters away from the channel margin but, as with WDF multistory bodies, channel-bounding surfaces do not trace into well developed paleosols or erosion surfaces in overbank areas. Channel body 581 has an internal architecture unlike the other multistory channel bodies in the section (Figs. 5, 16). Two stories are separated by a prominent, flat-lying, fifth- or sixth-order erosion surface that terminates against the channel margin, and each story contains several individual channel fills defined by concave-up basal surfaces. Overall, the multistory bodies contain numerous erosion surfaces that cut into incompletely preserved channel elements ("erosion-dominated" architecture of Gibling 2006). Channel elements contain sandy, downstream-accretion barforms with abundant low-angle erosion surfaces. Plant fragments include a wetland assemblage composed of lycopsid and sphenopsid remains with rare dryland elements. A large (~ 1 m diameter), *in situ* lycopsid was entombed near the edge of the channel body.

The internal architecture of channel body 705 is similar to that of the WDF multistory bodies, particularly channel body 114 (Figs. 5, 15). This succession-dominated channel body contains several stories with concave-up basal surfaces, each story composed of sandy bedforms and/or lateral-accretion deposits. Plant remains consist of wetland floras, predominantly small calamite and lycopsid fragments.

Interpretation.—The multistory bodies would likely be classified as narrow to broad sheets if fully exposed (minimum W/T 12.4 and 8.1). Channel elements appear similar in size and shape to those in the WDF multistory bodies (Fig. 13), and the bodies are interpreted as channel-belt

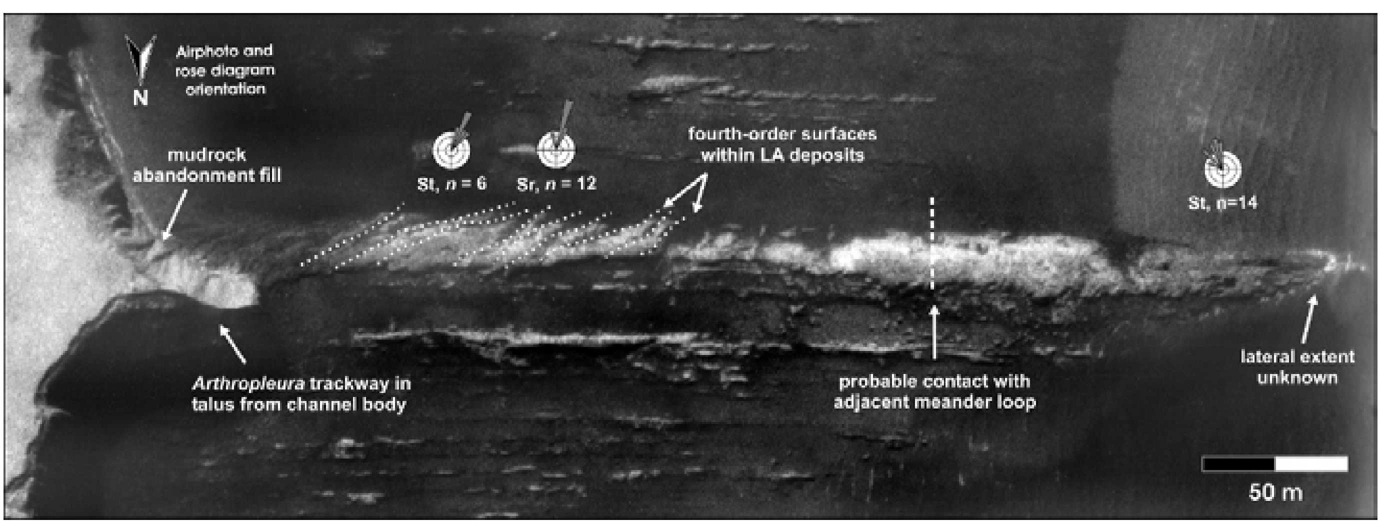


FIG. 14.— Labeled airphoto showing Coal Mine Point (channel body 648), a large meandering-channel body within poorly drained strata of cycle 10 (image is an enlarged portion of Fig. 2).

TABLE 4.—*Characteristics of multistory channel bodies in the Joggins Formation.*

	Well Drained Facies Association	Poorly Drained Facies Association	
Internal Architecture	Succession Dominated	Erosion Dominated	Succession Dominated
Number	3	1	1
Thickness	5.3 to 6.5 m (5.9 m mean)	9.2	7.4
Minimum Width/Thickness	> 7.8 to 56.3 (28.6 mean)	> 12.4	> 8.1
Channel Base	Flat sixth-order surface with erosional steps locally; passes into well defined margin	Flat sixth-order surface; passes laterally into well defined margin	
Stories	> 3, defined by concave-up fifth order surfaces	2, each of which is subdivided into > 5 channel elements defined by concave-up fifth-order surfaces	> 3, defined by concave-up fifth-order surfaces
Channel-Element Thickness and W/T	T = 1.6 to 4.4 m (3.1 m mean) W/T = 2.1 to 7.3 (3.9 mean)	Very poor preservation	Inaccessible, appears identical to WDFA examples
Fill Organization	Crosscutting channel elements defined by fifth-order surfaces; fully preserved stories near top	Crosscutting channel elements and scours defined by fifth-order surfaces; poor preservation of stories throughout	Crosscutting channel elements defined by fifth-order surfaces; fully preserved stories near top
Macroforms	DA, LA, AF, SB, GB	SB and DA	LA, DA, SB, AF
Grain Size	FS to MS with mudrock abandonment fills; pebble-sized IFC locally	FS to MS; pebble-sized IFC locally	FS to MS with mudrock abandonment fills; pebble-sized IFC locally
Common Lithofacies	Sr, St, Fm, Fr, Sp, Scr, Sl, Gp	Sr, St, Sl	St, St, Fm, Fl, Sl
Paleochannel Depth	1.8 to 4.8 m (3.5 m mean)	Poorly preserved; appear similar in size and shape to paleochannels in WDF bodies	
Paleochannels W/D	1.9 to 6.7 (3.6 mean)		
Modern Analogues	Similar in size but muddier than the lower Niobrara River (Ethridge et al. 1999; Skelly et al. 2003); mixed sandbed and meandering characteristics similar to the Old Brahmaputra (Bristow 1999)	Lower Niobrara and South Saskatchewan Rivers (Cant and Walker 1978; Ethridge et al. 1999; Skelly et al. 2003)	Similar in size but muddier than the lower Niobrara River (Ethridge et al. 1999; Skelly et al. 2003); mixed sandbed and meandering characteristics similar to the Old Brahmaputra (Bristow 1999)
Ancient Analogues	Solling Formation (Olsen 1988); Campodarbe Group (Bristow 1999)	Sandy, erosion-dominated fills similar in architecture (but not scale) to the Castlegate Sandstone (Miall 1994)	Solling Formation (Olsen 1988); Campodarbe Group (Bristow 1999)

deposits composed of the deposits of considerably smaller, fixed to meandering channels (probably ~ 3.5 m deep, W/D = 3.9). The abundance of wetland floras within and adjacent to these deposits indicates that channel incision and filling occurred within the poorly drained floodplain. Given the lack of laterally equivalent paleosols in overbank areas and the lack of evidence for a basinward shift in facies, these bodies cannot be confidently inferred to mark erosional sequence boundaries formed in association with a fall in relative sea level.

The sandstone-dominated fill of channel body 581 is unique amongst the multistory channel bodies and was deposited by a sand-bed river similar in both size and facies to the lower Niobrara and South Saskatchewan Rivers (Table 4). The sandy, erosion-dominated nature of this body suggests that it formed in a fluvial system that experienced strong flow pulses—perhaps a signature of climate-induced changes in sediment supply (Van der Zwan 2002; Törnqvist et al. 2003). Although channel body 581 sits erosionally atop the open water strata of cycle 10, the presence of a distal distributary channel at 569 m and the wetland floral assemblages within channel 581 strongly suggests that it simply records a large channel feeding into a standing body of water. Channel body 705 contains abundant mudrock and was filled with mixed-load, fixed-channel and meandering-channel deposits similar to those in the multistory WDF bodies.

CHANNEL-BODY GEOMETRY AND PALEOCHANNEL FORM: SUMMARY

Joggins channel bodies are classified into fixed, meandering, and multistory groups based only on architectural criteria observable in the field (Fig. 5). All three groups are present in poorly drained and well drained floodplain successions, and they occupy distinct but non-exclusive regions in W-T space (Fig. 17). Comparison of channel-body thickness using ANOVA analysis shows that multistory (6.9 m mean), meandering (4.0 m mean), and fixed (2.5 m mean) channel types represent distinct populations ($p < 0.001$, Fig. 17). W/T for fixed-channel (6.2 mean) and meandering-channel (28.6 mean) bodies also belong to distinct populations ($p < 0.001$, Fig. 17); the five multistory bodies were incompletely exposed and could not be analyzed using this criterion.

Comparison of paleochannel depth using ANOVA analysis (Fig. 13) shows significant differences for the five different paleochannel groups ($p = 0.002$). This result reflects the greater depth of the PDF meandering channels (5.3 m mean). Excluding the latter group, the four remaining types (no values for PDF multistory paleochannels available) are indistinguishable ($p = 0.\ 29$).

Conversely, paleochannel width/depth ratio for all five groups is similar ($p = 0.30$), indicating that all these active channels had a similar shape (W/D means from 3.6 to 8.3), regardless of the type of body that they would eventually deposit. Plots of paleochannel width and depth (Fig. 13) show that paleochannel width generally increased with paleochannel depth (Bridge and Leeder 1979; Bridge and Mackey 1993); the apparent weakness of this trend ($r^2 = 0.659$) probably reflects the limited range of channel depths in the Joggins Formation.

The present analysis shows statistical similarity between instantaneous depth for four of the five groups of Joggins paleochannels, regardless of the type of channel body preserved and whether they belong to well drained or poorly drained associations. A continuum of this kind in fluvial form, process, and preservation across different facies tracts is well known from modern channel networks and numerical models (Knighton and Nanson 1993; Bridge 2003) but has only rarely been documented in the ancient record.

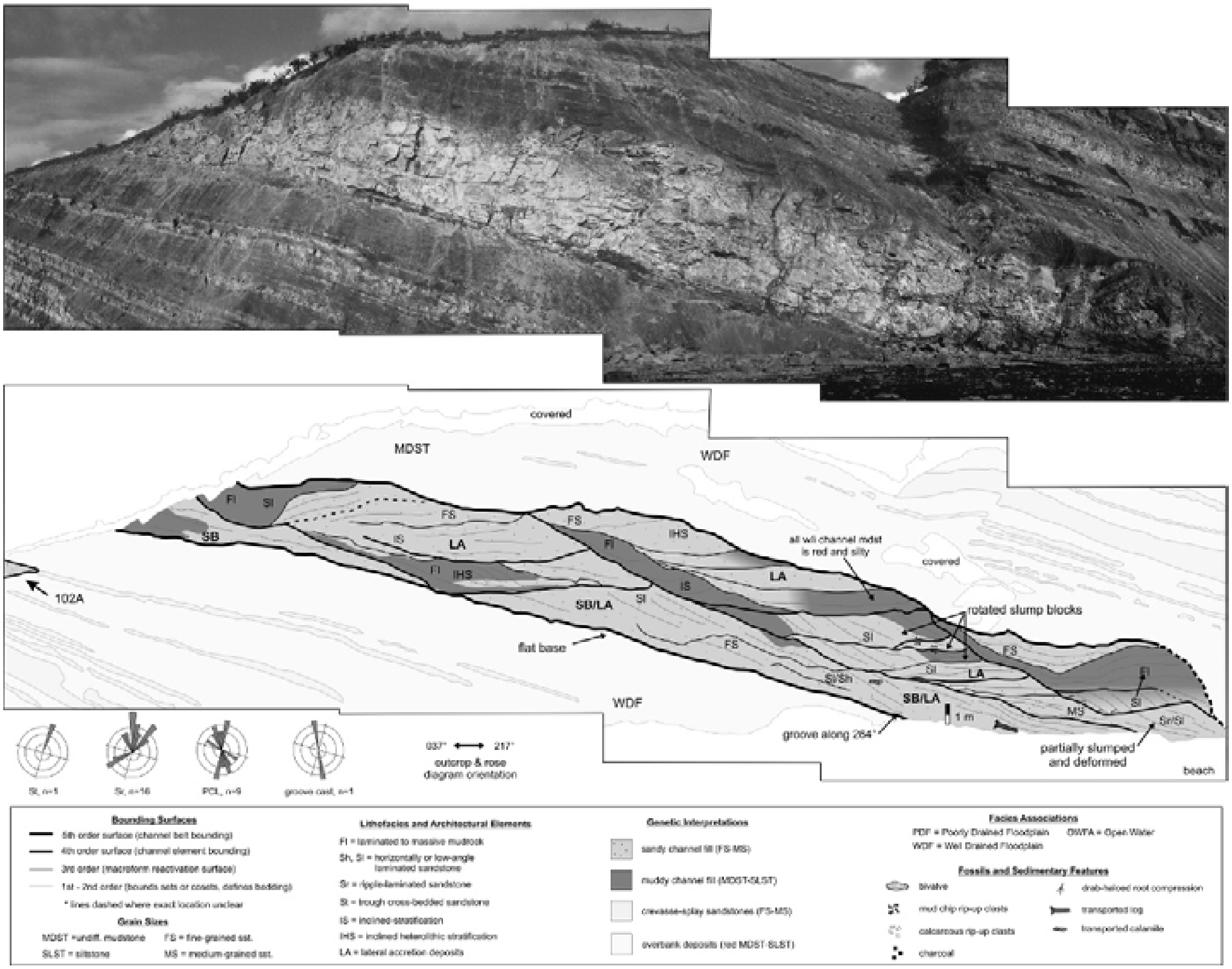


FIG. 15.—Photograph and interpretive tracing of channel body 114, a succession-dominated, multistory body within the well drained facies association of cycle 3. 1 m scale is shown on the tracing where the channel body meets the intertidal zone.

CONTROLS ON FLUVIAL FORM IN THE JOGGINS FORMATION

Bank Materials and Overbank Deposits

For other deposits, the presence of peat (Smith and Pérez-Arlucea 2004), vegetated banks (Smith 1976), sand (Aslan et al. 2005), cohesive floodplain mud (Rust and Legun 1983), and indurated paleosols (Gibling and Rust 1990) have been demonstrated to influence bank strength. Meandering-channel body 494a cuts through heterolithic floodplain deposits and has a flat base that rests upon a coal. Aside from this single example, substrate does not appear to have profoundly influenced channel-body geometry in the Joggins Formation, which lacks indurated duricrusts and thick coals. Additionally, the thinly interbedded nature of floodplain muds and sands (floodplain sands are almost all $<$ 1 m thick) and ubiquity of riparian vegetation probably caused channels to interact with bank materials of comparable overall cohesiveness, despite local differences in lithology. Floodplain deposits in the well drained and poorly drained floodplain successions contain similar proportions of sheet sandstone and have comparable numbers of channel bodies per unit thickness. These similarities suggest that successive cycles formed in a broadly similar geomorphic setting.

Climate

As previously mentioned, the impact of climate change on strata of the Joggins Formation has been difficult to document. Marked floral differences between well drained and poorly drained strata indicate that floral communities responded to changes in local drainage conditions. Although it is possible that such differences reflect climate change, this scenario is not testable without correlative inland sections or the identification of paleoclimatically significant paleosols. The similarity of fluvial styles between poorly drained and well drained strata further points to broadly similar climatic conditions for both drainage conditions. The influence of discharge variation may perhaps be seen in the local incision events that created the multistory bodies. Given the variable positioning of the multistory channel bodies within cycles and facies assemblages, Falcon-Lang's (1999) hypothesis that these bodies record fluxes of sediment introduced into the basin as a result of upland wildfires remains the best candidate for a marked climatic imprint. That said, multistory bodies are an integral part of both poorly drained and well drained strata and represent a fluvial endmember in both sets of floodplain drainages.

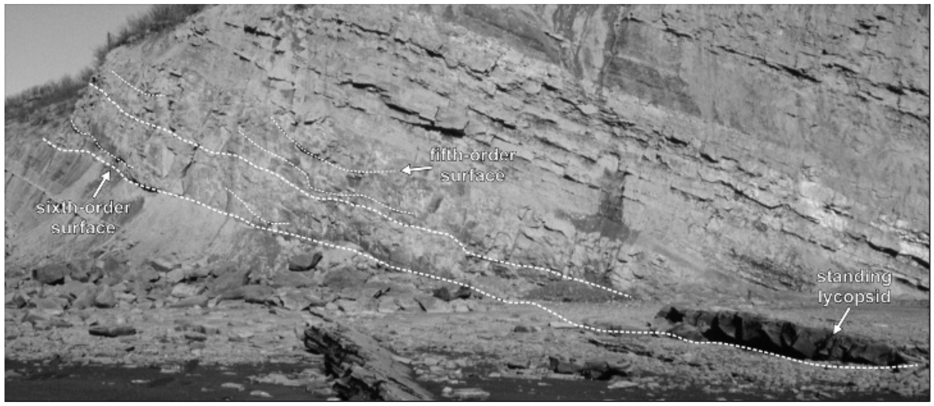


FIG. 16.—Photograph showing channel body 581, an erosion-dominated, multistory channel body within the poorly drained facies association of cycle 9.

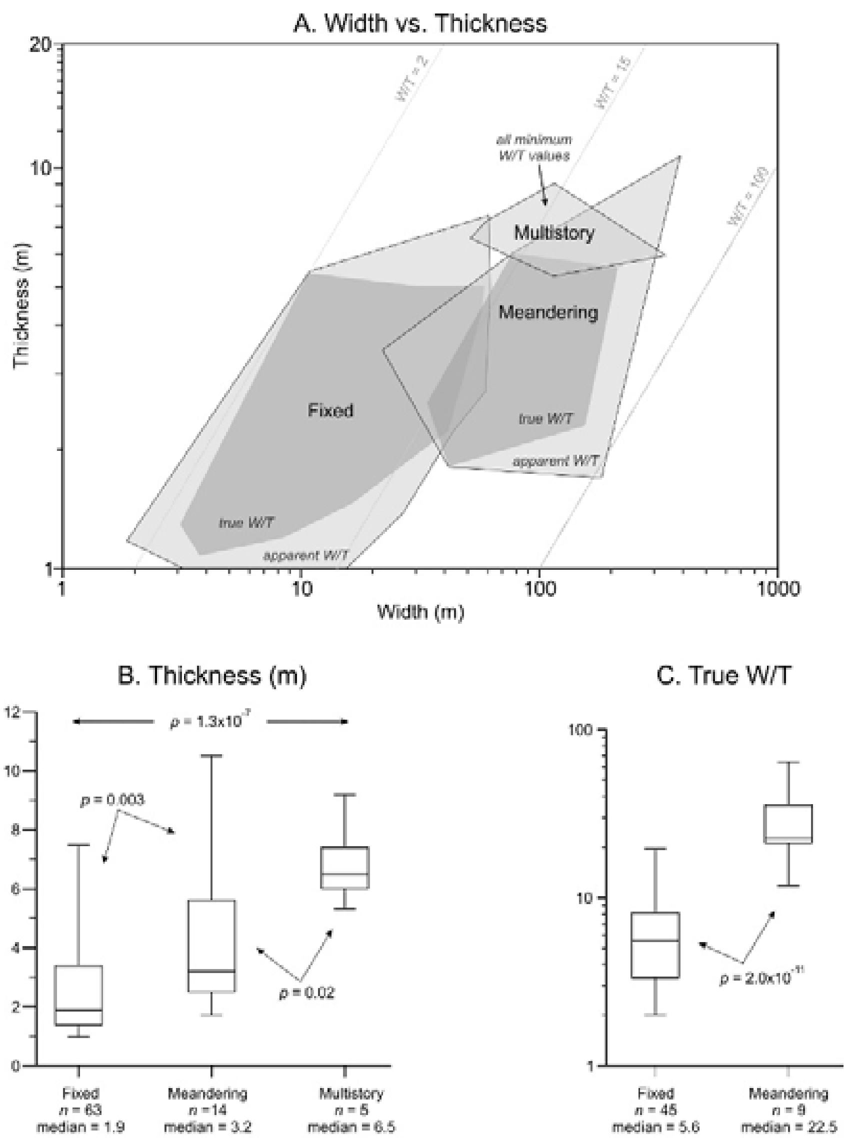


FIG. 17.—Diagram summarizing the width, thickness, and width/thickness information for the three different types of channel bodies within the Joggins Formation.

Accommodation

In the Joggins Formation, the sporadically distributed multistory bodies are not clearly related to changes in relative base level. They may be a consequence of changes in precipitation and discharge (compare with Gibling et al. 2005) or may simply be multistory channel belts that represent large trunk drainages. Indeed, these bodies occur in both the poorly drained and well drained floodplain associations, indicating that the conditions necessary for modest incision existed periodically, perhaps simultaneously, across the entire Joggins floodplain. Furthermore, their thickness is matched or exceeded by several fixed-channel and meandering-channel bodies, indicating that, although the fill architecture is unique, the degree of incision was comparable to that achieved by other channels. Thus, multistory bodies may have been a natural part of the channel form-continuum throughout deposition of the Joggins Formation. The variety of fluvial forms observed in the Joggins Formation supports Adams and Bhattacharya's (2005) observation that fluvial planform may be somewhat independent of change in accommodation and base-level and that the present understanding of fluvial style within sequence stratigraphic models may not capture the full range of natural variability in fluvial systems.

Systematic changes in fluvial architecture could not confidently be identified within individual cycles or within the Joggins Formation as a whole. This probably reflects the high-accommodation setting, associated with a rapid sedimentation rate, a high proportion of overbank deposits throughout, and the long-term maintenance of an accommodation/sediment supply ratio near unity. Although the Joggins cycles represent relative sea-level change, probably caused by glacioeustasy, the effects of sea-level fall would have been damped down by rapid subsidence (Davies and Gibling 2003). Under these conditions, the fluvial system was probably relatively insensitive to modest changes in the rate at which accommodation was created.

Nature of Subsidence

The 1,174-m-thick Boss Point Formation is the oldest Pennsylvanian unit in the Cumberland Basin (Fig. 1); much like the Joggins Formation, this unit is assumed to have been deposited in $<$ 1 My period in the earliest Langsettian (Menning et al. 2000; Utting and Wagner 2005) and records an average subsidence rate of at least $\sim$ 1 mm/yr. Despite these similarities, the two formations exhibit marked differences in fluvial style, subsidence pattern, and lithology. During deposition of the Joggins Formation this part of the basin probably experienced low-magnitude, high-frequency halokinetic events accompanied by motion along the basin-bounding faults (Waldron and Rygel 2005). In contrast, halokinesis was probably not active during Boss Point time (Waldron and Rygel 2005) and episodic motion along basin-bounding faults appears to have caused essentially instantaneous subsidence of several meters in this part of the basin (Browne and Plint 1994).

The resulting Boss Point "event stratigraphy" in this part of the basin consists of alternate 10 to 50-m-thick lacustrine shales (26% of formation thickness) deposited following downdrop of the basin floor and 20 to 90-m-thick packages of braidplain sandstone (74% of formation thickness) with deeply incised basal surfaces (Plint and Browne 1994). Despite differences in the proportion of channel sandstone and the uncertain influence of climate change, the striking contrast in fluvial architecture and tectonic conditions between the Boss Point and Joggins formations suggests that fluvial architecture was controlled by both the manner and rate at which the basin subsided. The preservation of a relatively intact drainage network through the stacked cycles of the Joggins Formation may in part reflect the steadier subsidence induced by halokinesis.

PALEOGEOMORPHOLOGY AND PALEOGEOGRAPHY OF THE JOGGINS FLOODPLAIN

The well drained Joggins floodplain was traversed by a network of laterally stable channels with local meandering reaches, up to 8.3 m deep (Fig. 13), that formed anabranches within a dryland river system. Smaller fixed channels represent a network of crevasse channels associated with sandy splays. In some places, small (5 to 7 m deep) channel belts/valleys were occupied by shallow sinuous, mixed-load channels. Farther from the bordering uplands towards the basin center, the poorly drained Joggins floodplain was also traversed by fluvial systems with a tripartite organization. Meandering channels up to 11.6 m deep represented the largest active channels, and meandering and fixed channels up to 6.7 m deep formed a network of tributary and distributary channels. Channel belts or valleys up to 9 m deep were occupied by considerably smaller sand-bed and mixed-load fluvial systems. Shallow channels cut into mouth-bar deposits represent terminal distributary channels formed at the most basinward extent of channelized flow.

Major channel bodies in the poorly drained floodplain are generally larger than those in their well drained counterparts, a relationship that supports the Waltherian interpretation of the facies associations and the presence of gaining streams on the Joggins floodplain. Overall, the Joggins floodplain represents a rapidly subsiding system where large amounts of sediment were delivered to the floodplain via dynamic fluvial systems. Channel avulsion in a high-accommodation setting yielded an alluvial succession in which channel bodies almost never reworked preexisting fluvial deposits.

Despite the marked decrease in the number of channel sandstones that crop out above the 650 m level (Fig. 2), the measured section shows that the proportion of overbank sandstone stays relatively constant above the 150 m level (Fig. 3). Comparison of the surface area of channel bodies and overbank deposits in the intertidal zone shows that the change above the 650 m level reflects a decrease in the abundance of channel sandstones, from 4.3% in the lower ten cycles to 0.7% in the upper four cycles (Fig. 3). This decrease in abundance of channel sandstone represents the second of three apparent coarsening-upwards cycles in the western Cumberland Basin (Gibling 1987). The similarity in facies above and below this level and the persistence of these trends throughout multiple cycles (and formations) suggests that these long-term changes in the abundance of channel sandstones probably record a shift in the locus of fluvial activity within the basin.

Paleoflow measurements show that channel bodies greater than 5 m thick (Fig. 18) originated from headwaters in the Caledonia Highlands or beyond in the exposed and eroding New Brunswick Platform (107° mean, $r = 0.67$). Although these measurements have a 168° range, such a level of variance is to be expected in sinuous systems (Olariu and Bhattacharya 2006). The broadly southeastward paleoflow direction for major channels is similar to that observed in overlying and underlying formations (Rust et al. 1984; Browne and Plint 1994), suggesting that the Caledonia Highlands of New Brunswick supplied most of the sediment deposited in this part of the basin. These rivers probably continued in a southeastward direction until they reached the center of the syndepositional Athol Syncline, where they may have formed an axial system that flowed northeastward out of the basin (Gibling et al. 1992; Calder 1994).

GEOMORPHIC VARIABILITY IN ANCIENT FLUVIAL SYSTEMS

Paleodrainage networks can be investigated by mapping individual channel bodies or fluvial stratigraphic units over large areas (Siever 1951; Dolson et al. 1991; Hirst 1991; Plint 2002). However, outcrop distribution is rarely suitable for such an endeavor, and most assessments of fluvial systems are based on channel-body variability through tens to hundreds of meters of section in particularly well exposed sections. Such studies are inherently prone to link changes in fluvial style to changing extrabasinal

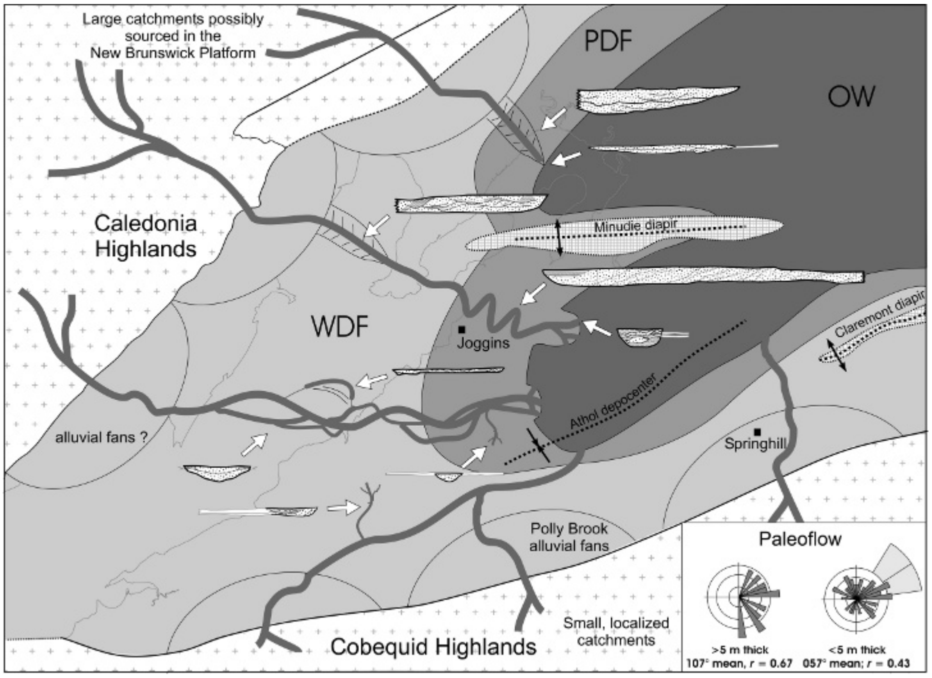


FIG. 18.—Schematic paleogeographic map of the western Cumberland Basin during deposition of the Joggins Formation. Channel-body types (symbols from Fig. 5) are shown in their probable geomorphic position. Rose diagrams present paleoflow information for the channel bodies examined in this study.

controls through time. Any drainage basin shows large changes in channel dimensions and architecture—changes of the same order of magnitude as those induced by external forcing factors—and considerable care is needed to distinguish spatial geomorphic variability at a given time from variability caused by external forcing factors that vary in their influence through time. The present study shows that drainage networks can be reconstructed through coastal and inland tracts using detailed paleochannel analysis of large suites of channel bodies.

In reality, drainage networks experience continually changing external conditions, especially short-term changes in climate and sediment supply (Blum et al. 1994; Bogaart et al. 2003), and individual reaches frequently cross thresholds for geomorphic change. For example, in monsoonal areas such as the Ganga Plains of India, changes in discharge and sediment supply may convert "channels" to "valleys" on timescales of a few thousand to tens of thousands of years (Tandon et al. in press). The Joggins multistory bodies may represent the effect of external forcing factors in creating local channel belts/valleys within the drainage network, although such drainages appear to have been minor components of the network.

CONCLUSIONS

Eighty-two fluvial channel bodies crop out within coastal exposures of the Pennsylvanian Joggins Formation along the shore of the Bay of Fundy. The accessibility and almost complete exposure of this coastal section allows detailed description of channel-body geometry and internal architecture, as well as determination of original channel depth and width for many bodies. These observations are linked to a detailed measured section, thus allowing a comparison of channel bodies deposited across the full paleogeomorphic spectrum of the Joggins floodplain, from poorly drained coastal areas to well drained, inland alluvial plains.

By use only of field characteristics, these channel bodies were classified as fixed ($n = 63$), meandering ($n = 14$), and multistory types ($n = 5$), with each type present in coastal wetland and interior dryland facies associations. Multiple fixed and meandering channels incise from the same level, indicating that these channels formed part of an avulsive or possibly anastomosed tributary and distributary system, which was probably linked to a large, meandering trunk river. The multistory bodies represent small channel belts or valleys filled with the sandy to mixed-load deposits of much smaller active channels.

Analysis of completely exposed channel bodies shows that thickness values for each type are distinct, as are width/thickness values for fixed-channel and meandering-channel bodies; incomplete lateral exposure of multistory bodies prevented similar analysis. Conversely, paleochannel depth and width/depth determined for channel bodies of all types are similar, apart from a small group of unusually deep meandering channels in the coastal wetlands.

Joggins channel bodies were deposited during a period of rapid subsidence and preserve a wealth of information about the active channels that formed them. This situation contrasts with low-subsidence basins, which may be strongly affected by sea-level change and other forcing factors, resulting in widespread reworking of landscapes, a high proportion of channel bodies, and the preservation of a complex mosaic of channel-body styles. Multistory channel bodies are present in the Joggins section but do not appear to be linked to basinward advance of facies belts. Although forcing factors undoubtedly influenced the system (for example, creating the cycles and promoting minor incision), the Joggins channel bodies collectively reflect much of the geomorphic variability of the original drainage network, with systems of small fixed channels and a few large mobile channels in the coastal zone.

Striking contrasts between the fluvial architecture of the Joggins Formation, which formed during a period of salt withdrawal, and the underlying Boss Point Formation, which formed during a period of fault-related subsidence without halokinesis, suggest that both the style (gradual versus episodic) and magnitude of basin subsidence can profoundly influence channel-body architecture.

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Role of evaporite withdrawal in the preservation of a unique coal-bearing succession: Pennsylvanian Joggins Formation, Nova Scotia

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ABSTRACT

The Pennsylvanian Joggins Formation, in the Cumberland Group of Nova Scotia, is widely regarded as the world's best exposure of coal-bearing Carboniferous strata. This 1.5-km-thick coal-bearing unit is famous for upright fossil lycopsid trees, and is preferentially preserved in the Athol syncline in the western Cumberland basin. New seismic profiles show that the Athol syncline is atop a salt weld and that the Joggins Formation thins on the flanks of adjacent evaporite-cored anticlines. These observations indicate that during deposition of the Joggins Formation, at least 1 km of syndepositional subsidence was facilitated by flow of underlying salt into the adjacent anticlines. In contrast, halokinesis was mainly active during the Mississippian in the eastern Cumberland basin (Tatamagouche syncline); minibasins were filled by Mabou Group sediments, whereas the Cumberland Group is thin and lacks significant coals. This basinwide comparison shows that much of the subsidence responsible for the preservation of the coal-bearing Joggins Formation was the result of salt withdrawal at depth.

Keywords: Carboniferous, lycopsid, Maritimes basin, evaporites, halokinesis, subsidence.

INTRODUCTION

The Joggins section is a 4.5-km-thick section of Carboniferous rocks exposed in a gently dipping coastal section along the Bay of Fundy in northwestern Nova Scotia (Fig. 1). Widely regarded as the world's best coal-bearing Pennsylvanian exposure, the 1552 m ''classic'' Joggins section (the Joggins Formation) contains at least 76 coal seams (0.05–1.5 m thick) and 63 forested horizons with standing lycopsids 5–6 m tall. Hailed in 1842 by Charles Lyell (1881, p. 64–65) as ''the most wonderful phenomenon perhaps that I have ever seen,'' Joggins is mentioned in his *Principles of Geology* (Lyell, 1872) and Darwin's (1859) *On the Origin of Species*. This remarkable section, proposed as a UNESCO World Heritage Site (Falcon-Lang and Calder, 2004), profoundly influenced the young science of geology by serving as a proving ground for the principles of uniformitarianism, in situ botanical origin of coal, and incompleteness of the fossil record.

Despite these contributions, relatively little is known about the basin dynamics responsible for the preservation of this window into the Carboniferous world. This paper demonstrates that the localized rapid subsidence necessary for preservation of the Joggins Formation was created by the withdrawal of underlying Mississippian evaporites.

REGIONAL GEOLOGY

The Joggins Formation is in the Cumberland basin of Nova Scotia (Fig. 1), a depocenter within the Paleozoic Maritimes basin, interpreted as either a basin dominated by strike-slip motion, a rift, or a transtensional combination of the two (Bradley, 1982; Gibling, 1995; Pascucci et al., 2000; Waldron, 2004). Fluvial to lacustrine clastic sedimentary rocks compose the majority of the 12-km-thick Maritimes basin fill, but repeated marine incursions during the Mississippian are recorded by carbonates and evaporites of the Windsor Group. The Cumberland basin is near the southwest corner of the Maritimes basin and contains a 7–9 km stratal succession comprising the Mississippian Windsor and Mabou Groups and the overlying Pennsylvanian Cumberland and Pictou Groups (Fig. 1B). The floor of the basin is unexposed, but observations elsewhere in the region indicate that Devonian to Mississippian clastic rocks (Horton Group) and/or volcanic rocks (Fountain Lake Group) may be present. Although the majority of the basin is bounded by a complex network of faults (Fig. 1), the Cumberland Group locally onlaps basement to the southeast and northwest.

The dominant structural features within the Cumberland basin are the Minudie and Claremont anticlines, and the adjacent Athol and Tatamagouche synclines (Fig. 1C). Anticlines are cored by Windsor Group evaporites and conglomeratic redbeds of the Mabou Group. In the western Cumberland basin (Athol syncline; Fig. 1), the overlying 4.2-km-thick Pennsylvanian Cumberland Group consists of sandstone-shale cycles of the Boss Point Formation, and a 2.2-km-thick coal-bearing interval (Joggins and Springhill Mines Formations) capped by conglomerates and redbeds (Polly Brook, Ragged Reef, and Malagash Formations). Farther east (Tatamagouche syncline; Fig. 1), thick coal-bearing units are absent and the remaining Cumberland Group thins to $<$450 m. These units are overlain with angular unconformity by Pictou Group red beds.

Intra-Pennsylvanian halokinesis is well known within the Maritimes basin (Calder, 1998) and has been inferred within the Cumberland basin (Calder, 1994; Boehner, 1992; Carter, 1987), where it was linked to extensional detachments by Lynch and Keller (1998). However, detailed inferences on the timing and kinematics of salt movement were limited by the lack of outcrop and quality of previous seismic data.

JOGGINS SECTION

At its type section, the Joggins Formation forms the medial coal-bearing portion of the 4.2-km-thick Cumberland Group. This 1552-m-thick unit was deposited over ~1.5 m.y. in the early Langsettian (Dolby, 1991; Menning et al., 2000). With sedimentation rates of $\geq$1 mm/yr (compaction effects neglected), the Joggins Formation had one of the highest average sedimentation rates among coal-bearing Carboniferous units (McCabe, 1991).

Red beds compose much of the lower 636 m of the formation, but 64% of the upper 916 m consists of wetland deposits, including 76 coal seams (71 are $<$50 cm thick). The absence of pronounced sequence boundaries and deep-water deposits, as well as the rheotrophic (groundwater fed) nature of the precursor peats, suggests that the sediment surface remained close to relative base level throughout deposition of the Joggins Formation (Davies and Gibling, 2003). With subsidence and sedimentation rates almost perfectly balanced near the threshold for peat accumulation (Haszeldine, 1989), conditions were optimal for lycopsid entombment during deposition of the Joggins Formation. Calder (1994) showed that conditions for peat accumulation migrated

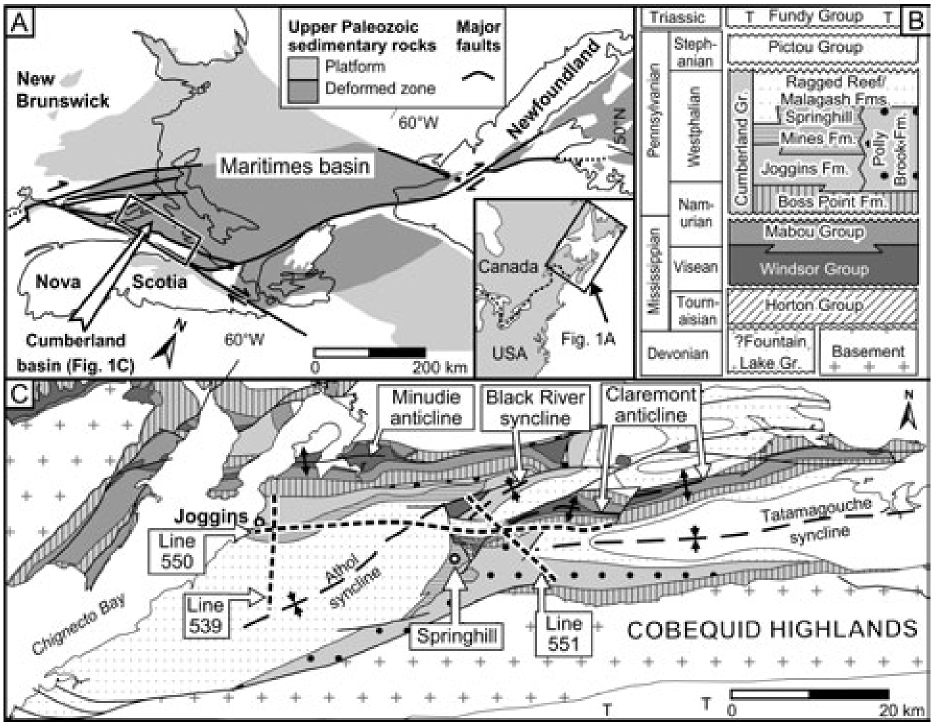


Figure 1. A: Location of Cumberland basin within larger Maritimes basin. Inset shows location in North America. B: Stratigraphic column showing shading used for stratigraphic units in C. C: Map showing major features of Cumberland basin (after Ryan et al., 1991).

to the east over time, during deposition of the Joggins and Springhill Mines Formations.

SEISMIC DATA

Two-dimensional seismic reflection profiles were collected by Devon Canada along a network of lines in the Cumberland basin in 2002 (Fig. 1). The profiles are of much higher quality than previous data sets and allow reflectors to be traced to the surface and identified by using existing geologic maps.

Athol Syncline

Dip line 539 (Fig. 2A[1]) is 1–6 km inland from the Joggins section, approximately perpendicular to strike. Stratigraphic boundaries can be projected from the coast into the profile with an accuracy of $\pm$50 m, and seismic velocities can be estimated in the absence of drilling. The base of the Joggins Formation is a reflector that can be traced (Fig. 2A) from the surface to a depth of ~1.5 s two-way traveltime (TWT) beneath the Athol syncline. Beneath it, the measured stratigraphic thickness (1074 m) and dip (22°) of the Boss Point Formation were used to identify the base of the Cumberland Group, which projects to the surface ~2.4 km beyond the north end of line 539. A similar calculation allowed identification of the conformably underlying Mabou Group. Higher units in the Cumberland Group were picked from their mapped positions at the surface. The coal-bearing units (Joggins and Springhill Mines Formations) are marked by a diachronous zone of strong coherent reflectivity that marks the changing locus of coal deposition within the basin (Calder and Bromley, 2005). Traced downdip, the coal-bearing units lose coherence and pass into a lens of diffuse reflectivity interpreted as the Polly Brook Formation, an alluvial-fan conglomerate that interdigitates with the coal-bearing units in outcrop (Ryan et al., 1991; Calder, 1994).

By tying line 539 to line 550, the units identified along the coast can be traced east toward the closure of the SW-plunging Athol syncline (Fig. 1) and the adjacent Claremont anticline (Figs. 2A, 2B; see footnote 1). Strong out-of-plane dips (not corrected by the migration of the two-dimensional data) cause some reflections to appear at different TWTs at the tie point, but reflections are easily correlated by their distinctive character.

To the east, strata of the Cumberland and Mabou Groups slope upward and converge (Fig. 2B). Convergence is most conspicuous in the Joggins Formation, which is reduced to less than one-third of its thickness (confirming observations by Copeland, 1959). The Cumberland Group is cut by a near-vertical zone of complex structure (labeled C in Fig. 2B; see footnote 1) in the Claremont anticline near Springhill. Windsor Group evaporites occur as surficial karst features in this structure, along with variably oriented regions of Cumberland Group strata, interpreted as fault-bounded blocks in current geologic maps (see compilation in Ryan et al., 1991; Ryan and Boehner, 1994; Calder, 1995). At depth, zone C appears continuous with a triangular region of discontinuous reflectivity that underlies the Mabou Group, and clearly pinches out to the west at the location labeled W. Zone C is interpreted as largely filled by Windsor Group evaporites, and pinchout W is inferred to represent a salt weld (Jackson and Cramez, 1989) created by evaporite withdrawal. The eastward convergence of reflections in the overlying succession indicates that deposition of the Joggins Formation was accompanied by salt flow into the adjacent anticlines and at least 1 km of differential subsidence in the Athol syncline.

Beneath the inferred weld, subhorizontal diffuse reflections at 3.0–3.6 s TWT are interpreted to represent deeper units of the Windsor, Horton, and/or Fountain Lake Groups. Though poorly imaged, these units appear to continue beneath the evaporite-filled structure at Springhill.

Tatamagouche Syncline and Black River Minibasin

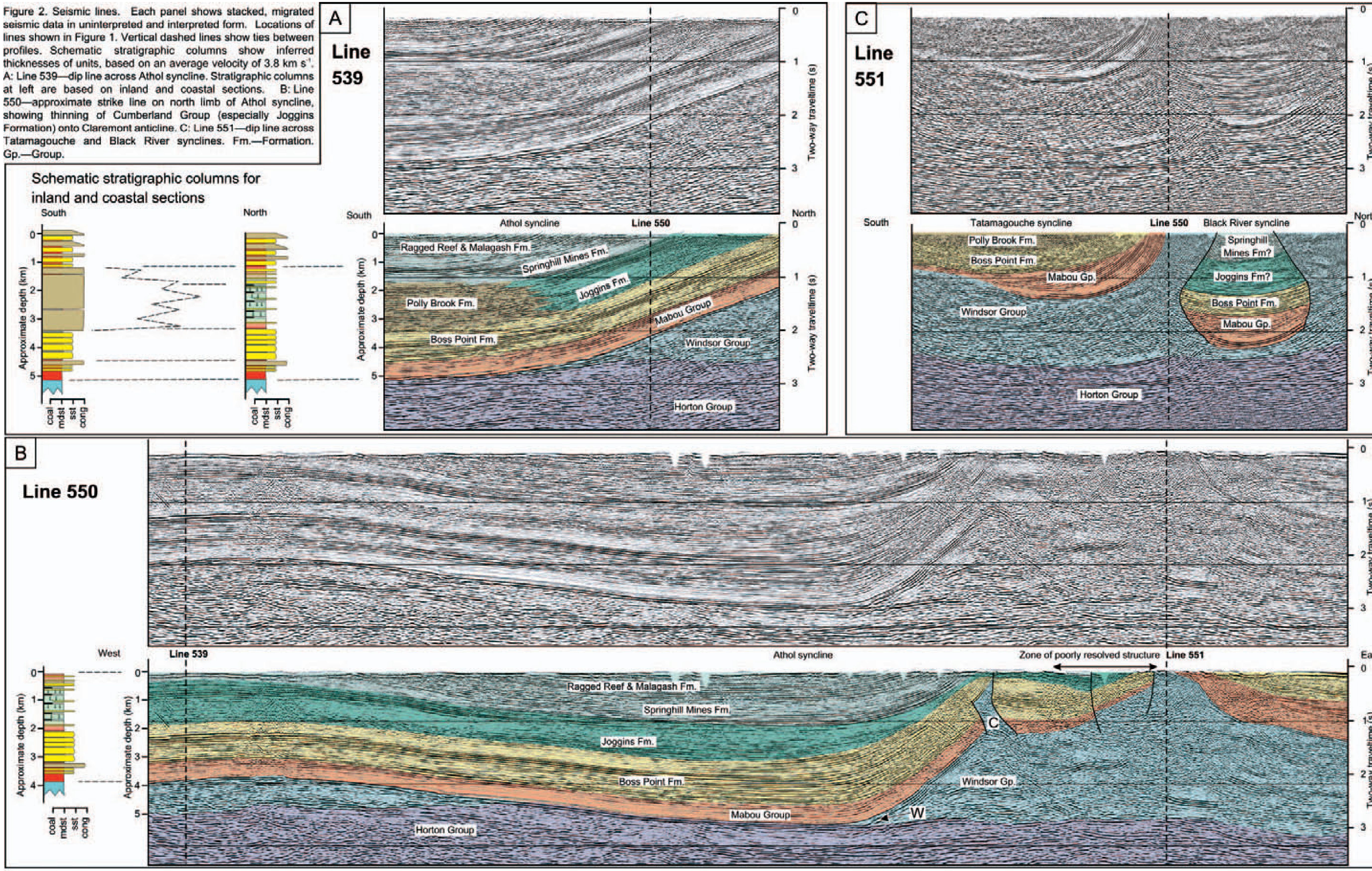
Profiles across the Tatamagouche and Black River synclines were also interpreted by using mapped stratigraphic boundaries. In contrast to the Athol syncline, the Mabou Group–Cumberland Group contact in the southeast part of line 550 (Fig. 2C; see footnote 1) is a distinct angular unconformity. The Mabou Group thickens considerably and shows internal nonparallel reflectors that converge downdip to the southeast. This configuration is interpreted as a minibasin that syndepositionally subsided into the evaporite-bearing Windsor Group, similar to minibasins deposited above evaporites in offshore settings (Jackson et al., 1995).

The unit beneath the minibasin is interpreted as Windsor Group. It shows complex internal structure marked by converging bundles of discontinuous reflectors, indicating that halokinesis began soon after deposition of thick lower Windsor evaporites, with upper Windsor strata filling additional minibasins. Diffuse subhorizontal reflections at ~3 s TWT probably represent the basal Windsor and/or Horton and Fountain Lake Groups beneath the evaporites.

In the northwest part of line 551 (Fig. 2C), in the Black River syncline, a second minibasin extends from the surface to ~2.2 s TWT. The Mabou stratigraphy can be identified from its seismic character, and its upper unconformable contact is clear. However, in this minibasin, a thick overlying Cumberland

[1]Loose insert: Figure 2. Seismic lines.

Figure 2. Seismic lines. Each panel shows stacked, migrated seismic data in uninterpreted and interpreted form. Locations of lines shown in Figure 1. Vertical dashed lines show ties between profiles. Schematic stratigraphic columns show inferred thicknesses of units, based on an average velocity of 3.8 km s⁻¹. A: Line 539—dip line across Athol syncline. Stratigraphic columns at left are based on inland and coastal sections. B: Line 550—approximate strike line on north limb of Athol syncline, showing thinning of Cumberland Group (especially Joggins Formation) onto Claremont anticline. C: Line 551—dip line across Tatamagouche and Black River synclines. Fm.—Formation. Gp.—Group.



Role of evaporite withdrawal in the preservation of a unique coal-bearing succession: Pennsylvanian Joggins Formation, Nova Scotia
Figure 2
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Group indicates that evaporite withdrawal continued through the early Pennsylvanian.

DISCUSSION

Basin Evolution

Rapid subsidence during deposition of the Joggins Formation has long been attributed primarily to basin-bounding faults (Browne and Plint, 1994; Davies and Gibling, 2003), although Calder (1994) speculated that salt withdrawal may have played a role. Lines 550 and 551 show striking intrabasinal contrasts in subsidence history and dramatic thinning of stratal units against salt-cored anticlines, strong indicators of evaporite involvement (Rowan et al., 2003). The general continuity of sub-Windsor reflections at ~3 s TWT suggests that the dramatic thickness changes across the basin resulted from evaporite flow. It is possible that the process may have been initiated and localized by motion along basement and/or basin-bounding faults (Bradley, 1982; Howie, 1986) or by the resulting progradation of alluvial fans near the basin margin (e.g., models of Gemmer et al., 2004).

The amount of differential subsidence can be used to place lower limits on the original thickness of evaporites. The Tatamagouche syncline minibasin records at least 0.9 km of differential subsidence during deposition of the Mabou Group. The contrasting depth of the Boss Point Formation in the Black River syncline indicates an additional 1.6 km of differential subsidence during deposition of the Cumberland Group, and thus the removal of at least 2.5 km of evaporites.

There is no indication of differential subsidence during Mabou Group deposition beneath the Athol syncline. Halokinesis and minibasin development began during deposition of the Cumberland Group, as indicated in line 550 by an evaporite weld at depth, the great thickness of coal-bearing Cumberland Group, and the lateral thickness and facies changes shown by the Cumberland Group (especially the Joggins Formation). These features indicate that the Athol syncline also has the character of a minibasin, albeit significantly larger than those in the east. Comparison of the depths to the Boss Point Formation in lines 539 and 551 indicates that salt withdrawal was accompanied by at least 3.3 km of differential subsidence in the Athol syncline. This amount requires a much larger thickness of Windsor Group than has been previously envisaged for this area (Boehner, 1992).

Figure 3 shows inferred Cumberland basin evolution. Within the Cumberland Group, the Joggins Formation shows the most obvious evidence for evaporite-controlled differential subsidence. The amount of halokinetic subsidence occurring during deposition of the Joggins Formation was at least 1 km (the amount of differential thickness variation within the formation), and perhaps the entire 1.5 km thickness of the unit.

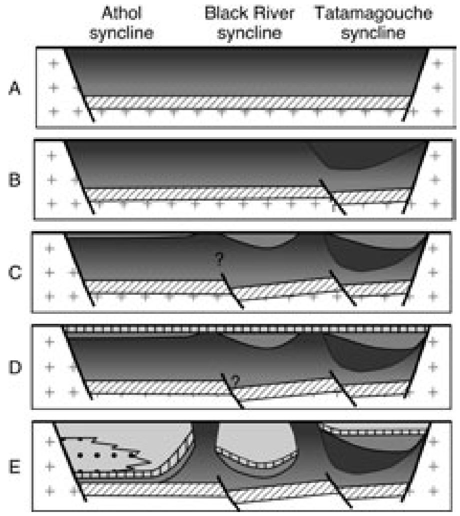

Figure 3. Possible basin history. A: Initial thick section of lower Windsor Group evaporites fill fault-bounded Mississippian Cumberland basin. B: Possible deposition of upper Windsor Group clastic rocks, limestones, and additional evaporites in minibasins formed during early evaporite flow. C: Further halokinesis allows deposition of Mabou Group in minibasins. D: Basin-wide deposition of Boss Point Formation during period of relative halokinetic quiescence. E: Evaporite withdrawal below Athol syncline allows preservation of thick coal-bearing succession. Patterns as in Figure 1. Not to scale.

Subsidence in the Athol Syncline

Interpretation of the Athol syncline as a terrestrial minibasin provides a viable mechanism to explain the limited extent and high rate of subsidence recorded by the Joggins Formation. The overall rate of subsidence (>1 mm/yr) compares well with values of 0.4–7 mm/yr for minibasins in the Gulf of Mexico (Rowan, 1995; McBride et al., 1998) and with numerical models of evaporite flow (e.g., Poliakov et al., 1996). Although the conglomerates of the Polly Brook Formation indicate early Westphalian fault motion along the southern basin margin, the sedimentology of the Joggins Formation (Davies and Gibling, 2003) suggests a basin that subsided steadily rather than by major episodic downdropping. This interpretation stands in contrast to that proposed for the underlying Boss Point Formation, wherein alternating braidplain and lacustrine cycles have been linked to intermittent motion along the bounding faults (Browne and Plint, 1994).

The Joggins lycopsid casts, commonly 5–6 m tall, and reportedly as tall as 12 m (Lyell, 1881), are among the tallest known. Lycopsids had a soft pith supported by a rigid periderm, and entombment must have occurred within a few decades after smothering of the stigmarian roots (Gastaldo et al., 2004; Calder et al., 2005). However, Joggins lycopsids are generally entombed by stacked packages of heterolithic strata that make burial by a single catastrophic flood or earthquake unlikely (J.H. Calder, 2005, personal commun.). If complete burial is assumed to have occurred within 100 yr, entombment of the Joggins lycopsids required frequent sedimentation rates of >50 mm/yr and perhaps as high as 120 mm/yr. Early peat compaction has been suggested as a mechanism for preserving erect tree fossils (e.g., Gastaldo et al., 1991). However, most (n = 59) forested horizons at Joggins occur in association with thin organic-rich horizons or mineral soils; the few (n = 4) coal seams found below lycopsids are thin (≤10 cm) and would have generated only a few tens of centimeters of accommodation as they compacted. Gastaldo et al. (2004) also considered the role of eustasy in a study of 4.5-m-tall lycopsids in the Mary Lee Coal Zone of the southeastern United States, and suggested that eustasy alone could not have generated the necessary rapid accommodation, and instead invoked coseismic subsidence.

Therefore, it is likely that salt withdrawal contributed significantly to the generation of accommodation over short time scales. Although time-averaged vertical movement rates in Quaternary diapirs range only up to 18 mm/yr (e.g., Frumkin, 1996), brittle deformation of sedimentary cover above flowing evaporites is common (e.g., Vendeville and Jackson, 1992; Poliakov et al., 1996). In southwestern Tadjikistan, salt withdrawal causes hundreds of low-magnitude earthquakes (M < 5.2) per decade (Leith and Simpson, 1986). Therefore, rapid development of accommodation at Joggins was probably the result of salt withdrawal combined with episodic brittle deformation, dissolution, seasonal climate, and/or episodic changes in base level. A motif of subsidence that was episodic on a scale of decades but geologically continuous provides a mechanism to explain the ubiquitous fossil forests and thin coals of the Joggins Formation.

CONCLUSIONS

The Joggins section, one of the world's most remarkable and most studied Carboniferous outcrops, is preserved within a minibasin created by the withdrawal of evaporites into adjacent diapiric structures. In this minibasin, the Cumberland Group is 4.2 km thick and contains 2.2 km of coal-bearing strata (Joggins and Springhill Mines Formations); equivalent units in the Tatamagouche syncline are thinner (<500 m) and lack coal-bearing units. Halokinesis provided sustained rapid subsidence, optimal conditions for peat accumulation and lycopsid entombment, and may have driven the eastward migration of the ''coal window'' (Calder, 1994). Subsidence may have been episodic at a time scale of years to decades, thus enabling the repeated preservation of remarkable standing lycopsid casts 5–6 m tall. The subsidence history indicates the initial presence of several kilometers of evaporites in the Cumberland basin, a much thicker Mississippian succession than previously envisaged.

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Response of Late Carboniferous tropical vegetation to transgressive–regressive rhythms at Joggins, Nova Scotia

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Abstract: Fossil plant assemblages are described in their sequence stratigraphic context from the Upper Carboniferous (Langsettian) Joggins Formation of Nova Scotia to elucidate ecosystem response to transgressive–regressive rhythms. Results show that rising base level resulted in retrograding submerged coastal mires co-dominated by *Lepidodendron* and *Lepidophloios*, which were replaced by short-lived *Paralycopodites* communities immediately following mire drowning. Extensive brackish bays existed during early highstand, distally fringed by gymnospermous and putative progymnospermous coastal and/or upland vegetation. Late highstand bay filling generated prograding distributary wetlands dominated by flood-disturbed lycopsid–pteridosperm–sphenopsid communities, and locally by cordaite mangroves. As base level fell, well-drained alluvial plains were dominated by fire-prone cordaite and/or *Sigillaria* communities, which persisted until the next phase of base-level rise. This rhythmic ecosystem succession repeatedly occurred on a *c*. 50–200 ka time scale, and was probably driven by glacial–interglacial climate rhythms.

Keywords: Late Carboniferous, sequence stratigraphy, vegetation, global change.

The Late Carboniferous (Westphalian) tropical vegetation biome is arguably one of the best understood terrestrial ecosystems in pre-Tertiary history (DiMichele & Phillips 1994; DiMichele *et al*. 2001). Fossil plant-bearing strata of this age and palaeolatitude are widespread across North America, Europe and northern Asia (Calder & Gibling 1994), and have been studied for more than two centuries (Scott 1977). To date research has mainly focused on the taxonomy, biology and phylogeny of particular plant groups, and aspects of community structure and ecology (e.g. Gastaldo 1987; Phillips & DiMichele 1992; Falcon-Lang 2000).

The rock successions containing the remains of these terrestrial ecosystems are characterized by repeated marine transgressive–regressive rhythms (Collier *et al*. 1990), resulting from the complex interaction of climate-forced changes in sea level and sediment supply, and variations in basin subsidence rates (Leeder *et al*. 1998). Recent studies have emphasized the long-term persistence of Late Carboniferous tropical vegetation ecosystems through tens of these major environmental perturbations (DiMichele *et al*. 1996; Pfefferkorn *et al*. 2000); however, medium-term ecosystem change within individual transgressive–regressive rhythms remains largely unknown. This latter scale of ecosystem dynamics may be elucidated through analysis of fossil plant assemblages in their sequence stratigraphic context.

In this paper, floral assemblages are described within a sequence stratigraphic framework from the classic Upper Carboniferous Joggins Formation, Nova Scotia (Davies & Gibling 2003), the results of which demonstrate more clearly than before the marked response of Late Carboniferous ecosystems to repeated transgressive–regressive rhythms on a 50–200 ka time scale.

Geological setting

The 1430 m thick Upper Carboniferous (Langsettian) Joggins Formation crops out in spectacular sea-cliffs on the Bay of Fundy, Nova Scotia, Canada (Fig. 1). This coal-bearing section was brought to international attention by Sir Charles Lyell and is particularly famous for its upright fossil trees and the earliest reptiles (Scott 1998). Strata were deposited in the rapidly subsiding, strike-slip Cumberland sub-basin of the Maritimes Basin, which drained northeastwards into the Mid-European Sea (Gibling *et al*. 1992; Calder 1998). Despite being positioned in an intra-continental setting, minimally hundreds of kilometres from open marine waters, brackish bay facies at Joggins attest to short-lived marine incursions during periods of elevated base level (Archer *et al*. 1995).

Sedimentology and sequence stratigraphy

This study focuses on the lower 600 m of the Joggins Formation in which Davies & Gibling (2003) described the following facies associations (outlined here using a slightly revised nomenclature). Grey mudstone units containing coals (10–80 cm thick) are interpreted as retrogradational poorly drained coastal plain deposits dominated by temporally persistent mires. Units bearing organic-rich limestones containing an oligohaline fauna are interpreted as basin-wide brackish open water deposits. Grey, coarsening-upward units dominated by thick channelized sandstone beds and subhorizontal heterolithic beds are interpreted as progradational poorly drained coastal plain deposits characterized by large distributary channels and interdistributary wetlands. Red units containing small channel sandstones and pedogenic carbonate nodules are interpreted as the deposits of well-drained alluvial plains characterized by anastomosed channel networks. Thin grey–green intervals within well-drained alluvial plain units containing millimetre-thick coals are interpreted as alluvial plain deposits characterized by an oscillating water table. Although Davies & Gibling (2003) included these latter units in the well-drained alluvial plain facies association, they contain a distinct flora, and are formally identified in this paper as a partially

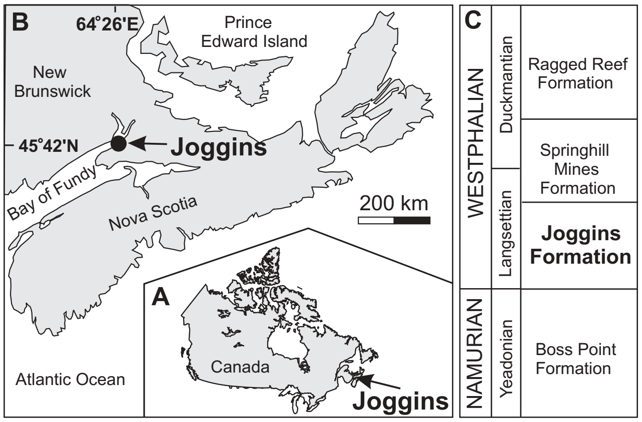

Fig. 1. Location of Joggins in (**a**) Canada and (**b**) Nova Scotia. (**c**) Stratigraphy of the Cumberland sub-basin.

drained alluvial plain association, intermediate between well-drained alluvial plain settings and progradational poorly drained coastal plain settings.

Davies & Gibling (2003) noted that Joggins Formation facies associations are organized into eight sedimentary rhythms in the studied section (Fig. 2). Rhythms 1 and 5–8 are 25–80 m thick, and consist of retrogradational poorly drained coastal plain units overlain by brackish open water units, capped by progradational poorly drained coastal plain units. Rhythms 2–4 are 70 m, 30 m and 210 m thick, respectively, and comprise a very similar succession differing only in the additional occurrence of multiple intercalated partially drained and well-drained alluvial plain units above the progradational coastal plain unit and below the retrogradational coastal plain unit of the following rhythm (progradational coastal plain deposits are suppressed in rhythm 3). Given that the section represents about half the thickness of Langsettian strata in the Cumberland sub-basin (Calder 1998), and that this stage has an approximate duration of 2–3 Ma (Menning *et al*. 2000), rhythms may typically represent *c*. 50–200 ka duration, with the abnormally thick fourth rhythm representing *c*. 300–500 ka duration.

Depositional rhythms are interpreted as resulting from a relatively rapid base-level rise (retrogradational coastal plain units and lower brackish open water units), followed by coastal plain progradation close to mean water table during highstand (upper brackish open water units and progradational coastal plain units) and, in rhythms 2–4 only, by alluvial plain aggradation above mean water table and/or punctuated base-level fall (partially drained and well-drained alluvial plain units), before renewed base-level rise (retrogradational coastal plain units and lower brackish open water units). It is important to emphasize that because of the high accommodation setting, parasequences bounded by flooding surfaces predominate and sequence boundaries are not observed. Consequently, it is inappropriate to apply conventional Exxon-type nomenclature to the succession: system tracts are not readily identifiable in this kind of tectonic setting (Davies & Gibling 2003).

Plant assemblages in facies association context

The stratigraphic distribution of the seven major types of plant assemblages is indicated in Figure 2. The retrogradational coastal plain facies association is characterized by thick coal seams, interpreted as temporally persistent peat mire deposits. It con-

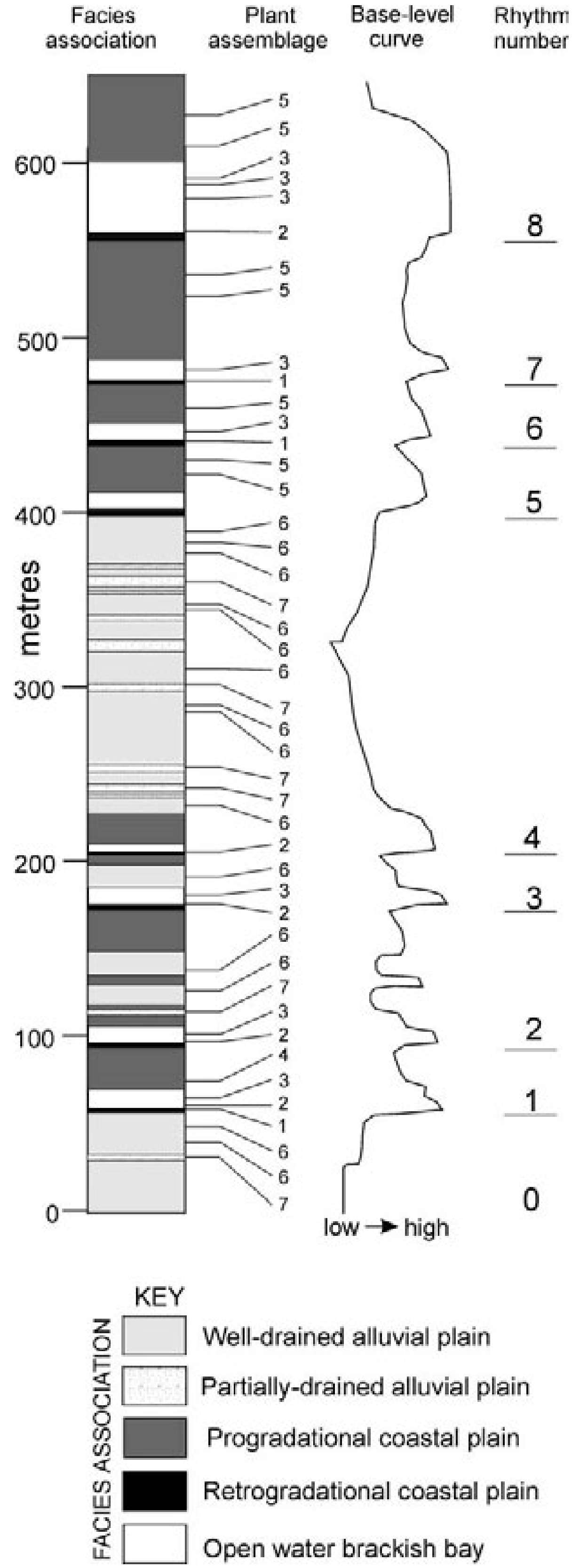

Fig. 2. Stratigraphic column of lower 600 m of Joggins Formation showing facies associations, sedimentary rhythms, base-level curve and major plant assemblages (after Davies & Gibling 2003).

tains parautochthonous megaflora and palynoflora dominantly indicative of *Lepidodendron*, *Lepidophloiois* and *Diaphrodendron* (Hower *et al*. 2000). Other lycopsids (*Sigillaria*) and pteridosperms (*Alethopteris*, *Neuropteris*) are less common, and are typically restricted to a few clastic-rich intervals containing rare lycopsid charcoal, interpreted as flood- or fire-disturbed mires. Grey siltstone units, interpreted as poorly drained, clastic substrate floodbasin deposits, are dominated by allochthonous compressions of *Sigillaria* trunks (up to 35 cm in diameter) together with minor *Alethopteris* and *Neuropteris*. Collectively retrogradational coastal plain assemblages are referred to as Assemblage 1.

The brackish open water facies association contains two major plant assemblages. The first (Assemblage 2) occurs in organic limestone beds, interbedded with coaly laminae, or immediately overlying the thick coals of the retrogradational coastal plain association, interpreted as very shallow, transgressive bay margin deposits. Megafloral compressions of lycopsid rootstocks (*Stigmaria*) and allochthonous decorticated lycopsid trunks are common. Palynological assemblages indicate the dominance of the lycopsid *Paralycopodites* (Hower *et al*. 2000). The second plant assemblage (Assemblage 3) occurs at higher intervals in the brackish open water units, in beds totally devoid of any rooting structures. Organic-rich siltstones and planar-bedded sandstones locally exhibiting hummocky cross-stratification and wave-rippled tops, interpreted as open brackish bay deposits, contain purely allochthonous, fragmentary compressions of putative progymnosperms (*Pseudadiantites* and *Rhacopterium*; Wagner 2001), pteridosperms (*Alethopteris*, *Karinopteris* and *Paripteris*), sphenopsids (*Calamites* and *Asterophyllites*) and cordaitaleans (*Cordaites*). Rare, charred pycnoxylic wood also occurs, being dominated by cordaitaleans (*Dadoxylon materiarium* Dawson; Falcon-Lang & Scott 2000) and other gymnosperms of indeterminate affinity (*D. recentium* Dawson). No palynomorphs were recovered.

The progradational coastal plain facies association also contains two major plant assemblages. The first (Assemblage 4) is restricted to a single stratigraphic interval near the base of one progradational coastal plain unit (Rhythm 1), and consists of thinly bedded, undulatory, heterolithic strata, interpreted as very shallow interdistributary lagoonal deposits on the bay margin. These are dominated by abundant allochthonous cordaitalean compressions (*Cordaites*, *Cordaicarpus*). Numerous, slender (up to 12 cm diameter), upright trees with flared bases, woody trunks with narrow piths, and complex adventitious rooting systems are rooted at multiple intervals in these beds. These enigmatic trees are tentatively interpreted as cordaitaleans based on their association with an exclusively cordaitalean allochthonous assemblage.

The second progradational coastal plain assemblage (Assemblage 5) occurs in channelized sandstone bodies of up to 8 m thickness locally exhibiting inclined stratification, interpreted as large distributary channel deposits, and in sheet sandstone bodies, interpreted as crevasse splay deposits. These contain abundant allochthonous metre-long lycopsid trunk compressions (*Lepidodendron*, *Lepidopholois*, *Sigillaria*; 35–40 cm diameter), common sphenopsids (*Calamites*), and locally common to rare cordaitaleans (*Cordaites*, *Artisia*). Rare, allochthonous charcoal in the same beds contains an equal mixture of indeterminate lycopsid periderm and cordaite wood (*Dadoxylon materiarium*). Closely spaced upright *Calamites* stems (up to 13 m^{-2}) are commonly rooted within multiple crevasse splay complexes. Inclined to horizontal, heterolithic stratal packages, interpreted as rapidly aggrading interdistributary floodbasin deposits, contain tens of upright, sandstone-cast lycopsid trees (20–40 cm diameter, up to 2–3 m high). Although upright lycopsid trunks are decorticated and therefore of indeterminate genus, one calcareously permineralized individual is characteristic of *Sigillaria*. Facies-associated parautochthonous compressions and palynoflora indicate the predominance by *Sigillaria* and *Lepidodendron* lycopsids, with common sphenopsids (*Calamites*), pteridosperms (*Alethopteris*, *Neuropteris* and *Sphenopteris*) and cordaitaleans (*Cordaites*).

The well-drained alluvial plain facies association is characterized by small, channelized sandstone bodies, interpreted as anastomosed river channel deposits, and associated sheet sandstone bodies interpreted as crevasse splays dissected by feeder channels. These contain allochthonous assemblages dominated by the impressions, compressions and calcareous permineralizations of cordaitaleans (*Artisia*, *Cordaites*, *Cordaixylon*, *Dadoxylon materiarium* and *D. acadianum* Dawson) with minor pteridosperms (*Alethopteris*, *Eusphenopteris*) and sphenopsids (*Calamites*, *Asterophyllites*), and very rare lycopsids (*Sigillaria*). Abundant allochthonous charcoal assemblages are dominated by cordaitalean woods (*Dadoxylon materiarium* and *D. acadianum*) with an additional wood of indeterminate gymnosperm affinity (*D. recentium*). Autochthonous lycopsid and calamitean stems rarely occur rooted in the channel margin deposits. Red, desiccation-cracked, mudstone units bearing carbonate nodules, interpreted as well-drained floodbasin deposits, contain parautochthonous compressions and impressions dominated by cordaitaleans (*Cordaites*, *Cordaicarpus*) with minor pteridosperms (*Eusphenopteris*). Parautochthonous charcoal assemblages are composed entirely of cordaitalean wood (*Dadoxylon materiarium*). No palynomorphs were recovered. Collectively well-drained alluvial plain assemblages are referred to as Assemblage 6.

The partially drained alluvial plain association characterized by mottled grey–red mudstones interpreted as wet–dry floodbasin deposits contains allochthonous megafloral compressions dominated by lycopsids (*Sigillaria*, *Lepidodendron*) with minor pteridosperms (*Alethopteris*, *Neuropteris*, *Sphenopteris*), cordaitaleans (*Cordaites*, *Cordaiocarpus*), and sphenopsids (*Calamites*, *Annularia*, *Asterophyllites*). Intercalated 1–8 mm thick muddy coals, interpreted as extremely short-lived mires, contain tens of calcareously permineralized autochthonous lycopsid stumps (24–131 cm basal diameter) with attached *Stigmaria* attributed solely to *Sigillaria* based on periderm anatomy (Falcon-Lang 1999). Associated parautochthonous assemblages of common megafloral compressions, abundant charcoal mesofossils, and palynoflora in the thin coals are dominantly indicative of *Sigillaria* with minor medullosan pteridosperms (*Alethopteris*, *Trigonocarpus*), cordaitaleans (*Cordaites*, *Dadoxylon materiarium*) and sphenopsids (*Calamites*, *Asterophyllites*). Collectively these transitional assemblages are referred to as Assemblage 7.

Ecosystem response to transgressive–regressive rhythms

Analysis of facies-associated plant assemblages in the context of the Joggins Formation sedimentary rhythms provides important information concerning ecosystem response to base-level fluctuations (Fig. 3).

Assemblage 1 in the thick coals of the progradational coastal plain units suggests that initial base-level rise resulted in temporally persistent mires dominated by *Lepidodendron*, *Lepidophloiois* and *Diaphrodendron* lycopsid forests. The known ecological tolerances of these plants suggest an undisturbed, permanently submerged mire environment (DiMichele & Phillips 1994). Assemblages in charcoal-bearing clastic partings indicate

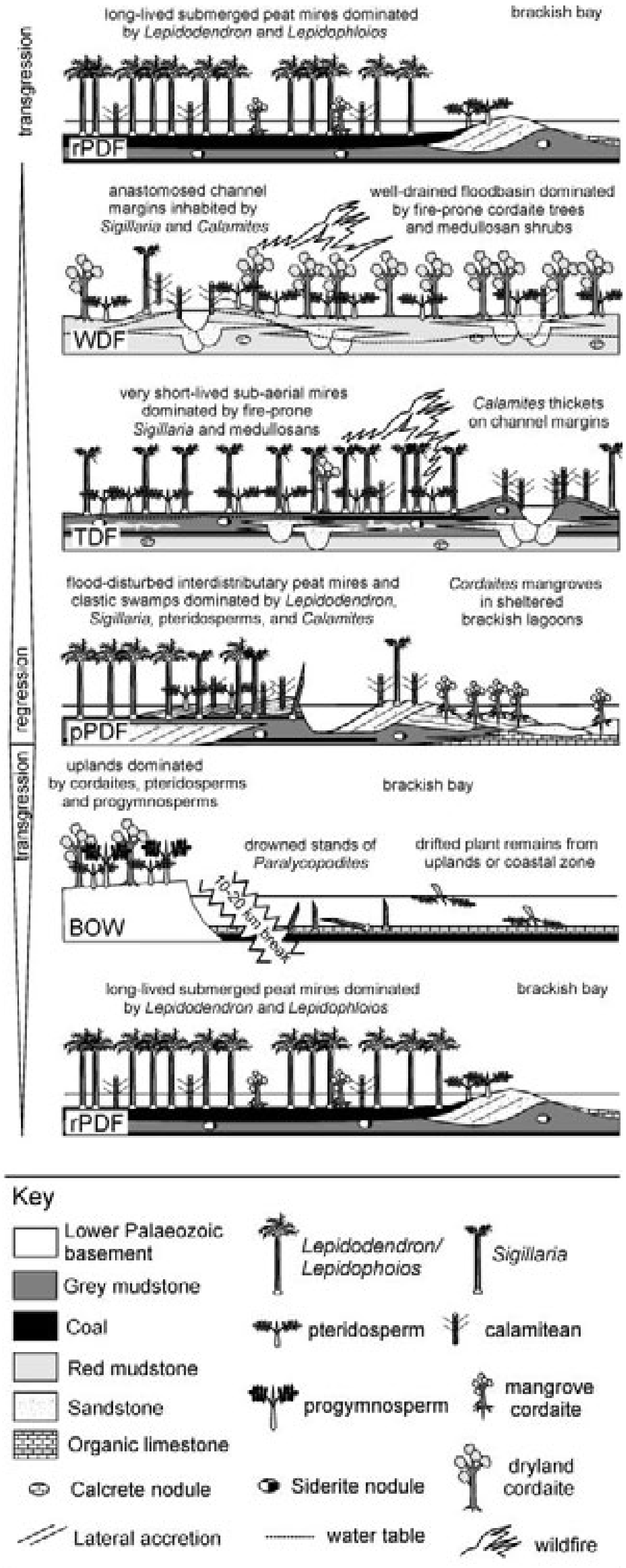

Fig. 3. Summary palaeoecological reconstruction showing idealized ecosystem response to a trangressive–regressive rhythm. rPDF, retrogradational coastal plain; WDF, well-drained alluvial plain; TDF, partially drained alluvial plain; pPDF, progradational coastal plain; BOW, brackish open water bay.

that rare disturbances by fires and floods resulted in short-lived successional communities of *Sigillaria* lycopsids and pteridosperms. Based on estimates of modern peat accumulation rates and Carboniferous coal compaction coefficients (Falcon-Lang 2000), coal bed thickness data suggest that retrograding lycopsid-dominated coastal mires kept pace with rising base level for at least several hundred years before finally being drowned.

Assemblage 2 in organic-rich limestones at the base of brackish open water units, immediately overlying the retrogradational poorly drained coastal plain mire deposits, indicates that *Paralycopodites*, an ecotonal lycopsid (DiMichele & Phillips 1994), initially colonized very shallow clastic-starved bays for a short period following mire drowning. However, as base level continued to rise, and the bays deepened, all vegetation was eventually excluded from the local region. Allochthonous Assemblage 3 in the bay deposits is dominated by gymnosperms and progymnosperms, plants that presumably must have been colonizing distal shorelines and/or emergent uplands during highstand (see Scott *et al*. 1997; Falcon-Lang & Scott 2000), most probably on Lower Palaeozoic basement blocks, 10–20 km from the Joggins Formation depocentre (Gibling *et al*. 1992). The occurrence of progymnosperms in these deposits (flora most typical of Early Carboniferous times) is particularly interesting, perhaps suggesting that these archaic elements had continued to survive in 'upland' settings (Wagner 2001).

Assemblage 4 at the base of the progradational coastal plain unit in Rhythm 1 suggests that, as the brackish bays began to infill by means of coastal progradation, stands of slender cordaite trees locally developed in sheltered lagoons as mangrove-like communities (see Cridland 1964). The more widespread Assemblage 5 in channelized sandstones and heterolithic beds in the progradational coastal plain units (including the classic sandstone-cast fossil forests for which Joggins is most famous), indicates that additional progradation resulted in interdistributary wetlands dominated by diverse, spatially complex vegetation. These intergrading flood-disturbed communities were variously populated by lycopsids (*Sigillaria* and *Lepidodendron*), sphenopsids or pteridosperms (Scott 1998).

In five rhythms (1 and 5–8), this progradational phase is followed by renewed base-level rise and a return to the *Lepidodendron–Lepidophloios*-dominated mires of the retrogradational coastal plain setting. However, in rhythms 2–4 continued aggradation of the coastal plain above mean water table, possibly coupled with base-level fall, resulted in the development of well-drained alluvial plains. Assemblage 6 in these well-drained alluvial plain units indicates that this environment was colonized by low-diversity cordaite vegetation, with common pteridosperm shrubs (*Alethopteris*, *Eusphenopteris*), and a very few lycopsids (*Sigillaria*) and calamiteans restricted to riparian niches where the water table was closest to the surface. Charcoal abundance demonstrates that these were highly fire-prone communities, and dominance–diversity assemblage characteristics imply ecological stress (Falcon-Lang 2003). Assemblage 7 in the partially drained alluvial plain units intercalated with the well-drained alluvial plain units indicates that the fire-prone cordaite vegetation of the latter deposits was repeatedly succeeded by fire-prone *Sigillaria*-dominated communities, which locally formed short-lived mires, during periods of slightly elevated water table.

Discussion

This study has demonstrated that Late Carboniferous vegetation ecosystems repeatedly changed in response to transgressive–

regressive rhythms. Two main communities are recognized in the Joggins Formation: (1) wetland vegetation dominated by lycopsids existed during periods of rising base level (retrogradational poorly drained coastal plain units and the lower part of brackish open water units) and late highstand (progradational poorly drained coastal plain units); (2) dryland vegetation dominated by fire-prone cordaites and/or sigillarian lycopsids existed during periods of low base level (partially drained and well-drained alluvial plain units). A third, poorly defined community dominated by progymnosperms and gymnosperms is identifiable during early highstand phases (upper part of brackish open water units), and may represent upland and/or coastal vegetation distally fringing the brackish bays.

Two complementary hypotheses may account for the observed ecosystem response to transgressive–regressive rhythms. First, changes in ocean proximity may have altered local humidity, with highstand periods being most humid, and lowstand periods, when Joggins became isolated within an intermontane continental interior setting, being most arid (Ziegler *et al*. 2002). Second, although sedimentary rhythms related to glacial–interglacial climate changes cannot be unequivocally identified at Joggins because of the high accommodation setting (Davies & Gibling 2003), it is probable that dry lowstand periods mostly correlate with glacial phases and wet highstand periods with interglacial phases (see Tandon & Gibling 1994). Either or both of these mechanisms for generating lowstand aridity and highstand humidity adequately account for vegetation change because lycopsids were drought intolerant (with the exception of *Sigillaria*) and would therefore be restricted to transgressive–highstand periods, whereas gymnosperms, by virtue of the innovation of the seed habit, were drought resistant, and would have had the ecological advantage in well-drained regressive–lowstand settings (DiMichele & Phillips 1994).

This pattern of lowstand aridity and highstand humidity has been seen at many other Late Carboniferous palaeotropical sites in Europe and North America, with the limited palaeobotanical data demonstrating the dominance of lycopsid-dominated peat mire ecosystems during the early part of transgressive phases and late highstand phases (e.g. Hartley 1993; Tandon & Gibling 1994; Demko & Gastaldo 1996). This suggests that the rhythmic ecosystem response to transgressive–regressive phases demonstrated in the Joggins Formation may actually have been characteristic for most of the Late Carboniferous tropical world, with a few local exceptions where climatic humidity and sea level apparently fluctuated out of phase (e.g. Cecil 1990).

The recognition that Late Carboniferous tropical terrestrial ecosystems repeatedly oscillated between lycopsid rainforests and cordaite drylands in response to base-level fluctuations on a 50–200 ka time scale probably driven by glacial–interglacial climate rhythms is highly significant. This is not least because it may shed some light on the current controversy concerning the extent to which tropical rainforests became fragmented by more drought-tolerant vegetation during the relatively arid Last Glacial Maximum, and whether climate change augmented speciation rate by repeatedly isolating populations (e.g. Hooghiemstra & van der Hammen 1998; Colinvaux *et al*. 2001). Considerable further work is therefore required to examine the impact of medium-term global change on the Late Carboniferous world, and to consider its impact on the biodiversity of this early rainforest biome.

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Feature

UNESCO World Heritage and the Joggins cliffs of Nova Scotia

UNESCO World Heritage status is the highest honour that may be bestowed on a palaeontological site. In addition to heightening conservation status, it confers international recognition of a locality's 'outstanding universal value' and often triggers the release of substantial regional development funds. Despite these incentives it is, perhaps, not surprising that only a handful of fossil sites have successfully navigated the World Heritage selection process. In this feature, we draw on our recent experience of developing a World Heritage bid for the Pennsylvanian 'Coal Age' locality of Joggins, Nova Scotia. As well as demonstrating the huge significance of Joggins, we hope that our findings will provide valuable guidelines for the assessment of World Heritage fossil sites in general.

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There is still an amazing thrill for us in returning to Joggins. These spectacular sea-cliffs fringe the Bay of Fundy in eastern Canada for many tens of kilometres, and have been carved out by the world's highest tides (Fig. 1). To take the road to Joggins as it winds through blood red marshes and tidal creeks is to follow in the footsteps of Sir Charles Lyell, the founder of modern geology. Lyell first visited these Pennsylvanian coal measures at the height of his career in 1842. Of the many important things he observed, none excited him more than the occurrence of numerous upright fossil trees rooted in thin coal layers. A 'most wonderful phenomenon' he remarked in a letter to his sister on 30 July 1842, and one that conclusively demonstrated for the first time that coal seams formed as the soil layer of ancient forests. In fact so many of his uniformitarian principles were confirmed at Joggins that he later wrote in 1845 that nowhere else had his 'scientific pursuits [been] more zealously forwarded than in Nova Scotia'. The impact of this place on Lyell, and its subsequent incorporation into Darwin's *Origin of Species*, has led to Joggins being described as the 'Coal Age Galapagos'.

When we began our research in the 1990s, very little geological investigation had been undertaken at Joggins for nearly a century. Lyell's initial research had been followed up by several prominent nineteenth century geologists, most notably Sir William

Logan and Sir William Dawson (Fig. 2), and it is possible that subsequent workers thought there was nothing further to add to the story. However, two factors suggested to us that the geological interest of Joggins was far from exhausted. Not only did Joggins contain one of the thickest, and therefore most complete, Pennsylvanian successions in the world, but also the cliff section was being eroded back by the Fundy tides at a terrific rate. Consequently, each year a massive volume of new rock was becoming available for sedimentological and palaeontological study.

The many exciting, new, discoveries that have resulted from our 'new look' at Joggins (see Suggested Reading) have convinced us that Lyell was absolutely right when, in his *Student's Elements of Geology* (1871), he described the site as 'the finest example in the world of a natural [Pennsylvanian] exposure'. This article describes our ongoing work to formally gain international recognition for Joggins through the World Heritage programme of the United Nations Educational, Scientific and Cultural Organisation (UNESCO). In doing so, we hope to clarify some of the essential criteria that are needed to assess competing World Heritage candidate sites in general, and touch upon the intrinsic difficulties inherent in proving that one fossil site is more important than another.

Defining the goal posts

According to Articles 2.43–2.44 of the *UNESCO World Heritage Convention* (1972), a fossil site may be eligible for inscription on the World Heritage List if it is of 'outstanding universal value' representing the best example of a 'major stage of the Earth's history'. To date UNESCO has tended to recognize sites that are representative of specific geological periods, eras, or even key evolutionary events. The handful of existing World Heritage fossil sites include the Burgess Shale of Canada erected for the 'Cambrian Explosion' in metazoan diversity and the UK's Dorset–Devonshire coast that encompasses the environments and ecosystems of the Mesozoic Era. The first crucial step of our work at Joggins was therefore to define the goal posts. In other words, to carefully consider precisely of what our site was being considered representative.

Given Lyell's unrestrained praise for Joggins, one might think that the obvious answer would be the Pennsylvanian System. However, there is a major philosophical flaw in identifying *any* site as being representative of a particular time-period. This problem, which has never been adequately discussed in any earlier World Heritage proposals, is caused by biogeography. Ever since Late Palaeozoic times, terrestrial ecosystems have been organized into distinct, climate-controlled biomes. If we think about our modern world, the difficulties this raises are immediately evident. Which single site would we choose as representative of today? Would we plump for the tropical rainforests of Amazonia for their high biodiversity or the peat bogs of Siberia for their great areal extent?

One way round this problem is to use concept of iconography. In his *Book of Life* (1993), the late Stephen J. Gould pointed out that, because we are intrinsically visual beings, the history of life has always been told through series of evocative, pictorial reconstructions. Of the many Pennsylvanian successions world-wide, none have been studied in more detail or more frequently conceptualized in museum dioramas than the palaeotropical coal-bearing deposits of Europe and North America (Fig. 3). True, excellent and informative Pennsylvanian depos-

Fig. 1. The classic Joggins section of Nova Scotia looking north from Coal Mine Point.

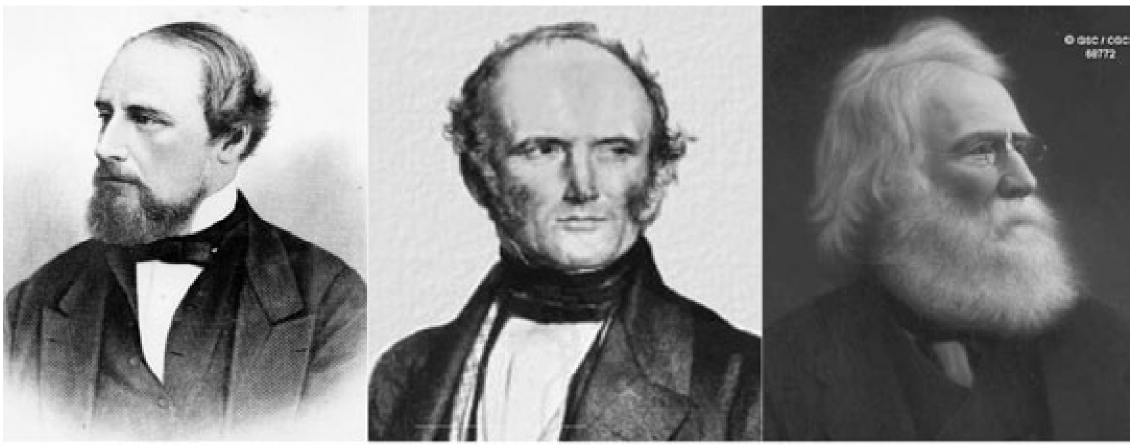

Fig. 2. The 'founding fathers' of Joggins. Left to right: portraits of Sir William Dawson (1820–1899), Sir Charles Lyell (1797–1875), and Sir William Logan (1798–1875).

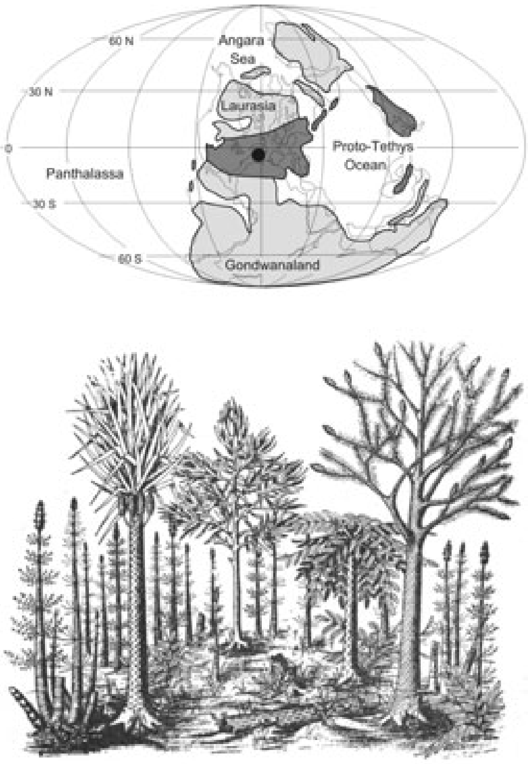

Fig. 3. The Pennsylvanian world. Above: Palaeogeographic map showing the tropical zone (dark grey) and the location of Joggins (black circle). Below: Reconstruction of a Pennyslvannian coal mire (from Falcon-Lang *et al.* 2004)

its have been preserved from mid-to-high palaeolatitudes, but ask a geologist what the Pennsylvanian world was like and you will be immediately regaled with tales of steamy tropical rainforests. Therefore, following Gould's reasoning, any candidate World Heritage site for the Pennsylvanian 'Coal Age' must encompass the iconography of the wetland rainforest biome. Place the major evolutionary event of the 'dawn of reptiles' into this diorama and you have distilled the essence of this time-period.

Biodiversity and evolutionary significance

Having narrowed our search down to a single iconic biome, what criteria are useful for assessing the merits of competing sites? Most past World Heritage bids have tended to emphasize the biodiversity and evolutionary significance of fossil assemblages above all else. As we will see later, this approach can result in a distorted picture of the true value of a fossil site. Nevertheless, it is a valuable place to start. Biodiversity is most usefully assessed at a variety of taxonomic levels so that not only is the richness of the fossil assemblage considered (species level) but also its overall variability (phylum level). A similar weighting is needed when dealing with evolutionary significance. Not only should the origination of new families be assessed, but also the occurrence of major watersheds in the evolution of life on Earth.

Applying these criteria to Pennsylvanian 'Coal Age' sites marks out Joggins as one of the top three or four sites in the world. One of Joggins' strongest competitors in this assessment category is the famous Mazon Creek site of Illinois. In comparison to Joggins, it contains a far richer and more diverse fossil assemblage with a much greater evolutionary significance. However, marine animals that lived in the estuaries and shallow seas adjacent to the coal forests comprise a large proportion of Mazon Creek's amazing biodiversity. Consequently, whilst extremely important, this fossil assemblage has not contributed as greatly to the classical iconography of Pennsylvanian times as other rival sites such as the Sydney Coalfield of Nova Scotia and the Freeport coal measures of Ohio and Pennsylvania.

However, Joggins triumphs over all these sites in two iconic aspects of the Pennsylvanian world. First, Joggins contains the world's best examples of upright Coal Age trees, a fossil record of the bizarre arborescent club-mosses that dominated forest ecosystems at this time. Second, it contains the earliest known reptile. This lizard-sized animal was discovered by Sir William Dawson within the hollowed-out stump of a fossil club-moss tree in 1859 (Fig. 4). *Hylonomus lyelli*, which Dawson named in honour of his British colleague, appeared on a Canadian stamp in 1992, and was designated provincial fossil of Nova Scotia in

Fig. 4. *Hylonomus lyelli*, the earliest known reptile, sheltering from a forest fire in a hollow tree trunk (painting by Steve Greb, Kentucky Geological Survey).

2002. Its occurrence records one of the most important evolutionary events in the Palaeozoic, the final step in the adaptation of vertebrate animals to life on land.

Quality of fossil archive

A second crucial category of assessment, criteria grossly under-utilized in past World Heritage bids, relates to the quality of the fossil archive. Biodiversity is, of course, of prime importance but also significant is the geological context and preservational quality of a fossil assemblage. Fossils on their own can say little about palaeoecology, community structure, and biotic response to environmental change. Such information can only be inferred by analyzing superbly-preserved fossil assemblages within their palaeo-environmental context over long periods of geological time.

It is in this assessment category in particular that Joggins rises head and shoulders above all its nearest rivals. The Joggins coal measures were deposited in a strike-slip basin that was undergoing extremely rapid subsidence, and consequently the classic section contains one of the thickest and most complete Pennsylvanian successions in the world. Specifically, Joggins combines uniquely a very large geological window (some two million years) with a very wide range of environments, including continental drylands, peat-forming wetlands, and coastal bays. Furthermore biotic remains are preserved as 'fossilized ecosystems' from which detailed insights into the dynamic nature of the Pennsylvanian tropical biome may be ascertained.

This quality of preservation, for which we propose the term 'eco-lagerstätten' is rarely seen in other Pennsylvanian sites, although comparable detail occurs in the younger Sydney coalfield of Nova Scotia. Whereas sites like Mazon Creek, whose fossils are mixed together from a variety of different environments, remain mute about ecological and environmental interactions, Joggins and Sydney speak eloquently of tropical rainforests obliterated by catastrophic floods, reptiles fleeing gigantic forest fires, and the long-term impact of climate change. The huge significance that this style of preservation affords these two Nova Scotian sites was clearly understood by Sir William Dawson. In a letter to Lyell dated 13 August 1868, he wrote prophetically that it is better to study fossils 'as they stand in the cliffs of Sydney and Joggins, instead of on the shelves of the British Museum' (Fig. 5). We agree. Geological context is essential for proper appreciation of a fossil assemblage's significance.

Integrity and impact

A third category necessary to assess World Heritage status is a consideration of a site's 'integrity' and 'impact'. In using these terms, we wish to address several related factors. Firstly, *integrity* refers to the expected permanence of a candidate site. What is the nature of the fossil locality and what is its expected lifespan? We must not lose sight of the fact this is a process to define *sites*. Obviously natural coastal cliff sections are more-or-less permanent geomorphic features that will persist for many thousands of years. In contrast, opencast mines are intrinsically ephemeral exposures dependent on continued mineral extraction. Clearly, when assigning World Heritage status, preference should be given to relatively long-lived sites. Secondly, *impact* refers both to the past contribution of a fossil site to our developing knowledge of the History of Life, and also to the likelihood that it will continue to do so in the future. This latter aspect may be inferred by examining the historical record of site exploration to see whether most discoveries were made in the distant past or still continue today.

Of the four most influential Pennsylvanian localities already mentioned, only Joggins and Sydney in Nova Scotia are natural coastal cliff exposures, with a high degree of expected permanence. Exposures in the Freeport coalfield of eastern USA are currently good,

Fig. 5. Fossil tree preserved in its original growth position following burial by flood-deposited sands, Joggins, Nova Scotia.

but are likely to degrade when mining operations inevitability cease. This scenario has already been played out for the famous Mazon Creek site, whose original exposures have now all but vanished. The only lasting legacy of this once-significant site is the excellent fossil collections that are now distributed throughout international museums.

Whilst all the sites reviewed so far (with the possible exception of the Sydney Coalfield) have made an illustrious contribution to our knowledge of the Pennsylvanian Subsystem, only a few will continue to do so. New research at Mazon Creek, for example, is now limited to an analysis of museum collections, and literature reviews indicate a significant drop-off in the number of publications about the site since the 1960s. Not so with Joggins, however, whose outcrop is annually renewed by the power of the Fundy tides. In fact, literature studies suggest that, following a trough in the early twentieth century, new discoveries at Joggins are today occurring at an ever-accelerating rate. The same is true for the Sydney coalfield, a site which has been inadequately studied in the past, but which in the future may rival Joggins in its significance, provided that research impetus continues unabated at its present speed. That said, we cannot rewrite human or Earth history, and the role that Joggins played as a 'Coal Age Galapagos' for nineteenth century geologists is a matter of historical record.

Concluding remarks

In this article, we have attempted to provide a rigorous framework for the assessment of candidate UNESCO World Heritage sites, using the Pennsylvanian 'Coal Age' site at Joggins, Nova Scotia as a case study. It will be evident from our discussion that a multi-faceted approach is essential; an approach that judges sites, not only in terms of fossil content, but also with due consideration for archival quality and long-term integrity. When analyzed in this manner, the outstanding universal value of Joggins is clearly evident. This site is supremely iconic of the Pennsylvanian 'Coal Age', containing an unrivalled record of fossil biota preserved in a high-resolution palaeo-ecological context. History tells of the crucial role Joggins has played in the formulation of many fundamental geological insights since the time of Lyell, and there is every reason to believe that it will continue to do so in the future. As we write, Joggins has passed the first test in the World Heritage selection process. It has been placed on Canada's national list of potential UNESCO sites. We eagerly await future developments.

Suggestions for further reading about Joggins

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Parcs Canada Parks Canada

25 Eddy Street
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November 27, 2007

Mr. Bastian Bomhard
IUCN Headquarters
Rue Mauverney 28
CH-1196 Gland
Switzerland

Dear Mr. Bomhard:

On behalf of Canada, I am responding to a 14 November 2007 letter, submitted to us by the IUCN, with respect to **IUCN Evaluation of "The Joggins Fossil Cliffs" Canada – Nominated for inclusion on the World Heritage List**. In that letter, IUCN requested that Canada submit supplementary information relative to the nomination, following its evaluation mission to Joggins on 19-25 October 2007.

I understand that John Pinkerton of my office has communicated with you and Mr. Alessandro Balsamo of the World Heritage Centre about this request, and that you have both agreed to receive this information electronically at this point. I am pleased, therefore, to submit the requested information attached to this letter. As agreed, hard copies will follow by regular mail shortly.

Thank you for your collaboration for the implementation of the World Heritage Convention in Canada.

Yours sincerely,

Larry Ostola
Director General
National Historic Sites

cc Tim Badman, IUCN
Alessandro Balsamo, World Heritage Centre
HE Gilbert Laurin, Ambassador and Permanent Delegate of Canada to UNESCO
Jenna Boon, Joggins Fossil Institute

Canada

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November 27, 2007

Mr. Alessandro Balsamo
Assistant Programme Specialist
World Heritage Centre
7, place de Fontenoy
75352 Paris
France

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Thank you for your collaboration for the implementation of the World Heritage Convention in Canada.

Yours sincerely,

Larry Ostola
Director General
National Historic Sites

cc Bastian Bomhard, IUCN
HE Gilbert Laurin, Ambassador and Permanent Delegate of Canada to UNESCO
Jenna Boon, Joggins Fossil Institute

Joggins Fossil Institute

Analysis of Relative Significance of Terrestrial Tetrapod 'Icon'

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to consolidate (or extend if required) the information contained within the comparative analysis within the nomination and appendices to more clearly justify how this statement is supported by the evidence for Joggins and comparable sites, in particular in relation to the fossil record of terrestrial tetrapods and their evolution and ecology."

STATE PARTY RESPONSE:

Approach

Leading international experts on the fossil record, evolutionary significance and paleoecology of terrestrial tetrapods from this period of earth history were consulted. All have extensive experience in the global record, and specific knowledge of the fossil record at Joggins. Dr. Andrew Milner was asked, without prejudice, to lead a comprehensive evaluation of the significance of the record of terrestrial amniotes, with specific reference to the earliest amniotes (reptiles and related lineages). Supplementary information on the tetrapod trackway record was provided by Dr. Spencer Lucas, and a second opinion on the analysis was solicited of Dr. Jenny Clack (all appended).

• Dr. Jenny Clack, Vertebrate Palaeontologist and Director, Museum of Comparative Zoology, Cambridge University, UK, is the leading expert on the terrestrial adaptation of early tetrapods, and author of the definitive book on the subject, *Gaining Ground*.

• Dr. Spencer Lucas, Vertebrate Paleontologist & Acting Executive Director, New Mexico Museum of Natural History and Science, USA, is the leading expert on the fossil record of tetrapod footprints of the Late Paleozoic, including the Carboniferous.

• Dr. Andrew Milner, Vertebrate Palaeontologist, Natural History Museum, London, UK, is the leading expert on Carboniferous tetrapod ecology and has published extensively and worked directly on the relative significance of the fossil record of all major tetrapod localities from this period of earth history.

Joggins Fossil Institute

Analysis of Relative Significance of Terrestrial Tetrapod 'Icon'

Executive summary of expert analysis

Joggins has been confirmed as the most important site for its past, present, and future contributions to our understanding of the evolution of terrestrial tetrapods and the earliest amniotes.

The expert panel concluded that:

- "The Joggins locality is fundamental to our past and present understanding of the development of terrestrial ecosystems and the role of tetrapods within those ecosystems. It was the first such locality to give us information about this aspect of the evolution of life on Earth, and it continues to have more potential than any other locality to reveal more information about the events and structure of life at this time." [AM]
- "6 of the 10 species are the earliest members of their family-level taxon, while the amniotes are not only the earliest of this group (the reptile-bird-mammal) grouping but also the earliest members of the subgroups Reptilia and the Synapsida." [AM]
- "The presence at Joggins of the earliest representatives of crown-group amniotes and the two major amniote subgroups (Reptilia and Synapsida) makes the site and its fauna a key calibration point for all molecular phylogenetic studies of tetrapod evolution." [AM]
- The fossil record of tetrapod footprints at Joggins "represents the single most extensive assemblage of Carboniferous tracks known anywhere." [SL]
- "Joggins is the archetypal footprint assemblage of its time period—early Pennsylvanian. All other known footprint assemblages of this age (or similar age), which are from Europe and North America, are compared to Joggins." [SL]
- "Joggins is also the only surviving locality in which a combination of terrestrial tetrapods, terrestrial invertebrates, plants and trace-fossils are present in proximity and hence, in which all aspects of a terrestrial ecosystem [from this period of earth history] can be studied at the same time." [AM]

In reference to tetrapod footprints as conclusive evidence of amniotes, the panel concluded that:

- "Assumptions about the faunas that produce footprint assemblages … lack the rigour of conclusions drawn from skeletons" and that "the association of footprints with skeletal taxa is an exercise in reasonable probability, rather than an exact science." [AM]

- Older examples than those recently published of tetrapod footprints resembling those of amniote origin occur within the nominated property. [SL]
- "It is virtually impossible to be sure what constitutes an amniote from trackways alone ... The existence of true amniotes is presently, and almost certainly always will be, identifiable only by skeletal remains: the earliest site to yield undisputed amniote skeletal material is Joggins." [JC]

In her expert opinion of the analysis, Dr. Clack concludes that:

- "I am very happy to add my voice to support the Joggins Fossil Cliffs site in its proposal for status as a World Heritage Site. Dr Milner has made the case very clearly as to why the site is so important for understanding the early evolution of terrestrial vertebrates, and I can only endorsed his statement very strongly."
- "Joggins is one of only two existing sites that give us a window into the earliest terrestrial vertebrate life on this planet during a 40-million year period of earth history. The older, Mississippian site, however, predates the true 'Coal Age', is considerably more restricted in geographical, stratigraphical and taxonomic range, and does not contain true amniotes. Furthermore only the Joggins site can put the fauna into the environmental context of the Pennsylvanian 'Coal Age' ecosystem. It preserves not just the vertebrates, but gives us rich information about the plants and animals that surrounded them, and thus the circumstances in which they lived, what they fed on, and what fed on them. It is also unique in combining a significant body fossil record with a rich and diverse trackway fossil record that is second to none in the time period it represents." [JC]

Attachments

IUCN Clack letter_Nov30.pdf	Expert opinion on the analysis.
IUCN Milner tetrapod analysis.pdf	Analysis of relative significance of Carboniferous tetrapod sites.
IUCN tetrapod ichnotaxa_Lucas.pdf	Appendix dealing with the record and significance of tetrapod trackways.

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Friday, November 30, 2007

John Calder, PhD
Nova Scotia Department of Natural Resources
PO Box 698, Halifax
Nova Scotia, Canada
B3J 2T9

Dear Dr. Calder,

I am very happy to add my voice to support the Joggins Fossil Cliffs site in its proposal for status as a World Heritage Site. Dr Milner has made the case very clearly as to why the site is so important for understanding the early evolution of terrestrial vertebrates, and I can only endorsed his statement very strongly. Joggins is one of only two existing sites that give us a window into the earliest terrestrial vertebrate life on this planet during a 40-million year period of earth history. The older, Mississippian site, however, predates the true 'Coal Age', is considerably more restricted in geographical, stratigraphical and taxonomic range, and does not contain true amniotes. Furthermore only the Joggins site can put the fauna into the environmental context of the Pennsylvanian 'Coal Age' ecosystem. It preserves not just the vertebrates, but gives us rich information about the plants and animals that surrounded them, and thus the circumstances in which they lived, what they fed on, and what fed on them. It is also unique in combining a significant body fossil record with a rich and diverse trackway fossil record that is second to none in the time period it represents.

Recently, much has been made of the proposed existence of true amniote trackways from a site that has been considered earlier than the oldest amniote skeletons, which are from the Joggins Fossil Cliffs. (I do note that similar, and still older, trackways of this type apparently occur in older rocks of the nominated property). However, I cannot agree with the opinion that pentadactyl (five-toed) trackways equal amniote trackways. It is virtually impossible to be sure what consititutes an amniote from trackways alone. The existence of pentadactyly is not sufficient evidence, nor is the existence of small size or scaly skin impressions. All of those attributes could be expected in pre-amniote forms that were not identifiably amphibian. Amphibians in this context means the group known as temnospondyls, that can be recognized from their possession of only a four-digit manus (front foot) (though there are other forms with a four-digit manus that according to current phylogenies are stem amniotes). Most stem amniotes would have had a pentadactyl manus, and many of them clearly were small, and were probably covered by small scales. The earliest pentadactyl manus known from the skeletal fossil record is significantly earlier than the time represented by the Joggins Fossil Cliffs, but it is not a true amniote (Paton et al. 1999). The existence of true amniotes is presently, and almost certainly always will be, identifiable only by skeletal remains: the earliest site to yield undisputed amniote skeletal material is Joggins.

Nevertheless, the trackway record is important in preserving aspects of the vertebrate and invertebrate fauna that body fossils cannot give. At Joggins they preserve information about the fauna of 313 milllion years ago, such as the range of morphologies and sizes of the animals that lived at that time that are missing from the body fossil record, and instances of the animals' interactions that are unlikely to be captured in the skeletal record. It is in this respect that the Joggins Fossil Cliffs trackway horizons are of international importance.

With best wishes,

Prof. Jenny Clack

Reference cited:

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THE RECORD AND RELATIVE SIGNIFICANCE OF TERRESTRIAL TETRAPODS FROM CARBONIFEROUS FOSSIL LOCALITIES

Andrew R. Milner

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25 November 2007

ABSTRACT

The Joggins locality is fundamental to our past and present understanding of the development of terrestrial ecosystems and the role of tetrapods within those ecosystems. It was the first such locality to give us information about this aspect of the evolution of life on Earth, and it continues to have more potential than any other locality to reveal more information about the events and structure of life at this time.

Of the eight most significant Carboniferous tetrapod localities, Joggins is the only one which is sustainedly productive and one of only two still capable of supporting a protracted research programme into early terrestrial tetrapods and ecosystems. Of the others, four are completely destroyed, two have only residual spoil-heap exposures and one (East Kirkton) could only be reactivated at great expense. Joggins is also the only surviving locality in which a combination of terrestrial tetrapods, terrestrial invertebrates, plants and trace-fossils are present in proximity and hence, in which all aspects of a terrestrial ecosystem can be studied at the same time. Joggins is the earliest locality in which diverse terrestrial microsaurs, reptiles and synapsids are present, and after East Kirkton, is the second earliest with significant numbers of terrestrial tetrapods in the assemblage. The presence of the earliest representatives of crown-group amniotes and the two major amniote subgroups (Reptilia and Synapsida) at Joggins makes the site and fauna a key calibration point for all molecular phylogenetic studies of tetrapod evolution.

A). SITE COMPARISONS

INTRODUCTION

Prior to 1842, it was believed that there were no tetrapods in the Palaeozoic. The first to be collected – *Apateon pedestris* from the Lower Permian of Germany – demonstrated that at least aquatic tetrapods were present in the latest Palaeozoic. The discovery of terrestrial tetrapods in unambiguously Carboniferous strata at Joggins in 1852 produced a radical paradigm shift in palaeontologists' understanding of the early history of tetrapods and this historical significance can never be lost. Remarkably, the locality remained unchallenged as the earliest significant source of a terrestrial tetrapod fauna until the mid-1980's and, even now, only the Scottish East Kirkton site provides an earlier example of an assemblage containing terrestrial tetrapods.

The significance of the Joggins fossil tetrapod assemblage can best be explained by comparison with the other significant tetrapod-producing assemblages from the Upper Mississippian to Middle Pennsylvanian inclusive. 'Significance' is here based on the presence in the fauna of at least six tetrapod taxa. There are just eight such fully described localities including Joggins, listed by age:

Name:	Age	Subperiod/stage
East Kirkton, Westlothian, Scotland:	328 Ma.	Brigantian = Late Mississippian.
Jarrow, Co Kilkenny, Ireland:	313 Ma	Langsettian = Lower Pennsylvanian.
Joggins, Nova Scotia, Canada:	313 Ma	Lower Pennsylvanian.
Newsham, Northumberland, England:	312 Ma	Duckmantian = Middle Pennsylv.
Mazon Creek, Illinois, USA:	309 Ma	Late Middle Pennsylvanian.
Linton, Ohio, USA:	307 Ma	Late Middle Pennsylvanian.
Florence, Sydney, Nova Scotia:	307 Ma	Late Middle Pennsylvanian.
Nýřany, Czech Republic:	307 Ma	Asturian = late Middle Pennsylv.

The ages given are from Gradstein, Ogg and Smith (2004). In the following account, the localities will be referred to by the name in bold. Over 90% of the tetrapod taxa from this era derive from these eight localities, most other localities producing just 1-2 specimens each.

THE SWAMP-LAKE ASSEMBLAGES

Four of the above-listed assemblages represent swamp-lake faunas with occasional terrestrial 'drop-ins'. All are from 19th century coal mines which no longer exist and only at Linton can occasional specimens be retrieved from a spoil-heap.

Jarrow

The Jarrow locality was a coal mine, worked through the mid-late 19th century. It is long defunct and further site-based research is impossible except from drill-cores. The productive horizon is contemporaneous with Joggins and is believed to have been an ox-bow lake in a lowland coal-swamp. The site produced about 150 skeletons, indifferently preserved but articulated, and the fauna is predominantly aquatic with a few terrestrial exotics. Of the *c*150 specimens about 30 are fish, 110 are aquatic tetrapods belonging to 10 taxa (Sequeira 1996), and three specimens are terrestrial tetrapods – the temnospondyl *Dendrerpeton* as found at Joggins. It is only by comparison with the better-preserved Joggins material that these specimens were recognised as such (Milner 1980a). There are no associated footprint beds and only 1-2 arthropod fossils.

Newsham
The Newsham locality was a coal-mine, worked in mid-19th to early 20th century. It is long defunct, the spoil-heap is burnt-out and further site-based research is impossible. It is the best example of many British Coal Measure assemblages of Langsettian-Bolsovian age. The productive horizon is slightly younger than Joggins and represents a large abandoned channel, effectively a long thin lake, in a coastal swamp. The site produced thousands of isolated bones and a few skeletons (Newman *et al*. 1996). The assemblage is almost entirely aquatic, comprising some 15 taxa of fish and six taxa of aquatic tetrapod. Two specimens – an anthracosaur and an aïstopod may be terrestrial accidentals. There are no associated footprint beds or arthropod fossils.

Linton
The Linton locality was a coalmine, worked in the mid-19th to early 20th century. The mine is long defunct but the spoil heap is still productive. The productive horizon can be studied in the vicinity and it represents a very local oxbow lake in a lowland coal swamp (Hook & Ferm 1988). It is late Middle Pennsylvanian in age – some 6 million years later than Joggins. The site produced at least 6000 vertebrate specimens comprising some 5,500 fish specimens in 12 taxa and about 500 tetrapod specimens in 27 taxa (Hook & Baird 1986). Most of the tetrapod taxa are of aquatic animals and these also comprise most of the specimens. About 30 specimens represent terrestrial exotics in several taxa including 20 specimens of two temnospondyls (*Platyrhinops, Stegops*), 2 specimens of a terrestrial anthracosaur (*Eusauropleura*), 3 specimens of a microsaur (*Tuditanus*), 7 specimens of reptiles or synapsids (*Anthracodromeus, Archaeothyris* and unnamed forms). This is a large number of terrestrial exotics for a coal-swamp locality but in proportion to the total number of specimens it is equivalent to the situation eleswhere. They represent exactly the same groups as comprise the Joggins fauna but are later genera. There are no associated footprint beds and few arthropods, mostly millepedes, from this locality.

Nýřany
The Nýřany localities were two coalmines, worked in the mid-19th to at least mid-20th century, though little collecting seems to have been possible from spoil heaps after 1970. The productive horizon is no longer exposed at the surface and is of Asturian age, some 6 million years younger than Joggins. It represents a small lake, possibly an oxbow lake in a coal-swamp in an intermontane basin, so further inland than the other localities. Preservation is excellent. The site produced at least 2000 specimens comprising 1200 fish specimens in 7 taxa and about 800 specimens of tetrapod in 22 taxa. Most of the tetrapod taxa are of aquatic animals and these also comprise most of the specimens. About 34 specimens of tetrapod represent terrestrial taxa including 9 specimens of two temnospondyls (*Platyrhinops, Mordex*), 16 specimens of terrestrial anthracosaurs (*Gephyrostegus, Solenodonsaurus*), 10 specimens of microsaur (*Sparodus, Crinodon, Ricnodon*) and three specimens of reptile or synapsid (*Brouffia, Coelostegus, Archaeothyris*) (Milner 1980b and unpublished), again the same groups as represented at Joggins but from later forms. There are no associated footprint beds but the site has produced several millepedes, spiders and one bushcricket.

Summary
These four localities, together have produced what we consider the stereotypical 'coal-swamp' tetrapod fauna, in actuality four distinct types of swamp-lake fauna with the larger assemblages having a small 'exotic' component of terrestrial vertebrates. None have associated footprint assemblages and the assumption of terrestriality of the rare elements in the faunas is based partly on structural criteria discussed below and partly by comparison with the Joggins assemblage.

Apart from a few arthropods in the Nýřany assemblage, we have little impression of associated terrestrial ecosystems from these assemblages. As noted above, all are from defunct mines and only occasional specimens can be collected from spoil-heaps at Linton. There are coal seams with fish remains on the beach at Joggins but to my knowledge they have not been systematically studied.

DELTA-FAN ASSEMBLAGE

Mazon Creek

The Francis Creek Shale fauna, originally from Mazon Creek, was ultimately collected from vast spoil-heaps from extensive strip-mining of coal in central Illinois. The mining has ceased and the spoil-heaps are stabilising but still quite productive. The productive horizon represents a vast delta-fan comparable in size to the Mississippi delta with regular flood-surges producing mud-banks with included material washed down a river. The horizon is late Middle Pennsylvanian in age – some 5 million years later than Joggins. The fossils are found in tiny siderite concretions and preservation is excellent, small arthropods being found regularly. The term fossil-lagerstatte is correctly applicable to this assemblage. Hundreds of thousands of specimens have been collected. They have produced a good picture of terrestrial plants and invertebrates with many tens of plant and arthropod taxa described. Only about 25 tetrapods have been collected – most collectors finding one in a life-time. Most are aquatic but at least four represent terrestrial forms – 3 temnospondyls (*Amphibamus*) and one reptile (*Cephalerpeton*) (Milner 1982, Godfrey 1997). There are no footprint assemblages associated with this fauna but the arthropod fauna is the baseline for discussion of mid-Pennsylvanian arthropod faunas. It is however, like the vertebrates, entirely derived from transported material.

Summary

There are several minor ‘Mazon-like’ assemblages from elsewhere but with specimens countable in hundreds at most and very few vertebrates. Such localities always have potential however and there is at least one such siderite concretion assemblage in the Joggins sequence.

CRATER-LAKE ASSEMBLAGE

East Kirkton

The East Kirkton assemblage was collected between 1984 and 1996 from a defunct limestone quarry and from stone walls in the vicinity. The quarry, having been used as an educational theme-park for some years, is reverting to its original neglected status but has the potential for further excavation. The productive horizons are of Brigantian age and some 15 Ma older than Joggins. The lake was an isolated volcanic crater lake with algal mats and a restricted fish-free fauna. About 200 tetrapod specimens were collected, along with numerous isolated bones, in both lake bed and ashfall layers. Some specimens were aquatic juveniles, but many were apparently small terrestrial animals perhaps moving into the water in response to volcanic events. The faunal diversity is not great with most specimens belonging to one temnospondyl (*Balanerpeton*), two anthracosaurs (*Silvanerpeton, Eldeceon*) and one ?microsaur/reptile (*Westlothiana*). *Westlothiana* was described as the earliest reptile, but later workers have noted microsaur-like features. Its reassessment has awaited the accessibility of two further specimens in private hands. Several other tetrapods of ambiguous lifestyle are known. The tuffe layers also produced isolated bones of larger terrestrial tetrapods, at present indeterminate. There are no associated footprint assemblages, but there are numerous millepedes, several scorpions and a harvestman spider.

Summary

The East Kirkton assemblage represents some sort of catastrophic event associated with vulcanism. It certainly predates Joggins and does provide a substantial body of data on late Mississippian terrestrial assemblages, particularly temnospondyls and anthracosaurs. At present there is only one animal which might be either a microsaur or a reptile and its status is uncertain. There is nothing comparable to the array of microsaurs and reptiles at Joggins.

LYCOPSID TRUNK ASSEMBLAGES

Florence

The Florence assemblage was collected in 1956 from five lycopsid trunks in one horizon at an open-cast quarry near Sydney, Nova Scotia (Carroll *et al.* 1972). The original working is now flooded, so further collection is not possible. It is late Middle Pennsylvanian in age – some 6 million years later than Joggins. Most of the material came from a single trunk. The fauna, like that at Joggins contains many fragments of skeletons and a precise count is difficult. All components appear to be terrestrial, comprising a minimum of 35 specimens namely, three temnospondyl specimens (*Cochleosaurus*), two anthracosaur specimens (*Carbonoherpeton*), one microsaur (unnamed), 19 reptile specimens (*Protorothyris*, *Limnostygis*) and 10+ specimens of synapsid (*Archeothyris*, *Echinerpeton*). Millepedes are present in the trunks and there are footprint beds in associated strata as at Joggins.

This assemblage is clearly a later counterpart to Joggins but with a different faunal content, not just for chronological reasons. Here reptiles and synapsids predominate and temnospondyls and microsaurs are rare. Had the locality survived and been further exploited, it would have provided a fascinating comparison with Joggins but we can only speculate to what extent the assemblage, largely from a single trunk, is a microcosm of the fauna at the time.

Joggins

The history of the Joggins assemblage is dealt with elsewhere in this document. Because the lycopsid stumps are continually being exposed by erosion, it continues to be a productive locality. The productive horizons are now dated as Langsettian-equivalent Lower Pennsylvanian at about 313 Ma. The tetrapod fauna from the lycopsid trunks is difficult to quantify because of the fragmentary and dispersed nature of many specimens but a rough census by the author suggests 140 specimens are known from the various productive trunk-horizons. The productive horizons are associated with footprint-bearing horizons, and millepedes, chelicerates and the earliest terrestrial gastropods have been found in the lycopsid trunks. Insects have been found in associated horizons.

Because the Joggins assemblage represents one of the earliest terrestrial vertebrate assemblages, its components represent, in many cases, the earliest examples of their taxa, both at family level and higher. This is summarised in the following table.

Temnospondyli

Dendrerpeton acadianum (70 specimens): = 2nd oldest temnospondyl

Cochleosauridae incertae sedis (1 specimen):

= Oldest member of Family Cochleosauridae (also at Jarrow)

= Oldest member of Superfamily Edopoidea (also at Jarrow)

Anthracosauria

Calligenethlon (10 specimens): no special status

Microsauria.

Asaphestera(10-20 specimens):

Oldest member of microsaur Family Tuditanidae

Leiocephalikon(15 specimens) *& Hylerpeton*(4 specimens*)*:

Oldest members of microsaur Family Gymnarthridae

Ricnodon(4 specimens) *& Archerpeton*(2 specimens*)*: no special status.

Amniota

Hylonomus (8-10 specimens): Oldest member of Family Protorothyrididae,

Oldest member of Class Reptilia,

= Oldest member of Amniota.

Protoclepsydrops and indeterminate ophiacodont (3-4 specimens):

Oldest member of Family Ophiacodontidae,

Oldest member of Class Synapsida,

= Oldest member of Amniota.

As can be seen from this listing, 6 of the 10 species are the earliest members of their family-level taxon, while the amniotes are not only the earliest of this group (the reptile-bird-mammal) grouping but also the earliest members of the subgroups Reptilia and the Synapsida. This has made them fundamental taxa for the calibration of molecular clocks in molecular-phylogenetic studies (e.g. Reisz & Müller 2004). They represent a latest date for the dichotomy of the reptile-bird clade and the mammal (synapsid) clade and are considered sufficiently close to real-time evolution by many workers that the age of Joggins is used as an absolute date as well as a latest date (Benton 1990) though this is controversial (Müller & Reisz 2005). As a result, the Joggins amniotes have a key position in the calibration of molecular dating throughout the vertebrates.

SUMMARY

General conclusions from the above comparisons are as follows:

1) Of the eight localities under consideration, Joggins is the only one which is sustainedly productive and one of only two still capable of supporting a protracted research programme. Of the others, Jarrow, Newsham, Nýřany and Florence are completely destroyed, Linton and Mazon Creek have residual spoil-heap exposures and East Kirkton could only be reactivated at great expense. The cliffs and beach at Joggins are capable of supporting sustained research into early terrestrial ecosystems.

2) Joggins and the defunct Florence locality are the only ones in which a combination of terrestrial tetrapods, terrestrial invertebrates, plants and trace-fossils are present in proximity. Joggins is the only surviving locality in which all aspects of a terrestrial ecosystem can be studied at the same time.

3) Joggins is, after East Kirkton, the second earliest locality with significant numbers of terrestrial tetrapods in the assemblage and the first in which diverse terrestrial microsaurs, reptiles and synapsids are present. Apart from *Westlothiana* at East Kirkton, all other terrestrial microsaur and amniote records are later.

4) The presence at Joggins of the earliest representatives of crown-group amniotes and the two major amniote subgroups (Reptilia and Synapsida) makes the site and its fauna a key calibration point for all molecular phylogenetic studies of tetrapod evolution.
5) As a general conclusion, the Joggins locality is fundamental to our past and present understanding of the development of terrestrial ecosystems and the role of tetrapods within those ecosystems. By an accident of history it was the first such locality to give us information about this aspect of the evolution of life on Earth, but it continues to have more potential than any other locality to reveal more information about the events and structure of life at this time.

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B. CRITERIA FOR ASSESSING TERRESTRIALITY AND APPROACHES TO THE AMNIOTE CONDITION.

The taphonomic/palaeoecological contexts in which fossils are found provide major clues as to the life-style of the original fauna, but there are a number of skeletal features (applicable to Joggins and contemporaneous sites) which are used as indicators of terrestriality regardless of taxon (structure of the skull and limbs) or of relationship to amniotes (reptiles and synapsids), regardless of lifestyle (structure of the braincase, neck, ribs, limbs and manus). These are described in greater detail below.

Terrestriality.

Undoubtedly early tetrapods filled a full range of niches from aquatic to terrestrial with a range of amphibious forms in between. On the assumption that form relates to function, and by analogy with living amphibians and reptiles, there are a few skeletal features that we can use as indicators of a predominantly terrestrial life-style.

1. Ossified carpals in wrists and tarsals in ankles, particularly in animals less than a metre in length. When wrists and ankles are used in walking, the skeletal elements in them have to resist compression and are ossified. In swimmers where the limbs are used a paddles, the same elements have to be torsion-resistant and are cartilaginous – leaving a ‘gap’ in the limb skeleton.
2. The presence of grooves in the skull for lateral-line canals indicates an aquatic life-style, their absence is more ambiguous but is consistent with a terrestrial life-style.
3. Skull shape associated with predominant feeding pattern. Aquatic tetrapods tend to be long-jawed fish-eaters or broad-skulled suction-gulpers with shallow gapes – all with spike-like teeth. Terrestrial tetrapods tend to have deep skulls and deep gapes and include a wide range of dental types for feeding on a range of terrestrial invertebrates.

Stem-amniotes and amniotes.

The approach to the amniote condition commenced with the replacement of buccal-pumping respiration by costal breathing. The former comprises ramming large mouthfuls of air into the lungs and its skeletal correlates are a large buccal (mouth and throat) region, no neck and small straight ribs. Costal breathing (sucking air into the lungs by expanding the rib-cage) requires long curved ‘wrap-around’ ribs and permits a smaller head on a mobile neck. These morphotypes can easily be recognised from skeletons. Not all stem-amniotes were terrestrial but most were. Crown-amniotes (reptiles and synapsids) are characterised by detailed features of the skull and neck construction (spin-offs of the head-neck mobility permitted by costal respiration), slender rod-like belly scales (body off the ground) and by slender limb-bones associated with more refined terrestrial locomotion. Some stem-amniotes (anthracosaurs) and all early crown-amniotes have a five-toed manus whereas most other early tetrapods have a four-toed manus. This can be recognised in both articulated skeletons and footprints.

Terrestriality in the Joggins tetrapod fauna

The Joggins fauna comprises the following taxa with their criteria listed: (The taxa indicated by asterisk are rare and known only from fragments and are identified as terrestrial or amniote by analogy, comparison with later material rather than by the innate properties of the Joggins specimens. All the commoner taxa can be recognised either as terrestrial or as early amniotes/stem-amniotes by the characteristics of the Joggins material.)

Temnospondyli

Dendrerpeton – ossified carpals and tarsals, no lateral-line canals, skull shape.

*Cochleosaurid – one fragment terrestrial by analogy with cochleosaurs from Florence and Linton.

Anthracosauria

Calligenethlon – ambiguous as a terrestrial animal but certainly a stem amniote with long recurved ribs and a small head with a distinct neck. Relatives elsewhere have the 5-toed manus. Microsauria. Where preservation permits, all Joggins microsaurs have ossified carpals and tarsals, no lateral-line canals, deep skulls with deep gapes and diverse dentitions associated with insect and mollusc-feeding. They have slender recurved ribs.

Asaphestera – tiny peg-like teeth

Ricnodon – small slender teeth

**Archerpeton* – poorly known from two fragments

Leiocephalikon – crushing dentition

Hylerpeton – crushing dentition

Amniota

Hylonomus – *Hylonomus* has ossified carpals and tarsals, no lateral-line canals, deep skull with a deep gape. It has detailed skull and neck construction of an amniote, recurved ribs, slender limbs, rod-like belly scales

**Protoclepsydrops* – known from a few fragments including an ophiacodont pelycosaur as found at Florence and Nýřany. Recognised by specific comparison with material elsewhere rather than general synapsid features.

Feet and footprints

The association of footprints with skeletal taxa is an exercise in reasonable probability, rather than an exact science. Temnospondyls and microsaurs have a 4-toed manus (hand) usually with fairly compact toes. Some stem-amniotes (anthracosaurs and diadectomorphs) and all early true amniotes (reptiles and synapsids) have a five-toed manus. These two groupings can obviously be distinguished from good footprints. In general (but not invariably), anthracosaurs and diadectomorphs have stout compact toes with no claws, whereas early reptiles and synapsids have longer more slender toes, often claw-bearing. We can make consistent working assumptions about the faunas that produce footprint assemblages, but such assumptions lack the rigour of conclusions drawn from skeletons. If skeletons and footprints are found in associated horizons, obviously the assumptions are seen as much more reasonable.

C. THE SIGNIFICANCE OF JOGGINS CARBONIFEROUS FOOTPRINTS

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November 26, 2007

SUMMARY ANALYSIS

Joggins is the archetypal footprint assemblage of its time period. All other known footprint assemblages of this age (or similar age) are compared to Joggins. At Joggins, the rocks exposed along the coastline have produced many thousands of footprint-bearing slabs that have been studied for more than 150 years. They represent the single most extensive assemblage of Carboniferous tracks known anywhere.

SALIENT POINTS

- The most extensive Carboniferous fossil footprint record comes from Nova Scotia (Canada).
- The Nova Scotian track record is the most complete single stratigraphic succession of Carboniferous tracks known.
- W. E. Logan first discovered Paleozoic tetrapod tracks in Nova Scotia in 1841. This was one of the earliest discoveries of fossil footprints anywhere, and the first Carboniferous footprint discovery in the New World.
- Extensive and now classic studies of the Nova Scotian footprint record by Willliam Dawson (1844, 1845, 1863a, b, 1868, 1872, 1882, 1893, 1895) and George Matthew (1903a, b, c, 1904, 1905) followed. Many more works were published in the twentieth century, and research and publication on the Carboniferous footprint record of Nova Scotia continues today.
- Various Carboniferous footprint localities are known in Nova Scotia, and the most extensive and prolific site is at Joggins. Here, the rocks exposed along the coastline have produced many thousands of footprint-bearing slabs that have been studied for more than 150 years. They represent the single most extensive assemblage of Carboniferous tracks known anywhere.

- Joggins thus is the archetypal footprint assemblage of its time period—early Pennsylvanian. All other known footprint assemblages of this age (or similar age), which are from Europe and North America, are compared to Joggins.

- Because of the early study and long study of fossil footprints from Joggins, many type specimens of fossil footprint ichnotaxa are from Joggins. By a recent compilation, the named ichnotaxa from Joggins encompass 18 ichnospecies assigned to 13 ichnogenera (see attached).

- This means that the original concept of many Carboniferous footprint ichnotaxa comes from Joggins, and that collections from Joggins--past, present and future--will continue to influence the better understanding of these ichnotaxa.

TETRAPOD FOOTPRINT ICHNOTAXA DEFINED FROM THE JOGGINS FOSSIL CLIFFS

Anthichnium
- *Anthichnium obtusum* (Matthew, 1905)
- *Anthichnium quadratum* (Matthew, 1905)

Asperipes
- *Asperipes avipes* Matthew, 1903
- *Asperipes flexilis* Matthew, 1905

Barillopus
- *Barillopus arctus* Matthew, 1905
- *Barillopus confusus* Matthew, 1905
- *Barillopus unguifer* (Matthew, 1903)

Baropezia
- *Baropezia abscissa* Matthew, 1905

Cursipes
- *Cursipes dawsoni* Matthew, 1903

Dromillopus
- *Dromillopus celer* (Matthew, 1903)
- *Dromillopus quadrifidus* Matthew, 1905

Hylopus
- *Hylopus minor* Matthew, 1905

Limnopus
- *Limnopus mcnaughtoni* (Matthew, 1903)

Matthewichnus

- *Matthewichnus velox* (Matthew, 1905)

Ornithoides

- *Ornithoides trifidus* (Dawson, 1895)

Quadropedia

- *Quadropedia levis* (Matthew, 1905)

Pseudobradypus

- *Pseudobradypus caudifer* (Dawson, 1882)

Salichnium

- *Salichnium adamsi* (Matthew, 1905)

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to confirm legal means for regulating the construction of coastal defence structures within the nominated property."

STATE PARTY RESPONSE:

Provincial legislation and municipal planning strategies and land use by laws regulate the construction of coastal defence structures at the Joggins Fossil Cliffs.

Provincial Legislation

The principal legislation defining the responsibilities for regulating any development of coastal protection in Nova Scotia is the *Beaches Act* (Revised Statutes of Nova Scotia 1989, Chapter 32). Official copies of the *Beaches Act* and *Regulations* were included in Appendix G:2 of Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007).

As described in the nomination documentation (Section 1.E (ii) on pages 15 and 16, Figures 4a and 4b and in Section 5.B (ii) on page 86), the *Beaches Act* (and associated *Regulations*) restricts activities from the mean high-water mark seaward and also landward of the mean high water mark for the Lower Cove protected beach. A permit is required to construct structures in these areas. Applications for permits must include the location of the property and information about the proposed development plans. Infilling in front of recreational or residential properties is generally not a permitted activity under the *Act*. The Department of Fisheries and Oceans (Canada) would also review proposed projects to identify any possible navigation and fish habitat concerns.

Bank protection work carried out entirely above the mean high-water mark does not require a permit from the Department of Natural Resources. Private land owners are responsible for implementing proper erosion control measures to protect the aquatic environment from saltation. If the bank protection requires placement of material, or operation of machinery, below the ordinary high-water mark, a permit is required through the Department of Natural Resources. In the case of the nominated property, given the recognition as a protected site through the provisions of the provincial *Special Places Protection Act*, permits would not be issued by the provincial government for such developments and activities.

Municipal Legislation

Although a permit to conduct protection work above the mean high-water mark is not required under provincial legislation, municipal land use planning and zoning by laws (Appendix G;4 Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007) apply at the Joggins Fossil Cliffs and provide overlapping protection. As indicated on page 87 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January 2007), two policies – "Cliffs and Shoreline Setbacks" and "Prohibited Uses and Structures" provide legal protection so that land use and development will not interfere with the natural erosion processes which regularly expose fossils at the cliffs. Furthermore, municipal policies prohibit grading or alteration in elevation or contour of the land, the deposition of fill, defacing the cliffs and constructing permanent or temporary structures within 20 metres of the cliffs and shoreline.

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to provide a summary of the plans for the consolidation and development of the work of the Joggins Fossil Institute over the next five years, including plans for funding, staffing, and main annual milestones to be achieved."

STATE PARTY RESPONSE:

Three appendices of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007), including E:6 Joggins Fossil Cliffs: Operating Revenue and Expenses Projections Report, E:2 Joggins Fossil Cliffs Emergency Response Plan, and E:3 Communications Plan for Joggins Fossil Cliffs and Cape Chignecto Provincial Park provide details related to the development work of the Joggins Fossil Institute. Specifically, Appendix E:6 provides a detailed review of funding projections and staffing plans. A tabular summary of development work related to funding and staffing is provided below (Tables 1 and 2).

Table 1. Key Initiative and Activities Related to Human Resource Management for the Joggins Fossil Institute

Human Resources – Staffing Key Initiatives	Year 1 11/07 –03/08	Year 2 04/08 –03/09	Year 3 04/09-03/10	Year 4 04/10-03/11	Year 5 04/11-03/12
Full time staffing in place – includes Director, Administrative Assistant, Science and Education Coordinator, Operations Coordinator and Custodian	Initiated 06/07 – Finalized 02/08	Implement performance management system	Reassess employment contracts →		
Hiring seasonal visitor services and interpretive staff	Finalized 03/08	Annual – hiring, training, assessment →			
Human resource policies developed and approved by JFI Board	Adopt CREDA policy	Adapt and approve JFI Policies – 05/08	Continuous improvement – annual review →		
Human Resource Audit (reassess staffing compliment – regarding relationship with CREDA and Cape Chignecto Provincial Park)			02/10 Revisit Staffing Plan	Implement changes	
Orientation and training manual finalized for seasonal staff	03/08	Continuous improvement – annual review & updates →			
Develop and implement mentoring program		Initiate 09/08	Implement 05/09	Review / Revise	Review / Revise
Develop seasonal recruitment and retention plan for CO-OP and summer students		Initiate 02/09	Implement 02/10		

Table 2. Key Activities Regarding Financial Management and Funding for the Joggins Fossil Institute

Funding and Financial Management Key Initiatives	Year 1 11/07 – 03/08	Year 2 04/08 –03/09	Year 3 04/09-03/10	Year 4 04/10-03/11	Year 5 04/11-03/12
Develop (implement and manage) a non-corporate fundraising program (long term) to implement with the "Friends of the Joggins Fossil Cliffs"		Initiate 04/08	Implement 04/09	Implement and Monitor	Implement and Monitor
Revisit Funding and Lease Agreements		Annual Fiscal Year	Annual Fiscal Year	Annual Fiscal Year	Annual Fiscal Year
Register the Joggins Fossil Institute as a "Charitable" Organization	02/08	Maintain Status	Maintain Status	Maintain Status	Maintain Status
Develop, implement and manage a Corporate Fund Raising Program	Initiated	06/08 Ready to Implement	Implement	Implement	Implement
Seek Certification (ISO or otherwise) to ensure international Standards are met		Research certification scheme and prepare documentation	05/09 Application	Monitor and Report	Monitor and Report
Financial management system including bookkeeping and audit – CREDA to JFI	CREDA to Assist	CREDA to Assist and Transition to JFI	Transition to JFI Complete 03/10	JFI management	JFI Management

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THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to summarize more clearly the governance and financial arrangements for the Joggins Fossil Institute, including the specific relationship with the Cumberland Regional Economic Development Association and the various funding bodies."

STATE PARTY RESPONSE:

Governance

The Joggins Fossil Institute (JFI) Association is the agency ultimately responsible for the management, presentation and promotion of the Joggins Fossil Cliffs. The JFI operates in partnership (through formal legal agreements) with relevant government authorities and non-government societies/associations.

The Joggins Fossil Institute is a registered not-for-profit society under the *Societies Act* of the province of Nova Scotia. The Joggins Fossil Institute Board of Directors ensures that the objectives (Section 5.C page 88 Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007) of the society are met. The composition of the twelve member Board of Directors is summarized as follows (as per the attached document, Joggins Fossil Institute Bylaws):

1. councillor proposed by the Municipality of the County of Cumberland
2. federal government representative (non-voting)
3. provincial government representative (non-voting)
4. provincial government representative (non-voting)
5. resident of district nine of Cumberland County
6. resident of Cumberland County
7. resident of Cumberland County
8. member at large
9. member at large
10. member at large
11. scientist
12. appointment by the Cumberland Regional Economic Development Association

The Board of Directors, as governing authority for the Joggins Fossil Institute, with powers vested in it by the Cumberland Regional Economic Development Association, the governments of the municipality, the province and the state, is responsible for the institute and therefore, the management of Joggins Fossil Cliffs property, its policies, its operational continuity and well-being, and the various assets which it holds in trust for the people of Nova Scotia, Canada and the world, to whom it is ultimately accountable. Governance policies guide Directors, other volunteers, employees and those affiliated with the Joggins Fossil Institute who are responsible for any aspect of site operation, management and governance.

The Joggins Fossil Institute's mission statement is:

> The Joggins Fossil Cliffs is a place where global heritage values are protected, respected, understood and presented, so that the story of these values and other cultural and natural heritage values can be told to the world.
>
> If inscribed on the World Heritage List, the board will be exemplary in fulfilling its responsibilities under the Convention for the Protection of World Cultural and Natural Heritage (the World Heritage Convention) to protect, conserve, present, and transmit to future generations the world heritage values of The Joggins Fossil Cliffs.
>
> The Joggins Fossil Institute will be a world leader in communicating its research (and the collections of the province of Nova Scotia) to increase understanding of the natural diversity in the Carboniferous Period and protecting and conserving the natural fossil heritage.

The Joggins Fossil Institute's vision statement is:

> The aim of the Joggins Fossil Institute is to hold for the benefit and education of humanity a collection and a geographic site representative of the Carboniferous Period and to ensure that the site and collection is conserved, safely studied and exhibited. The Joggins Fossil Cliffs will provide engaging visitor experiences that inspire wonder and build an understanding of the natural world.

The Joggins Fossil Institute's values statement is:

> The Joggins Fossil Institute values its key assets including its collections, its people, its land base, its infrastructure and its interaction with the community at large. The core values of the Joggins Fossil Institute are:
>
> - Life-long discovery and learning using its research, collections and programs
> - Respect for people including but not limited to visitors, employees, volunteers and partners

- Effective communication, innovation and action
- Socio-economic development through a sustainable management regime that protects the sites value in contributing to human welfare and environmental health

Joggins Fossil Institute Leadership Team

The staffing complement for the Joggins Fossil Institute has been outlined through the organization chart listed in Figure 1 (below) and further detailed in Section 5.J Staffing Levels on pages 101 through 103 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007). Recent (June 2007) revisions to the position descriptions include a consolidation of the "scientist" and "manager of programs" positions to a "science and education coordinator" and a revision to the position title and responsibilities of the "visitor services and marketing manager" to an "operations coordinator". An overview of the positions descriptions for the leadership team of the Institute including the Director, Science and Education Coordinator and the Operations Coordinator is included below.

Director

Reporting to the Joggins Fossil Institute Board, the Director is responsible for overseeing all aspects of the Joggins Fossil Institute, the Joggins Fossil Centre and the Joggins Fossil Cliffs to ensure that heritage values are managed, presented and promoted for future generations. The Director recommends policies and plans (including property management plans and operational plans for the Centre) to the JFI Board of Directors, implements policies and plans approved by the board (and relevant partners) and reports on the outcome of these plans and policies. The Director has overall responsibility for human resources management, occupational health and safety and management of the operations of the centre and property. The Director is responsible for financial management and seeking out sources of ongoing funding through private and public sources. The Director serves as the liaison with all levels of government and the local community, and develops strategies to promote the property locally, nationally and internationally. The Director, in collaboration with the institute coordinators, implements the strategic marketing plan for the Joggins Fossil Cliffs and Centre.

Science and Education Coordinator

The Science and Education Coordinator (SEC) is responsible for the security, preservation, documentation and interpretation of collections. The SEC works collaboratively with the JFI Science Advisory Committee to ensure the responsible management and authentic presentation of the Joggins Fossil Cliffs. The Science and Education Coordinator facilitates property-specific research, makes that research available to the public and liaises with other researchers and institutions in the scientific community. In conjunction with the Nova Scotia Museum, the Science and Education Coordinator provides curatorial input into the development of exhibitions and educational programs and is partially responsible for the training of interpretive staff. The SEC leads tours and provides other educational programming for post-secondary and professional groups. To enhance the visibility of the property with the larger scientific community and to further scientific research, the Science and Education Coordinator publishes scientific papers, attends conferences and conducts lectures on a regular basis. In partnership with the operations coordinator, the SEC is responsible for the development, scheduling, delivery and evaluation of educational programs for visitors to the Joggins Fossil Centre and Cliffs, as well as outreach programs and extension programs. The SEC develops educational materials to accompany exhibitions and provides input into the development of new and/or temporary exhibitions.

Operations Coordinator

The Operations Coordinator for the Joggins Fossil Institute is responsible for the overall quality of the services offered at the Centre and on the property and for ensuring that high standards of visitor care are met. The Operations Coordinator recruits and manages visitor service staff (admissions and retail) and the custodian. The Operations Coordinator designs and implements visitor use monitoring and social science research related to visitor satisfaction, expectations and trends. The Operations Coordinator is responsible for overseeing revenue-generation centres including the gift shop, internet café, rental of JFI facilities and the café. In partnership with the Science and Education Coordinator, the Operations Coordinator is responsible for scheduling, delivery and evaluation of educational programs for visitors to the Joggins Fossil Centre and Cliffs, as well as outreach and extension programs.

Joggins Fossil Institute Advisory Committees

The Joggins Fossil Institute Board of Directors, leadership team and staff have additional support from two advisory committees, a Science Advisory Committee and an Emergency Response Planning Committee (as detailed on page 103 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007)). Further detail of the mandate and reporting framework of these two advisory groups are attached (see Terms of Reference for the Joggins Fossil Institute Science Advisory Committee and Terms of Reference for the Joggins Fossil Institute Emergency Response Planning Committee).

The Joggins Fossil Institute and its Partners

The Joggins Fossil Institute has the benefit of working collaboratively with partners in setting policy and coordinating management for the nominated property. The Joggins Fossil Institute has established partnerships through **legal agreements** with various government and non-government authorities to ensure that the society continues to: build capacity through sharing expertise; provide for the long-term local management of the new Joggins Fossil Centre and the Joggins Fossil Cliffs protected site; and remain fiscally viable through funding contributions and in-kind support. Furthermore, such partnerships ensure that appropriate stakeholders from various sectors and relevant authorities are engaged in decision-making processes that will ensure the sustainable management of the Joggins Fossil Cliffs and operation of the Joggins Fossil Centre. Partnerships are integral to the work of the Joggins Fossil Institute as relationships build and strengthen capacity for managing, presenting, and promoting the Joggins Fossil Cliffs. The Joggins Fossil Institute recognizes that only by working together with government, non-government, private organizations and community the organization's mission can be achieved.

Current partners of the Joggins Fossil Institute include: the Cumberland Regional Economic Development Association; the Municipality of the County of Cumberland; the province of Nova Scotia, Department of Natural Resources, the province of Nova Scotia Department of Tourism, Culture and Heritage; and Parks Canada. Figure 1 (below) provides a schematic overview of the relationship between the Joggins Fossil Institute and its partners.

JFI and CREDA

The Joggins Fossil Institute and the Cumberland Regional Economic Development Association (CREDA) have a legal agreement that defines the partnership relationship between the two societies (see Appendix H.2 of Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007).

The Cumberland Regional Economic Development Association is one of thirteen regional development authorities in Nova Scotia. Regional development authorities are community-based groups that help individual and community ventures succeed. Regional development authorities' activities, initiatives and services take place at the local community level and are shaped by the *Nova Scotia Regional Community Development Act*. While core operational funding for regional development authorities, and therefore CREDA, comes from three levels of government – federal, provincial, and municipal, it is important to note that the "key" driving partner is the municipal government through its broad-based representation on the CREDA Board (see the CREDA 2006/2007 Business Plan - Appendix F:2 of Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007). The Cumberland Regional Economic Development Association incorporates internationally recognized quality management practices into its day-to-day operations by being International Standards Organization (ISO) 9001:2000 registered. ISO is a rigorous quality management system registration process awarded to business and organizations that meet internationally recognized performance standards.

The Cumberland Regional Economic Development Association's primary role with the Joggins Fossil Institute is as a facilitator. The Cumberland Regional Economic Development Association has assisted the Joggins Fossil institute in clearly identifying goals, developing reasonable and realistic plans to achieve the goals and in securing the resources required to attain those goals. This partnership has also assisted in increasing the Joggins Fossil Institute's ability to approach and address its goals using its own resources and expertise, thus building community capacity.

As indicated in Section 5.C (iv) on page 89 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007), the Joggins Fossil Institute Board of Directors has agreed to partner with CREDA as the Association has generously agreed to provide the Joggins Fossil Institute with administrative and staffing support during first three years of its operation (developmental phase: 2007 through to 2010) assuming that the JFI is operating at full capacity. The Cumberland Regional Economic Development Association also has been provided with the authority to enter into contracts relating to the development of the Joggins Fossil Institute. Furthermore, CREDA shall ensure that as it relates to the Joggins Fossil Cliffs, liability insurance shall be extended to the JFI and its Directors. The Joggins Fossil Institute will not only comply with its own bylaws but also comply with the bylaws of CREDA. The Joggins Fossil Institute Board of Directors includes an appointment from the Cumberland Regional Economic Development Association (Figure 2, below).

The agreement between these societies enables CREDA to assign its roles and responsibilities, related to the management of the Joggins Fossil Cliffs and Centre, with the provincial and municipal governments to the Joggins Fossil Institute. In addition, this agreement also enables funding from the province and the municipality for ongoing operations to be channelled through CREDA directly to the Joggins Fossil Institute (see attached amendment to JFI/CREDA agreement).

JFI and Provincial Partners

Working collaboratively with the Cumberland Regional Economic Development Association, the Joggins Fossil Institute has partnered with two provincial government departments: the Nova Scotia Department of Tourism, Culture and Heritage (DTCH); and the Nova Scotia Department of Natural Resources (DNR). The nature of these partnerships are outlined in legal agreements (Agreement between DTCH and CREDA- attached and Appendix H:1 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January 2007).

Furthermore, the membership of the Joggins Fossil Institute Board of Directors includes two non-voting provincial government appointments, one from the DTCH and the second from the DNR. These appointments are to be senior staff positions from each Department.

To ensure effective communication and appropriate input between the Institute and provincial government Departments regarding management of the nominated property (under the *Beaches Act* and *Regulations,* the *Mineral Resources Act* and the *Special Places Protection Act:* Appendices G:1, G:2 and G:3 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007)) and management of the fossil collections, the membership of Joggins Fossil Institute Science Advisory Committee includes two representatives from the provincial government: the Curator of Geology and the Manager of the Special Places Program Figure 2, below and see the attached Terms of Reference for Joggins Fossil Institute Science Advisory Committee). The Joggins Fossil Institute Emergency Response Planning Committee is also supported by the provincial government through membership from staff of the DNR (Figure 2 below and see attached Terms of Reference for the Joggins Fossil Institute Emergency Response Planning Committee).

JFI and Municipal Partners

Section 5.C (iii) of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007) outlines the relationship between the Municipality of the County of Cumberland and the Joggins Fossil Institute. As stated, the municipal government owns the newly-constructed Joggins Fossil Centre and the property where it is located, immediately adjacent to the Fossil Cliffs. The municipal government has delegated management of the building and land to the Joggins Fossil Institute.

Furthermore, the Municipality of the County of Cumberland has included the nominated property as a key consideration in development of municipally regulated land use zones and bylaws to ensure that the integrity of the Joggins Fossil Cliffs is maintained for future generations. The overriding goal of the secondary municipal planning strategy for the Joggins planning area is to:

> …support healthy and sustainable community development by ensuring that future growth and development throughout the Joggins Area will support the goals and priorities of local community members and maximize the benefits and minimize any adverse effects of the development of the Joggins Fossil Cliffs on the community, and, by *ensuring that future land uses and forms of development in the vicinity of the Joggins Fossil Cliffs will protect and enhance their fossil resources and valuable features and be appropriate and compatible with the nominated UNESCO World Heritage Site* and Fossil Centre (Appendix G:4 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January 2007)).

The Municipality of the County of Cumberland supports the Joggins Fossil Institute through engagement in managing lands adjacent to the nominated property. Municipal development control and building inspection officers address development proposals to ensure compliance with bylaws. The JFI is consulted with regarding assessment of development proposals for lands immediately adjacent to the nominated property.

The Municipality of the County of Cumberland appoints a member, the Councillor for District Nine – where the nominated property is located - to the Joggins Fossil Institute Board of Directors. This appointment supports ongoing community involvement in the management, presentation and promotion of the nominated property and ensures that management priorities for the property align with municipal government strategies. Additionally, the Municipality of the County of Cumberland supports the Joggins Fossil Institute through the Emergency Response Planning Committee membership (Figure 2 and see attached Terms of Reference for the Joggins Fossil Institute Emergency Response Planning Committee).

JFI and Federal Partners

The relationship between the Joggins Fossil Institute and Parks Canada pertains primarily to the support of the nomination of the site for inscription on the World Heritage list and for ongoing monitoring and reporting.

The local management of the protected site is unique in Canada and in the province of Nova Scotia and provides a model for community stewardship and engagement. At Joggins, the community has taken a leadership role in developing the nomination dossier, and supports the ongoing management, presentation and promotion of the property through a registered not-for-profit society (the Joggins Fossil Institute) who works in partnership with regulatory agencies and other stakeholders. The Joggins Fossil Institute has been working collaboratively with Parks Canada, the state party, to prepare and submit the nomination for inscription on the World Heritage list. A representative from Parks Canada holds a position on the Board of Directors for the Joggins Fossil Institute (Figure 2) and will act as a liaison for ongoing monitoring and reporting.

Financial Arrangements: Sources and Levels of Finance

Section 5.F (pages 94 and 95) and Appendix E:6 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007) documentation provides an overview of the sources and levels of funding for the operation of the Joggins Fossil Institute, the Joggins Fossil Centre and for the management of the property. Ongoing annual operational funding ($250,000 for a period of 10 years) from the Province of Nova Scotia has been provided to the Joggins Fossil Institute through the Cumberland Regional Economic Development Association (see attached letter articulating the provincial funding commitment).

In addition to funds received from the provincial government, the Municipality of the County of Cumberland will provide the Institute with annual operating support. Furthermore, the Municipality of the County of Cumberland has provided in-kind funding to permit the Joggins Fossil institute to lease the Joggins Fossil Centre at no charge (see attached draft agreement).

Additional potential funding sources through government and non-government sources will be sought out through a Joggins Fossil Institute Board sub-committee (the Friends of the Fossil Cliffs) to continue to enable the ongoing development of the Institute and to ensure that the nominated property is effectively managed, presented and promoted.

Figure 1. Joggins Fossil Institute and Partners

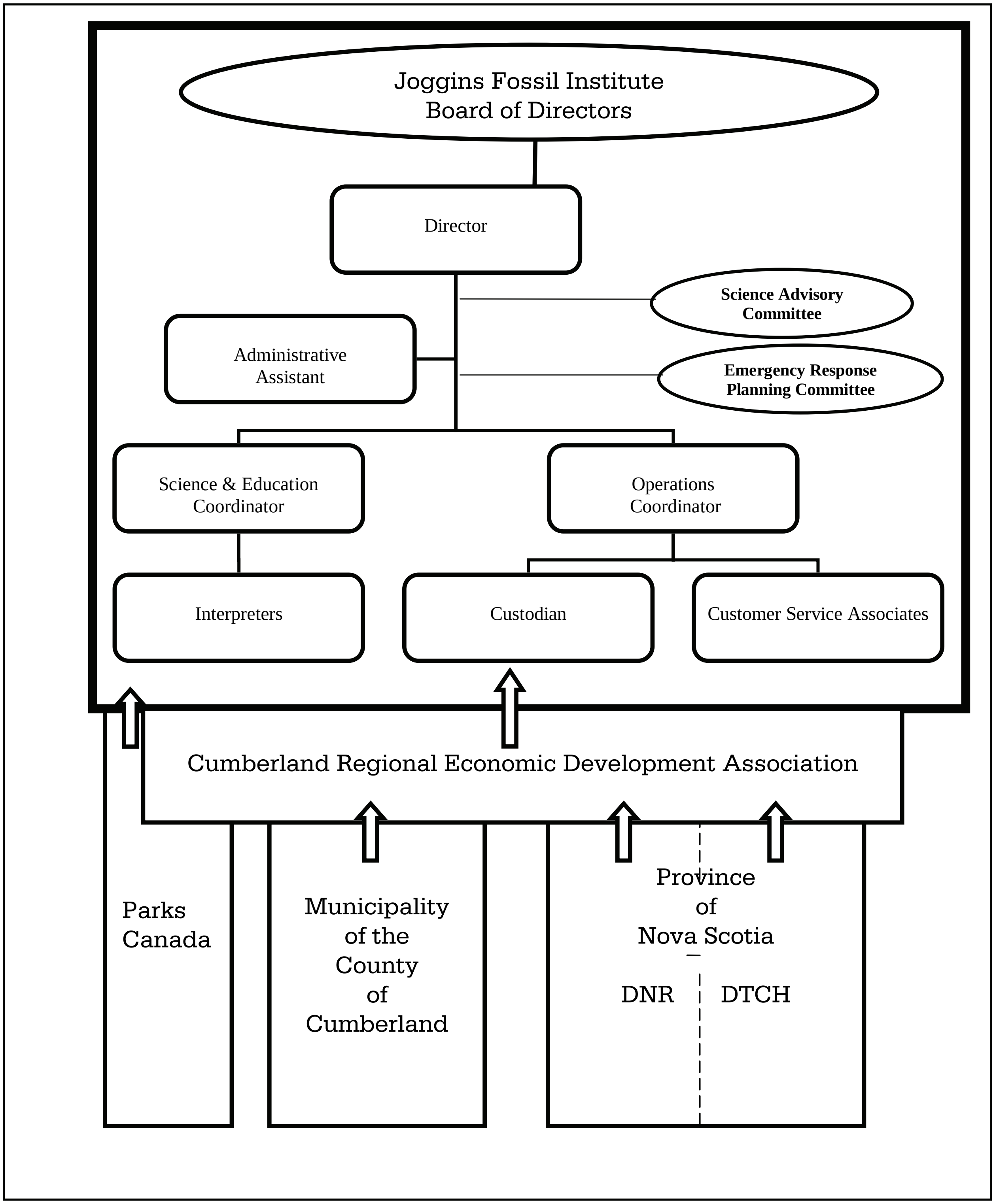
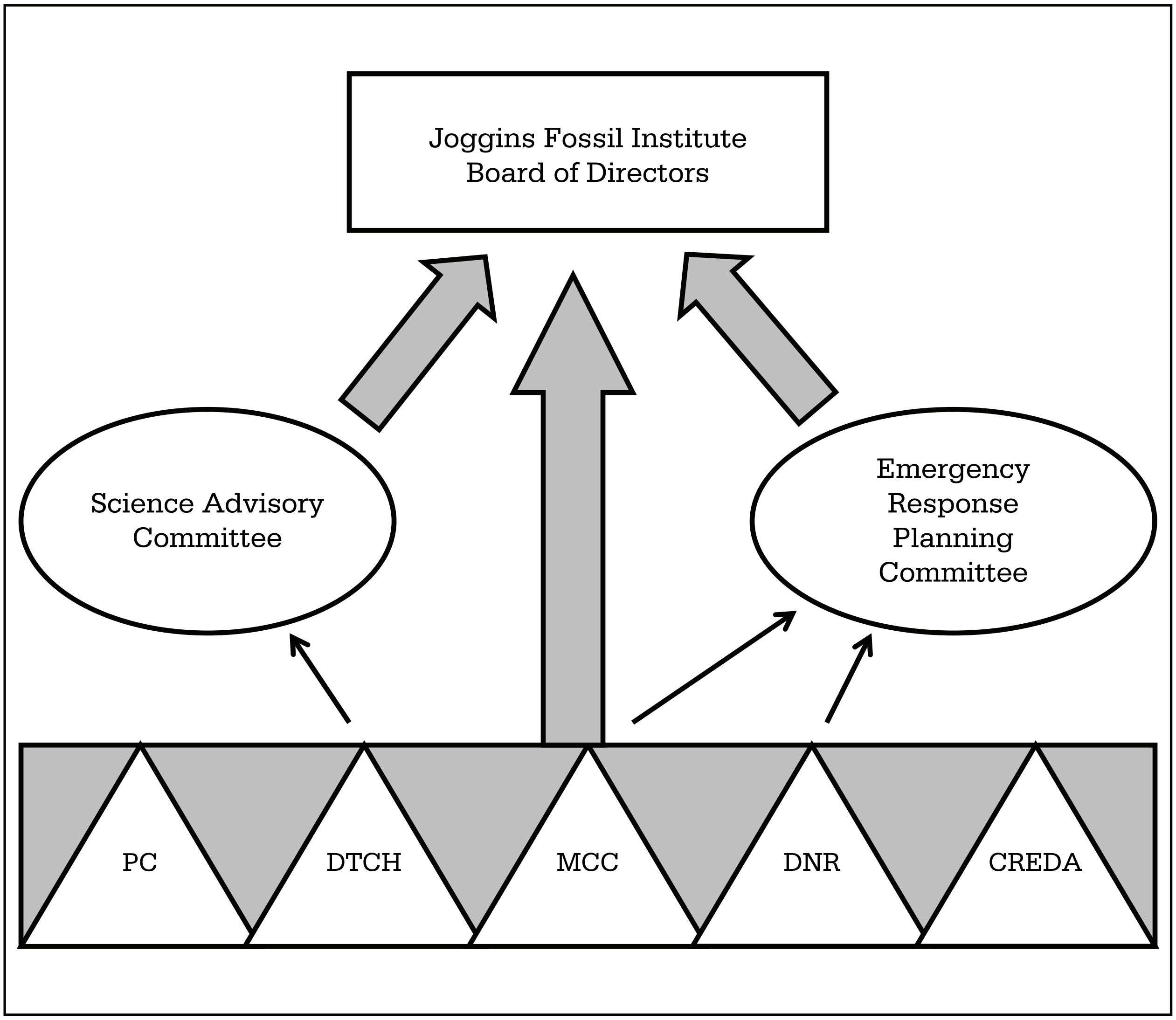


Figure 2. Joggins Fossil Institute Board and Committee Memberships.



Attachments

1. JFI_TOR_SAC.pdf — Terms of Reference for the Joggins Fossil Institute Science Advisory Committee
2. JFI_TOR_ERPC.pdf — Terms of Reference for the Joggins Fossil Institute Emergency Response Planning Committee

3. DTCH_CREDA_AGREE.pdf — Agreement between Nova Scotia Department of Tourism, Culture and Heritage and the Cumberland Regional Economic Development Association
4. MCC_CREDA_AGREE(D).pdf — Draft agreement between the Municipality of the County of Cumberland and the Cumberland Regional Economic Development Association
5. JFI_CREDA_AGREE.pdf — Amendment to agreement between the Joggins Fossil Institute and the Cumberland Regional Economic Development Association
6. JFI_MoAandBylaws.pdf — Joggins Fossil Institute Memorandum of Association and Bylaws
7. CONFIRM_DTCH_FUNDS.pdf — Letter to confirm provincial funding commitment for annual operations of the Centre and Institute

Joggins Fossil Institute
Science Advisory Committee
Terms of Reference

Last Revision: November 2007

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Background
The Joggins Fossil Institute (JFI) Association is committed to furthering scientific research associated with the Joggins Fossil Cliffs and to incorporating science-based decision making in the management and operation of the new Joggins Fossil Centre. In order to ensure that a broad range of scientific capability is brought to bear on issues, the JFI requires the advice and support of a Scientific Advisory Committee. This key advisory body, to be drawn from the scientific community and its associated communities of interest, will provide expert and credible advice to the Director and the Board of Director's of the JFI to inform science-based decision-making. The Scientific Advisory Committee was referenced in the nomination dossier to UNESCO and will have responsibilities related to ongoing reporting to UNESCO in the event that inscription on the World Heritage List is achieved.

Mission Statement
The mission of the Scientific Advisory Committee (hereafter the SAC) is to provide expert and comprehensive advice and support to the JFI on scientific matters respecting the development, conservation and management of the Joggins Fossil Cliffs property, the content of the Joggins Fossil Centre's programs, scientific research related to the fossil cliffs, and scientific issues arising from the site's status as a UNESCO World Heritage Site. The SAC will also assist in reporting on the status of monitoring programs and state of conservation of the Joggins Fossil Cliffs property.

Objectives
The objectives of the SAC are:
- to identify opportunities for the application of scientific knowledge to further the aims of the JFI;
- to ensure that excellent and appropriate scientific knowledge and expertise is a part of decision making in all areas of operation of the Joggins Fossil Cliffs property;
- to promote, encourage, and provide for excellence in scientific research related to the fossil cliffs and to promote and help maintain research partnerships related to the study of the fossil cliffs; and
- to provide scientific guidance and support to JFI staff in the performance of their responsibilities.
- to contribute to the monitoring of the science and conservation goals included in the *Joggins Fossil Cliffs Management Plan;*

Scope of Work

The SAC is not a decision-making body, but recommends science-based policies, actions, and protocols to the JFI Board of Directors. The scope of SAC deliberations includes but is not limited to:

- Evaluating research needs and proposals related to the geo-science of the Fossil Cliffs;
- Reviewing policies and protocols regarding all aspects of scientific research at the Joggins Fossil Centre;
- Providing opportunities for the promotion of the Joggins Fossil Cliffs, the Joggins Fossil Centre and the Joggins Fossil Institute within scientific communities, participating in conferences and other scientific meetings, recommending opportunities for promoting of the centre, the cliffs and the institute to the JFI Board of Directors;
- Assisting in establishing research partnerships related to study of the fossil cliffs;
- Assist the Director of the Joggins Fossil Institute in the evaluation of research grants;
- Advising the JFI director regarding the duties and responsibilities of the JFI scientific and educational coordinator, participating in preparation of job descriptions and scope of responsibilities;
- Providing guidance and support to the JFI scientific and educational coordinator and program officers in discharging their scientific responsibilities to the JFI;
- Providing guidance and advice regarding the fossil collections management policy and addressing issues related to the conservation and display of specimens from Joggins;
- Within the parameters of the management agreements between the provincial government (Department of Natural Resources and Tourism Culture and Heritage) assist with the development of the Joggins Fossil Cliffs management plan and monitoring framework;
- Supporting the evaluation of the state of conservation of the property and considering ways to improve the conservation of the site;
- Considering issues and proposals related to management of the property and making science-based recommendations where appropriate;
- Work with provincial partners to ensure parameters for fossil collecting are appropriate and report annually on collecting permits;
- Evaluating the environmental impact of infrastructure and programs on the site and its ecological integrity and making recommendations for addressing these impacts;
- Considering scientific matters related to the visitor experience, visitors programs and educational opportunities offered by the centre and making recommendations for enhancement;
- Evaluating the potential impact of off-site developments on the centre and property and making recommendations for mitigating/alleviating any threats to the integrity of the site

- Raising any scientific issues for discussion that SAC members feel are relevant to the operation of the centre and its programs;
- Preparing an annual report to the JFI Board of Directors on the activities of the committee and the status of scientific issues on the site;
- Contributing to the preparation reports on the state of conservation of the property (to JFI Board, Provincial Government – Department of Tourism Culture and Heritage and Department of Natural Resources - and to UNESCO – through Parks Canada).

Duties

Scientific Advisory Committee members are expected to:

- Attend SAC meetings whenever possible. A committee member who misses three consecutive meetings will have his/her participation on the committee reviewed by the JFI Board of Directors.
- Read documents, proposals, reports, and other materials provided for review and come to meetings prepared to provide thoughtful discussion and advice;
- Use his/her scientific expertise and knowledge in the best interests of the JFI, and
- Promote the advancement of the Joggins Fossil Institute and the Joggins Fossil Centre.

Deliverables

- Minutes from all SAC meetings will be circulated to all members and to the JFI Board of Directors.
- Recommendations of the SAC will be provided to the JFI Director and Board of Directors, along with any dissenting opinions.
- An annual report will be provided to the JFI Board of Directors summarizing the work of the SAC, reporting on issues it has dealt with, and recommending actions for the coming year.
- The committee may prepare position papers where it considers that such a paper would be beneficial to its objectives.

Organizational Structure and Reporting

The Joggins Fossil Institute Scientific Advisory Committee consists of eleven members:

- Chairperson (member of the JFI Board of Directors)
- 3 geological scientists
- 2 biological scientists
- 2 physical scientists, land use and conservation scientists or engineers
- 1 proponent of aboriginal traditional knowledge (optional)
- 1 member of the local community (optional and ex-officio)
- Curator of Geology, Nova Scotia Museums, Department of Tourism, Culture and Heritage
- Manager of Special Places, Heritage Division, Department of Tourism, Culture and Heritage

The Chairperson for the Scientific Advisory Committee will be a member of the Joggins Fossil Institute Board of Directors.

At least one of the three geoscientists should have skills, abilities and experience in sedimentary geology and/or paleontology specific to the Carboniferous time period. Skills, abilities and experience in coastal ecosystems and in particular the Bay of Fundy Ecosystem would be an asset for the biological scientists.

The SAC will be provided with administrative support from the JFI for facilitating communication among SAC members and between the JFI Board and SAC and can include preparing and distributing documents, planning meeting locations, and taking of minutes at meetings.

The JFI Scientific and Educational Coordinator is an *ex officio* member of the Scientific Advisory Committee.

Members of the Scientific Advisory Committee may be nominated by their community of interest or by the JFI Board of Directors at their discretion. Nominations are reviewed by the JFI Director in consultation with the JFI Scientific and Educational Coordinator and recommended to the JFI Board of Directors. Upon approval by the JFI Board of Directors, nominees are invited to serve a three year term that may be renewed at the discretion of the JFI Board of Directors.

The SAC reports to the JFI Board of Directors through the JFI Director.

Procedures and Decision Making

- Four members, including the Chair, constitute a quorum for the purposes of meetings.
- The SAC will seek consensus whenever possible. In the event that consensus cannot be achieved, a majority recommendation will be made and dissidents may provide a written dissenting opinion to the JFI Board of Directors.
- The Chair only votes in the case of a tie.

Communications

- The SAC communicates its deliberations directly with the JFI Director and Board of Directors, or with third parties as directed or approved by the JFI Board of Directors.
- The JFI Director and Chairperson of the SAC will ensure accurate and timely communication related to matters pertaining to activities of the SAC with staff and board.
- Members of the SAC cannot speak on behalf of the JFI without prior approval.
- Public inquiries or media requests should be referred to the JFI Director for coordination of a response.

Meetings

- The SAC will meet three times per year at a location to be determined by the Chair in consultation with SAC members and the JFI Board of Directors.
- At least one meeting per year will be at the Joggins Fossil Centre.
- Members may attend by teleconference if unable to attend in person and, in doing so, will be considered present for voting purposes.
- SAC meetings are not open to the public, but the committee may invite or accept a request for participation by anybody whom it believes may contribute to the deliberations of the committee at any time.

Compensation

- SAC members' travel costs for attending meetings will be paid by the JFI at rates to be determined by the JFI Board of Directors.
- Out of pocket expenses in the exercise of members' responsibilities will be reimbursed upon submission of receipts.
- SAC members serve as volunteers and will not be compensated for their time.

Adoption and Amendment

- These terms of reference must be adopted by the JFI Board of Directors to give them effect.
- They can be amended by the JFI Board of Directors at their discretion by approval of a motion to do so.

OATH OF OFFICE AND CONFIDENTIALITY AGREEMENT
(Joggins Fossil Institute Science Advisory Committee)

This agreement made this _______ day of ____________, 20____,

between

____ (the "Individual")

and

The Joggins Fossil Institute.

As a member of the Joggins Fossil Institute Science Advisory Committee, I may be entrusted with knowledge of the affairs of the Joggins Fossil Institute.

I hereby undertake neither to divulge any of this knowledge nor to discuss it at any time, or any place with an unauthorized person, except in the course of my duties relating to the business of the Institute or with the express consent of the Joggins Fossil Institute Director.

I also agree not to criticize the actions, decisions, resolutions or positions taken by the Joggins Fossil Institute, its Board of Directors and Officers, in any public forum, including the print media, radio, television, and any other media whatsoever.

I also acknowledge that a breach of this undertaking could result in disciplinary measures with possible removal from the Committee as determined by the Joggins Fossil Institute's Board of Directors.

The Individual

___________________________ ___________________________
Name (Please Print) Signature

___________________________ ___________________________
Date Signature of Witness

I have explained the implications of signing the **Declaration of Confidentiality** to the Individual noted above and am fully satisfied he/she is aware of the necessity to hold the affairs of the Joggins Fossil Institute Science Advisory Committee and the Joggins Fossil Institute in absolute confidence.

___________________________ ___________________________
Name (Please Print) Signature

Joggins Fossil Institute
Emergency Response Planning Committee
Terms of Reference

Last Revision: February 2007

Joggins Fossil Institute
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Table of Contents

Background
The Joggins Fossil Institute (JFI) Association is committed providing a safe and enjoyable experience for the visitor Joggins Fossil Cliffs and to provide a secure and agreeable work environment for management and staff of the Joggins Fossil Centre. In order to ensure that a broad range of efficient safe practices be adopted by the Joggins Fossil Centre, the JFI requires the advice and support of an Emergency Response Planning Committee (ERPC). This advisory body, to be drawn from the regional emergency services and its associated groups, will provide expert and credible advice to the Director and the Board of Director's of the JFI on the emergency response in order to provide a safe environment for all concerned.

Mission Statement
The Joggins Fossil Cliffs Emergency Response Planning Committee is committed to the planning and preparation in support of an Emergency Response Plan for the Joggins Fossil Institute which seeks to provide quick and assured emergency response through the teamwork of the various Emergency Services of Cumberland County, the Province of Nova Scotia and the Government of Canada. The Joggins Fossil Cliffs Emergency Response Planning Committee will not make direct policy change, but will make recommendations on policy change to Joggins Fossil Institute through liaison with the Director.

Scope of Work
The ERPC is not a decision-making body, but recommends emergency response policies, actions, and protocols to the JFI Board of Directors. The scope of ERPG deliberations includes but is not limited to:

- reviewing policies and protocols regarding all aspects of emergency planning at the Joggins Fossil Centre and the Joggins Fossil Cliffs;
- review the Joggins Fossil Cliffs Emergency Response Plan after every major incident and reporting any and all recommendations to the JFI Operations Coordinator;
- review and evaluate annually the performance of the Joggins Fossil Cliffs Emergency Response Plan to insure the safety of the staff and visitors to the Joggins Fossil Cliffs;
- advising the JFI Operations Coordinator regarding the duties and responsibilities of the staff within emergency response planning;
- work with provincial partners to ensure that all emergency requirements of the Joggins Fossil Centre are met;
- raising any issues for discussion that ERPC members feel are relevant to the operation of the centre and its programs;
- preparing an annual report to the JFI Board of Directors on the activities of the group and the status of emergency issues on the site;
- ensure that excellent and appropriate emergency planning knowledge and expertise is a part of decision making in all areas of operation of the Joggins Fossil Cliffs property.

- ensure prudent and proper management of the *Joggins Fossil Cliffs Emergency Response Planning Committee* resources.

Duties
Members of the Joggins Fossil Cliffs Emergency Response Planning Committee are expected to:
- Attend ERPC meetings whenever possible. A committee member who misses three consecutive meetings will have his/her participation on the committee reviewed by the JFI Board of Directors.
- Read documents, proposals, reports, and other materials provided for review and come to meetings prepared to provide thoughtful discussion and advice;
- Use his/her expertise and knowledge in the best interests of the JFI;
- Promote the advancement of the Joggins Fossil Institute and the Joggins Fossil Centre.

Deliverables
- Minutes from all ERPC meetings will be circulated to all members and to the JFI Board of Directors.
- Recommendations of the ERPC will be provided to the JFI Board of Directors through the Director of the Institute, along with any dissenting opinions.
- An annual report will be provided to the JFI Board of Directors summarizing the work of the ERPC, reporting on issues it has dealt with, and recommending actions for the coming year.
- The group may prepare reports where it considers that such reports would be beneficial to its objectives.

Organizational Structure and Reporting
The Joggins Fossil Institute Emergency Response Planning Committee consists of 7 members:
- 1 member to be proposed by the Emergency Measures Organization of the County of Cumberland (EMO);
- 1 member to be proposed by Emergency Health Services of Nova Scotia (EHS);
- 1 member to be proposed by Joggins Fire Department;
- 1 member to be proposed by the Royal Canadian Mounted Police (RCMP);
- 1 member to be proposed by Special Hazards Response Unit (SHRU);
- 1 member to be proposed by the Nova Scotia Department of Natural Resources;
- 1 member of the Joggins Fossil Institute – Operations Coordinator (Chair Person).

The ERPC will be provided with administrative support from the JFI for facilitating communication among ERPC members and between the JFI Board and ERPC and can include preparing and distributing documents, planning meeting locations, and taking of minutes at meetings.

Nominations of members are reviewed by the JFI Director and recommended to the JFI Board of Directors. Upon approval by the JFI Board of Directors, nominees are invited to serve a three year term that may be renewed at the discretion of the JFI Board of Directors.

The ERPC reports to the JFI Board of Directors through the JFI Director.

Procedures and Decision Making

- Four members, including the Chair, constitute a quorum for the purposes of meetings.
- The ERPC will seek consensus whenever possible. In the event that consensus cannot be achieved, a majority recommendation will be made and dissidents may provide a written dissenting opinion to the JFI Board of Directors.
- The Chair only votes in the case of a tie.

Communications

- The ERPC communicates its deliberations directly with the JFI Director, or with third parties as directed or approved by the JFI Director.
- Members of the ERPC cannot speak on behalf of the JFI without prior approval.
- Public inquiries or media requests should be referred to the JFI for coordination of a response.

Meetings

- The ERPC will meet at least two twice a year at a location to be determined by the Chair.
- At least one meeting per year will be at the Joggins Fossil Centre.
- Members may attend by teleconference if unable to attend in person and, in doing so, will be considered present for voting purposes.
- ERPC meetings are not open to the public, but the committee may invite or accept a request for participation by anybody whom it believes may contribute to the deliberations of the committee at any time.

Compensation

- A member of the group shall not receive any remuneration for being a member thereof, but shall be reimbursed for actual expenses incurred in connection therewith.
- ERPC members' travel costs for attending meetings will be paid by the JFI at rates to be determined by the JFI Board of Directors.

- Out of pocket expenses in the exercise of members' responsibilities will be reimbursed upon submission of receipts.
- ERPC members serve as volunteers (and fall under the JFI Volunteer Policy) and will not be compensated for their time.

Adoption and Amendment

- These terms of reference must be adopted by the JFI Board of Directors to give them effect.
- They can be amended by the JFI Board of Directors at their discretion by approval of a motion to do so.

OATH OF OFFICE AND CONFIDENTIALITY AGREEMENT
(Joggins Fossil Institute Emergency Response Planning Committee)

This agreement made this _______ day of ____________, 20____,

between

____ (the "Individual")

and

The Joggins Fossil Institute.

As a member of the Joggins Fossil Cliffs Emergency Response Planning Committee, I may be entrusted with knowledge of the affairs of the Joggins Fossil Institute.

I hereby undertake neither to divulge any of this knowledge nor to discuss it at any time, or any place with an unauthorized person, except in the course of my duties relating to the business of the Institute or with the express consent of the Joggins Fossil Institute Director.

I also agree not to criticize the actions, decisions, resolutions or positions taken by the Joggins Fossil Institute, its Board of Directors and Officers, in any public forum, including the print media, radio, television, and any other media whatsoever.

I also acknowledge that a breach of this undertaking could result in disciplinary measures with possible removal from the Committee as determined by the Joggins Fossil Institute's Board of Directors.

The Individual

____________________________ ________________________
Name (Please Print) Signature

____________________________ _________________________
Date Signature of Witness

I have explained the implications of signing the **Declaration of Confidentiality** to the Individual noted above and am fully satisfied he/she is aware of the necessity to hold the affairs of the Joggins Fossil Cliffs Emergency Response Planning Committee and the Joggins Fossil Institute in absolute confidence.

__________________________ __________________________
Name (Please Print) Signature

THIS AGREEMENT made the 28th day of November, 2007.

BETWEEN:

HER MAJESTY THE QUEEN in right of the Province of Nova Scotia, as represented by the **MINISTER OF TOURISM, CULTURE AND HERITAGE** (hereinafter "Minister")

OF THE FIRST PART

- and -

THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION, a Society incorporated pursuant to the Societies Act, with head office in Amherst, Nova Scotia (hereinafter "CREDA")

OF THE SECOND PART

WHEREAS the Joggins Fossil Cliffs is a site of world wide significance due to its fossil record, particularly in relation to the Carboniferous period;

AND WHEREAS the Minister, with the approval of the Governor in Council, has designated the Joggins Fossil Cliffs, shown on Schedule "A" attached hereto, as a protected site (the "Protected Site"), pursuant to the *Special Places Protection Act* ("*SPPA*");

AND WHEREAS CREDA, together with other parties, has nominated the Protected Site for designation as a UNESCO World Heritage Site;

AND WHEREAS the local community and regional governmental and developmental agencies believe the development of the Protected Site as a scientific and heritage tourism destination will bring benefits to the community, the region and the Province as a whole;

AND WHEREAS it is recognized that any development must be balanced with proper management and protection of the Protected Site;

AND WHEREAS CREDA together with other parties have formulated and are implementing a project which will simultaneously develop the Protected Site as an internationally recognized destination and pursue the designation as a UNESCO World Heritage Site;

AND WHEREAS the Minister supports the efforts of CREDA to pursue the designation of the Protected Site as a UNESCO World Heritage Site;

In consideration of the mutual promises contained in this Agreement, the Parties covenant and agree as follows:

1.0 PROTECTED SITE AND JOGGINS FOSSIL COLLECTION

1.1 The Parties agree that CREDA may undertake, on the Protected Site, activities related to scientific research, tourism and education purposes with the Minister's written approval. CREDA acknowledges that the Minister's approval does not authorize CREDA to undertake activities on any private lands forming part of the Protected Site without the consent of the landowners.

1.2 CREDA agrees to submit the final Site Management Plan, including provisions that address the Protected Site, to the Minister for final approval by April 2008.

1.3 CREDA shall at all times administer, manage and control the Protected Site in accordance with the Site Management Plan approved by the Minister, and shall not implement any changes to the Site Management Plan related to the Protected Site without the Minister's written approval.

1.4 CREDA agrees to establish and maintain a Scientific Advisory Committee for the Protected Site that will include permanent representation by the Curator of Geology and by the Manager of the Special Places Program of the Department of Tourism, Culture and Heritage.

1.5 The Parties acknowledge that the authority to protect all fossil resources in the Province rests with the Minister.

1.6 CREDA agrees that all fossil collecting will be undertaken in accordance with the provisions of the *SPPA* and the heritage research permits process set out by the Minister.

1.7 CREDA agrees that it will oversee the employment of a qualified palaeontologist. The Minister agrees to share heritage research permit applications for the Protected Site with the CREDA palaeontologist for his or her review and comments.

1.8 CREDA acknowledges that the final authority to issue heritage research permits rests with the Minister.

1.9 The Minister agrees that the Joggins fossil collection should be maintained intact for display and interpretation at the Joggins Fossil Centre wherever reasonably possible and for as long as the Joggins Fossil Centre is able to demonstrate operational sustainability with appropriate space to house and care for the fossil collection.

1.10 CREDA acknowledges that all fossils collected under the provisions of the *SPPA*, and/or since the *SPPA* was introduced, belong to the Province as part of the Provincial Collection.

1.11 CREDA agrees that all fossils from the Provincial Collection loaned to CREDA by the Province will be subject to the terms and conditions of Nova Scotia Museum loan agreements as determined by the Minister. CREDA agrees that it will execute a Nova Scotia Museum loan agreement prior to receiving any fossils to be loaned to CREDA by the Province.

1.12 CREDA agrees that all fossils from the Provincial Collection shall be managed as provided for in the provisions of the Collection Management Policy and Procedures of the Nova Scotia Museum.

1.13 CREDA agrees to comply in all respects with the *Canadian Museum Association Code of Ethics Guidelines (1999)* to ensure the integrity of the fossil collection.

1.14 The Minister may, at any time, upon giving notice to CREDA, impose additional conditions or restrictions in respect of the fossil collection or on any approvals referred to in this Agreement.

2.0 CONFIDENTIALITY

2.1 CREDA and the CREDA palaeontologist shall keep private, treat as confidential, and not make public or divulge during as well as after the term of this Agreement, any heritage research permit applications, as well as any information or material to which CREDA and the CREDA palaeontologist become privy as a result of receiving and reviewing heritage research permit applications for the Protected Site (collectively referred to as "Confidential Information").

2.2 CREDA agrees that it will safeguard the Confidential Information and will not further disclose it to any other party.

2.3 CREDA agrees that it will use the Confidential Information only for the purpose of reviewing heritage research permit applications and providing comments on the applications to the Minister, and not for any other purpose.

2.4 CREDA acknowledges that the Confidential Information may include personal information protected under the *Personal Information International Disclosure Protection Act* ("*PIIDPA*"). CREDA undertakes to comply with and be bound by *PIIDPA*.

2.5 CREDA agrees that following the review of a heritage research permit application, all copies of the Confidential Information will be promptly returned to the Minister, or securely destroyed by CREDA.

2.6 CREDA shall make the Confidential Information accessible only to the CREDA palaeontologist and not to any other employees, and shall ensure that the CREDA palaeontologist enters into a confidentiality agreement with the Minister prior to receiving any heritage research permit applications for the Protected Site.

2.7 CREDA shall notify the Minister if the CREDA palaeontologist is changed, and CREDA shall ensure that any new CREDA palaeontologist enters into a confidentiality agreement with the Minister prior to receiving any heritage research permit applications.

2.8 CREDA will immediately notify the Minister if CREDA knows or suspects that the Confidential Information may have been compromised or knows or suspects that any requirement of this Article 2.0 may have been breached.

2.9 The sharing of heritage research permit applications with the CREDA palaeontologist pursuant to Article 1.7 may be terminated by the Minister if, in the sole opinion of the Minister, CREDA or the CREDA palaeontologist has breached or failed to comply with any of the terms of this Agreement or the confidentiality agreement.

3.0 TRAINING AND OTHER OPPORTUNITIES

3.1 The Minister may provide training to CREDA with respect to the acquisition, documentation, preservation, use and disposition of the fossil collection.

4.0 CONTRACT OF SERVICES

4.1 The Parties agree that this Agreement is a contract for the performance of a service and that CREDA is an independent organization and neither it nor its employees, nor any third parties providing services to CREDA, whether or not for payment, shall be deemed to be an employee, servant or agent of the Minister.

4.2 The Parties agree that CREDA will make its own agreements and payments with respect to Worker's Compensation and other employment related issues

4.3 The Parties agree that CREDA shall comply with all laws and standards including all applicable labour and occupational health and safety legislation.

5.0 TERM AND TERMINATION

5.1 This Agreement shall be effective as of the date of signing and shall continue in effect for a period of ten (10) years unless terminated in accordance with the provisions of this Agreement.

5.2. The Parties may renew this Agreement only in writing and on such terms and conditions as the Parties find mutually acceptable.

5.3 This Agreement may be terminated by the Minister if, in the opinion of the Minister, CREDA has breached or defaulted or failed to comply with any of the terms and conditions of the Agreement and CREDA has failed to remedy the same after being given fifteen (15) days notice to remedy the breach, default or failure.

5.4 Either party may terminate this Agreement by providing one hundred and twenty (120) days written notice to the other Party of the intention to terminate.

5.5 Notwithstanding the preceding paragraphs of this section, the Minister may terminate this Agreement without notice to CREDA, if CREDA files a petition in bankruptcy, is adjudged bankrupt, becomes insolvent or takes the benefit or protection of any statute for bankrupt or insolvent debtors.

5.6 The Minister shall not be liable to CREDA for any damage, cost or expense, nor shall CREDA be entitled to any compensation from the Minister, in the event this Agreement is terminated in accordance with the terms of this Article 5.0.

6.0 LIABILITY

6.1 CREDA agrees that neither the Minister or the Province or any officer or employee of the Province shall be liable for any injury including death to any person, or for the loss of, or damage to, any property, that is caused in any way by its performance or non-performance of its obligations under this Agreement or that is related in any way to the operation of the Joggins Fossil Cliffs Centre unless the injury, loss or damage is caused by the negligence of an officer or employee of the Province while working within the scope of his or her employment.

6.2 CREDA agrees that it shall at all times indemnify and save harmless the Province, its Ministers, officers, employees and agents from and against all claims, demands, losses, costs, damages, actions, suits or other proceedings of any kind based upon injury to or death of a person or damage to or loss of property arising from any wilful or negligent act, omission or delay on the part of CREDA, its servants or agents.

6.3 Articles 6.1 and 6.2 shall survive the termination of this Agreement.

7.0 INSURANCE

7.1 CREDA shall at its own expense, shall purchase and maintain in full force during this Agreement insurances to protect itself, the Province of Nova Scotia ("Nova Scotia"), their successors and assigns and their respective directors, officers, employees, agents and servants involved in the operation of the Joggins Fossil Cliffs Centre and in the performance of this Agreement for the purposes and risks outlined herein and as set out in Schedule "B" attached hereto.

7.2 Such insurance shall provide coverage for all risks and shall protect Nova Scotia, CREDA, their successors and assigns, and their respective officers, directors and employees from all claims arising out of liability for property damage, bodily injury including death and personal injury.

7.3 All policies shall be issued by financially sound insurers licensed to carry on business in Canada and shall be subject to approval by Nova Scotia. Insurers shall not cancel or materially change the policy without 90 days prior written notice to Nova Scotia.

7.4 Certified copies of all insurance policies or related documentation, in form and content acceptable to Nova Scotia, shall be delivered to Nova Scotia prior to the opening of the Joggins Fossil Centre. Certificates of insurance evidencing renewal or replacement insurances, in form and content acceptable to Nova Scotia, shall be provided to Nova Scotia not later than fifteen (15) days prior to the expiration of existing policies. Upon request from Nova Scotia or its authorized representative, certified copies of any policy or policies shall be provided promptly.

7.5 All insurance policies shall include a provision whereby Nova Scotia (or its nominee) may, but will not be obligated to, assume direction and control of the insurance policy in the event the CREDA or any of its successors or assigns defaults in its obligations in connection with the project.

8.0 NOTICE

8.1 Notice to the Minister shall be directed to:

Nova Scotia Department of Tourism, Culture and Heritage
World Trade and Convention Centre, 6th Floor
P.O. Box 456, 1800 Arglye Street
Halifax, Nova Scotia, B3J 2 R5
Telephone - (902) 424 - 4889
Fax - (902) 424 - 4872

8.2 Notice to CREDA shall be directed to:

Cumberland Regional Economic Development Association
35 Church Street
P.O. Box 546
Amherst, Nova Scotia, B4H 4A1

ATTENTION: Executive Director
Telephone - (902) 667 - 3638
Fax - (902) 667 - 2270

8.3 Either Party may designate a new address for notices under this Agreement, which shall be provided in writing to the other Party.

8.4 Every notice given hereunder shall be given either in writing personally delivered or posted by prepaid mail or by facsimile transmission. If posted, notices shall be deemed to have been received by the intended recipient thereof, and shall be effective upon the 5th business day of the government next following the date of posting.

9.0 INTERPRETATION

9.1 This Agreement shall be construed and interpreted in accordance with the laws of the Province of Nova Scotia.

9.2 This Agreement may not be assigned in whole or in part without the prior written consent of the Minister, which consent may be withheld for any reason.

9.3 Any waiver by the Parties hereto of any breach of this Agreement by the other, whether such waiver be direct or implied, shall not be construed as a continuing waiver of or consent to any subsequent breach of this Agreement by the other.

9.4 This Agreement, including the preamble and the schedules, shall constitute the whole agreement between the Parties and no representation or statement not expressly contained herein shall be binding upon either Party.

9.5 If any term or provision of this Agreement shall be found to be illegal or unenforceable, this Agreement shall remain in full force and effect and such terms or provision shall be deemed removed from the Agreement.

9.6 This Agreement may only be altered by means of a written memorandum signed by all Parties, and the said memorandum shall be supplemental to and shall be deemed to form part of this Agreement.

9.7 This Agreement shall not be changed, modified or discharged orally.

IN WITNESS WHEREOF the Parties have hereunto set their hands and affixed their seals on the day and year first above written.

SIGNED, SEALED AND DELIVERED in the presence of	**HER MAJESTY THE QUEEN in right of the Province of Nova Scotia**
Witness	Minister of Tourism, Culture and Heritage
	THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION
	PER: ______________ c/s
Witness	PER: ______________ c/s

SCHEDULE "B"

INSURANCE

1. General Liability Insurance for liabilities arising out of property damage, personal injury and bodily injury including death resulting from any activity connected with this Agreement and with the existence, management, maintenance and operation of the Joggins Fossil Centre. All such policies shall name as Additional Insureds Nova Scotia, their successors and assigns, and their respective directors, officers and employees. This insurance will include the following provisions:

   - policy limit of liability of $2 million per occurrence (can be structured as primary plus supplementary layers or primary plus Umbrella and/or Excess)
   - Sudden & Accidental Pollution coverage for all insured perils
   - nil deductible for Bodily Injury
   - maximum deductible all other occurrences of $10,000 per occurrence, except Sudden & Accidental Pollution ($100,000 each claim)
   - contingent employers liability
   - personal injury liability
   - broad form occurrence property damage
   - fire fighting expense liability
   - non-owned automobile liability
   - incidental aircraft and water craft coverage (if applicable)
   - cross liability and separation of interest with respect to each Insured
   - Nova Scotia, CREDA and their respective directors, officers and employees included as Additional Insureds
   - breach of any of the terms or conditions of the policy, or any negligence or wilful act or omission or false representation by an Insured or any other person, shall not invalidate the insurance with respect to Nova Scotia
   - primary insurance without right of contribution of any other insurance carried by Nova Scotia

- 90 days prior written notice of material change or cancellation from Insurer to Nova Scotia

2. Automobile Liability Insurance insuring all licensed vehicles owned, leased or operated by CREDA. CREDA must ensure that evidence of comparable coverage is provided by all contractors, subcontractors and workmen or tradesmen working at the site. This insurance will include the following provisions:

   - policy combined limit of liability of $2.0 million per occurrence
   - overall limit of liability of $2 million per occurrence (can be structured as primary plus supplementary layers or primary plus Umbrella and/ or Excess)
   - maximum deductible of $10,000 per occurrence

3. Umbrella and Excess Liability Insurance with respect to, and following the form of, the Commercial General Liability or Comprehensive General Liability and Automobile Liability insurances. This insurance will include the following provisions:

   - overall limit of liability of $2 million per occurrence (can be structured as Primary plus supplementary layers and Umbrella and/or Excess, or primary plus Umbrella and/or Excess)
   - "drop-down" provision for impaired or exhausted aggregates in underlying insurances (automatic reinstatement or aggregate limits in underlying insurance acceptable alternative)

4. Directors & Officers Liability Insurance covering the directors and officers of the corporation. This insurance will include the following provisions:

   - policy limit of liability of $1 million each claim
   - Corporate Reimbursement maximum deductible of $100,000 per claim, nil for directors and officers

CONFIDENTIALITY AGREEMENT

MADE BY Cumberland Regional Economic Development Association (CREDA).
(Print Name)

in favour of

HER MAJESTY THE QUEEN in right of the Province of Nova Scotia, as represented by the **MINISTER OF TOURISM, CULTURE AND HERITAGE** (hereinafter "Minister")

WHEREAS by agreement dated November 28/07, the Minister and the Cumberland Regional Economic Development Association ("CREDA") entered into an agreement respecting the Joggins Fossil Cliffs Protected Site (the "Joggins Agreement");

AND WHEREAS under the Joggins Agreement, the Minister agreed to share heritage research permit applications for the Joggins Fossil Cliffs Protected Site with a palaeontologist employed by CREDA for his or her review and comments;

AND WHEREAS under the Joggins Agreement, the Minister requires CREDA to obtain from the palaeontologist who will receive and review heritage research permit applications, an agreement made in favour of the Minister respecting confidentiality;

THEREFORE I, Cumberland Regional Economic Development Association hereby agree as follows:
(Print Name)

1. I will keep private, treat as confidential, and not make public or divulge during as well as after the term of this Agreement, any heritage research permit applications, as well as any information or material to which I become privy as a result of receiving and reviewing heritage research permit applications (collectively referred to as "Confidential Information");

2. I will safeguard the Confidential Information and will not further disclose it to any other party;

3. I will use the Confidential Information only for the purpose of reviewing heritage research permit applications and providing comments on the applications to the Minister, and not for any other purpose;

4. I acknowledge that the Confidential Information may include personal information protected under the *Personal Information International Disclosure Protection Act* ("*PIIDPA*"). I undertake to comply with and be bound by *PIIDPA*;

5. Following the review of a heritage research permit application, all copies of the Confidential Information will be promptly returned to the Minister, or securely

destroyed by CREDA;

6. I will not make the Confidential Information accessible to any other employees of CREDA;

7. I will immediately notify the Minister if I know or suspect that the Confidential Information may have been compromised or know or suspect that any requirement of this agreement may have been breached; and

8. The Minister will have the right to terminate the sharing of heritage research permit applications with me if, in the sole opinion of the Minister, CREDA or I breach or fail to comply with any of the terms of this agreement or the Joggins Agreement.

Agreed to this 28th day of November, 2007.

Kathy Douglas	Rhonda Kelly
Witness Signature	Signature
Kathy Douglas	Rhonda Kelly
Witness Printed Name	Printed Name

Schedule A

JOGGINS FOSSIL CLIFFS PROTECTED SITE

ALL that certain tract of land and land covered by water as shown on a Plan of JOGGINS FOSSIL CLIFFS PROTECTED SITE at Joggins in the County of Cumberland, Province of Nova Scotia, on file at Department of Natural Resources Office at Halifax under Field Plot P- 044/04 and being more particularly described as follows:

BEGINNING at the northeastern point at the top of the cliff or bank (in its natural state) on the eastward side of Chignecto Bay, on the west side of the mouth of Downing Cove;

THENCE southwesterly and following the various courses of the top of the cliff or bank (in its natural state) and extending across the mouth of all tributaries on the eastward side of Chignecto Bay, to the northwestern point of Ragged Reef Point;

THENCE due grid north seaward to a point being located at a perpendicular distance of 500 metres northerly from the top of the cliff or bank, on the eastward side of Chignecto Bay;

THENCE in a generally northeasterly direction remaining parallel to and 500 metres perpendicularly distant from the top of the cliff or bank on the eastward side of Chignecto Bay, to a point being located due grid north from the PLACE OF BEGINNING;

THENCE due grid south to the PLACE OF BEGINNING.

CONTAINING an approximate area of 689 hectares.

THE ABOVE DESCRIBED PARCEL having a seaward boundary lying 500 metres perpendicularly distant from the top of the cliff or bank and having a landward boundary that will follow parallel to the top of the cliff or bank, as its location varies over time.

THIS LEASE made in duplicate as of the day of , 2007.

BETWEEN:

THE MUNICIPALITY OF THE COUNTY OF CUMBERLAND, Province of Nova Scotia,

Hereinafter called the **"LANDLORD"**,

- and -

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION, a registered Society incorporated pursuant to the Societies Act, with head office at Amherst, in the County of Cumberland and Province of Nova Scotia,

- and -

THE JOGGINS FOSSIL INSTITUTE ASSOCIATION, a registered Society incorporated pursuant to the Societies Act, with head office at Amherst, in the County of Cumberland and Province of Nova Scotia

Hereinafter called the **"TENANTS"**

IN CONSIDERATION of the rents to be paid and the obligations to be performed pursuant to the terms of this Lease, the Landlord leases to the Tenants, the property described in this Lease (called in this Lease "the premises") upon the terms and conditions described in this Lease.

PREMISES:

1.01 The Landlord hereby leases to the Tenants and the Tenants hereby lease from the Landlord, on and subject to the terms and conditions hereinafter set forth, all that property more particularly described in Schedule "A" attached to this Lease.

TERMS OF LEASE:

2.01 This Lease shall be for a term of Twenty-five (25) years, commencing on the 1st day of *, 2007. Renewable as provided in this Lease.

RENEWAL:

3.01 The Tenants shall have the option to renew this Lease for an additional term.

3.02 The rent for the renewal term shall be agreed between the parties no later than two months prior to the expiration of this Lease.

RENT:

4.01 The Tenants shall upon the signing of this Lease by the Tenants pay the Landlord the sum of One Dollar ($1.00) for the term of the Lease hereby granted.

PAYMENT OF TAXES:

5.01 The Tenants shall pay or cause to be paid all real property and occupancy taxes assessed against the premises during the existence of this Lease.

INSURANCE:

6.01 The Landlord agrees to maintain public liability and property damage insurance on the leased premises in the minimum amount of $. The parties acknowledge that the cost of said insurance coverage, proof of which shall be provided annually to the Tenants, shall be deducted from the annual operating grant payable by the Landlord to the Tenants.

USE:

7.01 The land and buildings contained in this Lease shall be used for the purposes of promoting tourism within the area by providing a Fossil Centre, a tourist information interpretive centre, as well as research and field laboratory facilities for the study of geology unique to this area.

7.02 The parties acknowledge that it is the intent of the Landlord to provide ongoing assistance, financial and otherwise, to the project undertaken by the Tenants. As such, in the event that the Tenants cease to exist, or are unable for any reason to continue the operation of the above noted facility, the Landlord shall have the option to take over the management of the facility, including designating the operation thereof to a third party.

NO RECOURSE AGAINST TITLE:

8.01 The Tenants accept this Lease upon the express condition that the Tenants shall have no recourse against the Landlord should the title to the leased premises be found to be defective.

TENANTS' IMPROVEMENTS:

9.01 The Tenants shall not construct or erect any buildings or other structures on the land without obtaining the written approval of the Landlord of plans showing the design and nature of construction and such buildings or structures and their proposed locations, and all such buildings or structures shall be constructed and thereafter maintained by and at the cost and expense of the Tenants to the satisfaction of the Landlord.

VESTING OF STRUCTURES:

10.01 Subject to clauses 11.2 and 11.3, title in all structures and fixtures affixed upon the leased premises, whether prior to or during the currency of this Lease, vests in the Landlord without any right to compensation on the part of the Tenants.

10.02 Notwithstanding clause 11.1 the Tenants shall be entitled to remove their trade fixtures, and contents.

10.03 Upon the termination of this Lease, whether by affluxion of time or in any other manner whatsoever, the Landlord shall have the right and option to require the Tenants, upon written notice, to remove any and all of the structures and fixtures affixed upon the leased premises by the Tenants, and the Tenants shall upon receipt thereof promptly remove those structures and fixtures and restore the leased premises to their original condition as of the date of this Lease all at the cost and expense of the Tenants and without any right on the part of the Tenants to seek compensation for any reason whatsoever.

APPROVAL OF ALTERATIONS:

11.01 The Tenants shall, before making any alterations or exterior renovations to the buildings, obtain the prior written approval of the Landlord of plans showing the design and nature of construction of the proposed alterations or renovations to the buildings, and all such alternations or renovations to the buildings, shall be made and thereafter maintained by and at the cost and expense of the Tenants to the satisfaction of the Landlord.

MAINTENANCE AND REPAIR:

12.01 The Tenants shall at all times during the currency of this Lease, keep the buildings in good repair and in sanitary and reasonably clean condition, in all respects to the entire satisfaction of the Landlord and at the sole cost and expense of the Tenants.

12.02. The Tenants shall not, during the currency of this Lease, do, suffer or permit to be done any act or thing which may impair, damage or injure the leased premises or buildings or any part thereof beyond the damage occasioned by reasonable use, and shall, at the Tenants' own cost and expense, repair all portions of the land and buildings which may at any time be damaged, reasonable wear and tear excepted.

12.03 The Tenants shall at all times during the currency of this Lease, keep any improvements made by the Tenants to the buildings, in good repair and shall, at the Tenants' own cost and expense, effect all repairs to any leasehold improvements which are, at any time damaged, reasonable wear and tear excepted.

PAYMENT OF RENT:

13.01 The Tenants shall pay all rent herein reserved at the time and in the manner in this Lease set forth, without any abatement or deduction whatever.

DESTRUCTION OF LEASED PREMISES:

14.01 Notwithstanding anything in this Lease contained, if the leased premises at any time becomes untenantable, by reason or in consequence of any catastrophic cause beyond the Landlord's or Tenants' control, this Lease may thereupon, by notice in writing from either party given to the other party within sixty (60) days from the date that the leased premises so become untenantable, be declared terminated from the happening of any such event.

14.02 If this Lease is terminated pursuant to this clause the Tenants shall be entitled to reimbursement on a pro rata basis of any advance payment of rent.

COMPLIANCE WITH STATUTES, REGULATIONS, BY-LAWS:

15.01 The Tenants shall, in all respects, abide by and comply with all lawful statutes, regulations and by-laws of the Federal Government, the Provincial Government, the Municipal Government, and any other governing bodies, in any manner affecting the leased premises and buildings.

ASSIGNMENT AND SUBLEASES:

16.01 The Tenants shall not make any assignment of this Lease nor any transfer or sublease of the whole or any part of the land or building leased hereunder, without obtaining the prior consent in writing of the Landlord to such assignment, transfer or sublease which consent the Landlord reserves the right to withhold.

ACCESS:

17.01 The Tenants shall permit the Landlord, its servants or agents, full and free access, at all reasonable times, during the currency hereof, to any and every part of the land and the buildings.

17.02 The Tenants shall be responsible for erecting and maintaining any fences and barriers, at their own costs and expenses, which are determined by the Landlord and Tenants to be a requirement for safety and protection of the **PUBLIC** arising from their use of the leased premises.

CLAIM OR DEMAND:

18.01 The Tenants shall not have any claim or demand against the Landlord for detriment, damage, injury or loss of any nature whatsoever or howsoever caused to the land, the buildings, or to any person or property, including any structures, erections, materials, supplies, motor or other vehicles, articles, effects or things at any time brought, placed, made or being in or upon the land or the buildings, unless such damage or injury is due to the negligence of any officer or servant of the Landlord while acting within the scope of his duties or employment.

DAMAGES TO STRUCTURE:

19.01 If at any time or times hereafter any damage or injury (ordinary wear and tear excepted) should be occasioned to the land, the buildings or any part thereof, by reason of or on account of the operations of the Tenants hereunder, or any action taken or things done or maintained by virtue thereof, then, and in every such case the Tenants shall, immediately upon notice thereof from the Landlord, given in writing, repair, rebuild and restore the same in good, sufficient and workmanlike manner to the entire satisfaction of the Landlord; and in the event of failure on the part of the Tenants to so repair, the Landlord may, at its option, repair such damage or injury, in which case the Tenants shall upon demand forthwith repay and reimburse the Landlord for all costs and expenses connected therewith or incidental thereto.

RIGHTS OF HER MAJESTY TO GRANT LICENSES:

20.01 This Lease is granted strictly subject to the right of Her Majesty the Queen in right of Canada to grant licenses, at any time during the currency of this Lease, covering the right and privilege or permission to construct, lay, maintain, operate or replace water mains, sewers, gas pipelines, oil pipelines, underground and overhead transmissions, electrical lines and telephone lines, and cables on, under, over and across the leased premises and for Her Majesty, Her agents, servants, and contractors, with vehicles, equipment and machinery, to enter upon the leased premises at any time for the purpose of installing, maintaining and replacing aids to navigation without interference from the Tenants and the exercise of such right shall not be deemed to constitute an interference with the Tenants' exclusive possession of the lease premises or constitute a derogation from the Lease hereby granted.

NUISANCE:

21.01 The Tenants shall not, at any time during the currency of this Lease, do, suffer or permit to be done, any act or thing in or upon the land or the buildings which shall or may be, or might become an annoyance, nuisance or disturbance to the occupiers of lands or premises adjoining or in the vicinity or the land or to the public generally, and of which matters the Landlord shall be the sole judge and its decision thereon binding on the Tenants.

OVERHOLDING:

22.01 If, after the expiration or termination of this Lease, the Tenants shall continue to occupy the leased premises, with or without consent of the Landlord, but without execution of a new lease or renewed lease of the leased premises, the Tenants shall be Tenants at will at a monthly rent, for the time of such occupation, of one-twelfth plus ten percent of one-twelfth of the annual rent payable immediately prior to overholding payable in advance on the first day of each month, and subject in all other respects to the same terms as are herein set out, insofar as they are applicable to a tenancy at will, and, upon the termination of the tenancy at will, any rental payments during the tenancy at will shall be considered payments on account only and, in the event that this Lease is renewed by agreement between the parties or a new lease of the premises herein demised is entered into by the parties, an adjustment shall be made upon the signature of a new or renewed lease to bring the amount paid in respect of the period of tenancy at will into accord with the provisions of the new or renewed lease, it being expressly agreed that the acceptance of rent, or any implied condition, or any implication of law, shall in no way renew this Lease or create any tenancy other than a tenancy at will.

DEFAULT AND RE-ENTRY:

23.01 It is expressly agreed that:

(a) if the Tenants shall be in default in the payment or rents or amounts collectable hereunder as rent, whether lawfully demanded or not, and such default shall continue for a period of 15 days after the rent has become due and payable; or

(b) if the Tenants shall be in default of any of its covenants or agreements hereunder (other than the covenant to pay rent or amounts collectable hereunder as rent) and such default shall continue for a period of 30 days (or such longer period as may be reasonably necessary to cure such default considering the nature thereof) after notice by the Landlord to the Tenant specifying with reasonable particularity the nature of such default and requiring the same to be remedied; or

(c) if the default set out in the notice given by the Tenants by the Landlord pursuant to paragraph (b) reasonably requires more time to cure than the thirty (30) day period referred to in that paragraph and the Tenants have not commenced remedying or curing the same within the thirty (30) day period or, in the opinion of the Landlord fail to diligently complete the same within a reasonable time; or

(d) if the Tenants shall make an assignment for the benefit of collectors, or shall make an assignment or have a receiving order made against them under the Bankruptcy Act, or becoming bankrupt or insolvent shall make application for relief under the insolvent debtors, or any action whatsoever, legislative or otherwise shall be taken with a view to the winding up, dissolution or liquidation of the Tenants;

then the current month's rent together with the rent for the three months next ensuring shall immediately become due and payable, and at the option of the Landlord the term hereby granted shall become forfeited and void, and the Landlord may without notice or any form of legal process whatsoever forthwith re-enter upon the leased premises or any part thereof in the name of the whole and repossess and enjoy the same as of its former estate, anything contained in any statute or law to the contrary notwithstanding.

23.02 Forfeiture of this Lease by the Tenants shall be wholly without prejudice to the right of the Landlord to recover arrears of rent or damages for any antecedent breach of covenant on the part of the Tenants, and notwithstanding any such forfeiture the Landlord may subsequently recover from the Tenants damages for loss of rent suffered by reason of the Lease having been determined prior to the end of the term of this Lease as set out in clause 2 hereof and this clause and the rights hereunder shall survive the termination of this Lease whether by act of the parties or by operation of Law.

INDEMNITY:

24.01 The Tenants shall at all times indemnify and save harmless the Landlord from and against all claims and demands, loss, costs, damages, actions, suits or other proceedings by whomsoever made, brought or prosecuted, in any manner based upon, occasioned by or attributable to the execution of this Lease, or any action taken or things done or maintained by virtue hereof, or the exercise in any manner of rights arising hereunder, except claims for damage resulting from the negligence of any officer or servant of the Landlord while acting within the scope of his duties or employment.

SERVICES:

25.01 That heat, water, sewage facilities and electrical energy will be supplied by the Tenants, in a manner satisfactory to the Landlord at the whole expense cost and expense of the Tenants.

NOTICES:

26.01 All notices and communications to the Landlord in connection with this Lease shall be addressed to:

Municipality of the County of Cumberland
P.O. Box 428
Amherst, Nova Scotia
B4H 3Z5

or such other address as the Landlord may advise the Tenants in writing.

26.02 All notices and communications to the Tenants in connection with the Lease shall be addressed to:

Cumberland Regional Economic Development Association
P.O. Box 546
35 Church Street
Amherst, Nova Scotia
B4H 4A1

26.03 Any notice given to either party hereto shall be effectively given if sent by letter or fax addressed to the party at its address as indicated above. Any notice so given shall be deemed to have been received by the other party at the time when in the ordinary course, such letter or fax should have reached its destination.

REMOVAL OF CHATTELS BY TENANTS:

27.01 Subject to clause 22.02 the Tenants shall not, unless required by the Landlord remove or cause or permit to be removed any goods, materials, effects or things from the land or the building until all rent due or to become due under this Lease is fully paid.

27.02 The Landlord may on termination of this Lease, request the Tenants to forthwith remove from the land and buildings all goods, chattels, structures, erections, materials, effects and things at any time erected, brought or placed thereon or therein by the Tenants, and the Tenants shall to the satisfaction of the Landlord repair all and every damage and injury occasioned to the land or building by reason of such removal or in the performance thereof, but the Tenants shall not, by reason of any action taken or things performed or required hereunder be entitled to any compensation whatever.

EFFECT OF LEASE:

28.01 This Lease and everything herein contained shall operate and take effect to the benefit of an be binding upon the heirs, executors, administrators, successors and lawful assigns, as the case may be, of each of the parties hereto, subject to the granting of consent by the Landlord as provided herein to any assignment, transfer or sublease of this Lease and where there is a male, female or corporate party, the provisions hereof shall be read with all grammatical changes to gender and number required by the context of all covenants and obligations shall be deemed joint and several and the invalidity of any clause for any reason whatsoever shall not invalidate any other clause of this Lease.

REMEDIES GENERALLY:

29.01 Mention in this Lease of any particular remedy of the Landlord in respect of the default by the Tenants does not preclude the Landlord from any other remedy in respect thereof, whether available at law or in equity or by statute or expressly provided for in this Lease.

END OF TERM:

30.01 Upon the expiration or other termination of the term of this Lease, the Tenants shall quit and surrender to the Landlord the Leased Premises, in good order and condition, ordinary wear excepted. The Tenants' obligations to observe or perform this covenant shall survive the expiration or other termination of the term of this Lease. If the last day of the term of this Lease falls on Sunday, this Lease shall expire on the business day immediately preceding.

PROVISION SEPARATELY VALID:

31.01 If any covenant, obligation, agreement, term or condition of this Lease or the application thereof to any person or circumstances shall, to any extent, be invalid or unenforceable, the remainder of this Lease or the application of such covenant, obligation, agreement, term or condition to persons or circumstances other than those in respect of which it is held invalid or unenforceable, shall not be affected thereby and each covenant, obligation, agreement, term and condition of this Lease shall be separately valid and enforceable to the fullest extent permitted by law.

NON-WAIVER

32.01 No condoning, excusing or overlooking by the Landlord of any default, breach or non-observance by the Tenants at any times in respect of any covenant, or condition of this Lease herein contained shall operate as a waiver of the Landlord's rights hereunder in respect of any continuing or subsequent default, breach or non-observance, or so as to defeat or affect in any way the rights of the Landlord in respect of any continuing or subsequent default or breach, and no waiver shall be inferred from or implied by anything done or omitted by the Landlord save only express waiver in writing. All rights and remedies of the Landlord contained in this Lease shall be cumulative and not alternative.

HEADINGS:

33.01 Any note appearing as a heading in this Lease has been inserted for convenience and reference only and cannot define, limit or expand the scope or meaning of this Lease or any of its provisions.

ENTIRE AGREEMENT:

34.01 This Lease constitutes the entire agreement between the Landlord and the Tenants hereto with respect to the subject matter hereof and shall supercede all previous negotiations, representations, and documents in relation hereto made by any party to this Lease.

IN WITNESS WHEREOF the parties hereto have executed this lease as of the date and year first above written.

SIGNED AND SEALED on the day of , 2007.

IN THE PRESENCE OF	)
	) **THE MUNICIPALITY OF THE COUNTY OF CUMBERLAND**
	) Per: ....
	) **THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION**
	) Per: ....
	) **THE JOGGINS IMPROVEMENT COMMITTEE**
	) Per:...
	) Per:..

PROVINCE OF NOVA SCOTIA
COUNTY OF CUMBERLAND SS

On this day of , 2007, before me, the subscriber personally came and appeared a subscribing witness to the foregoing Indenture, who having been by me duly sworn, made oath and said that **THE JOGGINS IMPROVEMENT COMMITTEE**, one of the parties mentioned in the foregoing Indenture, caused these presents to be executed by its proper officers and its corporate seal to be affixed thereto in h presence.

....
A Barrister of the Supreme
Court of Nova Scotia

PROVINCE OF NOVA SCOTIA
COUNTY OF CUMBERLAND SS

On this day of , 2007, before me, the subscriber personally came and appeared a subscribing witness to the foregoing Indenture, who having been by me duly sworn, made oath and said that ________________ and ______________________, two of the parties mentioned in the foregoing Indenture, signed, sealed and delivered the same in h presence.

....
A Barrister of the Supreme
Court of Nova Scotia

SCHEDULE "A"

ALL that certain lot, piece, parcel or area of land situate, lying and being at Joggins, County of Cumberland, Province of Nova Scotia, and being shown as Lot 05, on a Plan entitled "PLAN OF SURVEY OF LOT 05, CROWN LAND", prepared by Lyndon K. Crowe, N.S.L.S. and signed August 3, 2006, being filed at the Nova Scotia Department of Natural Resources Office at Halifax, under Field Plot P-004/06 and further recorded at the Cumberland County Land Registration Office at Amherst on April 17, 2007 as Plan No. 87612371, and being more particularly described as follows: **BEGINNING** at the intersection of a Southwestern boundary of Main Street, and a Northwestern boundary, lands of The Municipality of the County of Cumberland, and being situate North 48 degrees 23 minutes 16 seconds West, 269.609 metres from Nova Scotia Coordinate Monument 26763;**THENCE** South 50 degrees 44 minutes 39 seconds West, along a Northwestern boundary, lands of The Municipality of the County of Cumberland, 73.368 metres to a point on a Northeastern boundary, lands of James Leblanc;**THENCE** North 47 degrees 28 minutes 36 seconds West, along a Northeastern boundary, lands of James Leblanc, 20.876 metres to a point;**THENCE** South 31 degrees 47 minutes 04 seconds West, along a Northwestern boundary, lands of James Leblanc, 42.322 metres to a point at the Northern corner, lands of Shirley Brine;**THENCE** South 32 degrees 37 minutes 31 seconds West, along a Northwestern boundary, lands of Shirley Brine, 21.748 metres to a point at the Northern corner, lands of Catherine T. Hoeg;**THENCE** South 31 degrees 41 minutes 56 seconds West, along a Northwestern boundary, lands of Catherine T. Hoeg, 93.530 metres to a point;**THENCE** South 60 degrees 41 minutes 35 seconds East, along a Southwestern boundary, lands of Catherine T. Hoeg, 24.914 metres to a point at the Northern corner, lands of Darrell & Alice Leblanc;**THENCE** South 27 degrees 01 minutes 17 seconds West, along a Northwestern boundary, lands of Darrell & Alice Leblanc, 34.748 metres to a point at the Northern corner, lands of Russell A. Armstrong & Elizabeth Ann Wilson;**THENCE** South 39 degrees 30 minutes 35 seconds West, along a Northwestern boundary, lands of Russell A. Armstrong & Elizabeth Ann Wilson, 30.516 metres to a point;**THENCE** South 52 degrees 50 minutes 50 seconds East, along a Southwestern boundary, lands of Russell A. Armstrong & Elizabeth Ann Wilson, 54.565 metres to a point on a Northwestern boundary of Hurley Road;**THENCE** South 27 degrees 36 minutes 37 seconds West, along a Northwestern boundary of Hurley Road, 13.908 metres to a point on a Northeastern boundary, lands of Arthur A. & B. Jean Reid;**THENCE** North 52 degrees 50 minutes 50 seconds West, along a Northeastern boundary, lands of Arthur A. & B. Jean Reid, 79.267 metres to a point;**THENCE** South 25 degrees 18 minutes 06 seconds West, along Northwestern boundaries, lands of Arthur A. & B. Jean Reid, and lands of Darrah A. Brine & Helen Sims, 156.358 metres to a point;**THENCE** South 69 degrees 16 minutes 21 seconds West, along a Northern boundary, lands of Darrah A. Brine & Helen Sims, 188.735 metres to a witness point;**THENCE** continuing South 69 degrees 16 minutes 21 seconds West, along a Northern boundary, lands of Darrah A. Brine & Helen Sims, 65 metres more or less to a point on the Ordinary High Water Mark of Chignecto Bay;**THENCE** in a Northerly direction, along the Ordinary High Water Mark of Chignecto Bay, 800 metres more or less to a point on a Southwestern boundary, Main Street;**THENCE** South 50 degrees 11 minutes 08 seconds East, along a Southwestern boundary, Main Street, 38 metres more or less to a witness point (being a tie bearing and distance of North 10 degrees 33 minutes 15 seconds East, 723.228 metres from the first mentioned witness point);**THENCE** continuing South 50 degrees 11 minutes 08 seconds East, along a Southwestern boundary, Main Street, 29.992 metres to a point on a Northwestern boundary, lands of Edith Purdy;**THENCE** South 41 degrees 08 minutes 31 seconds West, along a Northwestern boundary, lands of Edith Purdy, 36.577 metres to a point;**THENCE** South 49 degrees 12 minutes 19 seconds East, along a Southwestern boundary, lands of Edith Purdy, 24.250 metres to a point;**THENCE** South 65 degrees 28 minutes 15 seconds East, along a Southwestern boundary, lands of Edith Purdy, 92.501 metres to a point;**THENCE** North 41 degrees 08 minutes 13 seconds East, along a Southeastern boundary, lands of Edith Purdy, 10.668 metres to a point on a Southwestern boundary, Main Street;**THENCE** South 48 degrees 51 minutes 27 seconds East, along a Southwestern boundary, Main Street, 41.600 metres to a point;**THENCE** South 47 degrees 28 minutes 52 seconds East, continuing along a Southwestern boundary, Main Street, 183.624 metres to a point;**THENCE** South 47 degrees 29 minutes 07 seconds East, continuing along a Southwestern boundary, Main Street, 41.615 metres to the **POINT OF BEGINNING;SAVING AND EXCEPTING THERE OUT** certain lands of The Municipality of the County of Cumberland, said certain lands being more particularly described as follows:

BEGINNING at a point, said point of beginning being situated North 52 degrees 50 minutes 50 seconds West, 39.603 metres, then North 10 degrees 00 minutes 10 seconds West, 13.719 metres along a Northeastern and Eastern boundary of a 13.716 metre wide Right of Way, from the Western corner, lands of Russell A. Armstrong & Elizabeth Ann Wilson;

THENCE South 79 degrees 49 minutes 14 seconds West, along a Northern boundary of the herein described Lot 05, 13.716 metres to a point;

THENCE continuing South 79 degrees 49 minutes 14 seconds West, along a Northern boundary of the herein described Lot 05, 105.158 metres to a point;

THENCE North 01 degrees 05 minutes 03 seconds East, along an Eastern boundary of the herein described Lot 05, 164.298 metres to a point;

THENCE North 01 degrees 07 minutes 57 seconds East, continuing along an Eastern boundary of the herein described Lot 05, 68.709 metres to a point;

THENCE South 89 degrees 47 minutes 41 seconds East, along a Southern boundary of the herein described Lot 05, 88.394 metres to a point;

THENCE South 51 degrees 48 minutes 54 seconds East, along a Southwestern boundary of the herein described Lot 05, 132.595 metres to a point;

THENCE South 31 degrees 41 minutes 54 seconds West, along a Northwestern boundary of the herein described Lot 05, 103.634 metres to a point;

THENCE continuing South 31 degrees 41 minutes 54 seconds West, along a Northwestern boundary of the herein described Lot 05, 48.768 metres to the **POINT OF BEGINNING**;The above described Lot 05 contains an area of 110,000 square metres (27 acres) more or less;

The above described Lot 05 is a portion of the lands described in Book 262 at Page 78, as recorded at the Registry of Deeds, Town of Amherst, County of Cumberland, Province of Nova Scotia; **SUBJECT TO** a Right of Way, in favour of the above described certain lands of The Municipality of the County of Cumberland, said Right of Way being more particularly described as follows:

BEGINNING at the intersection of a Northwestern boundary of Hurley Road, and a Northeastern boundary, lands of Arthur A. & B. Jean Reid;

THENCE North 52 degrees 50 minutes 50 seconds West, along a Northeastern boundary, lands of Arthur A. & B. Jean Reid, 79.267 metres to a point;

THENCE North 52 degrees 49 minutes 39 seconds West, 22.552 metres to a point;

THENCE North 10 degrees 05 minutes 33 seconds West, 19.079 metres to a point on a Southern boundary, lands of The Municipality of the County of Cumberland;
THENCE North 79 degrees 49 minutes 14 seconds East, along a Southern boundary, lands of The Municipality of the County of Cumberland, 13.716 metres to a point;
THENCE South 10 degrees 00 minutes 10 seconds East, 13.719 metres to a point;
THENCE South 52 degrees 50 minutes 50 seconds East, 39.603 metres to a point at the Western corner, lands of Russell A. Armstrong & Elizabeth Ann Wilson;
THENCE South 52 degrees 50 minutes 50 seconds East, along a Southwestern boundary, lands of Russell A. Armstrong & Elizabeth Ann Wilson, 54.565 metres to a point on a Northwestern boundary of Hurley Road;
THENCE South 27 degrees 36 minutes 37 seconds West, along a Northwestern boundary of Hurley Road, 13.908 metres to the **POINT OF BEGINNING;ALL BEARINGS** referred to herein are based on the Nova Scotia Coordinate System, Zone 5, Central Meridian 64 degrees 30 minutes West Longitude.

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AMENDMENT TO MEMORANDUM OF UNDERSTANDING

BETWEEN:

THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

hereinafter "CREDA"

- and -

THE JOGGINS FOSSIL INSTITUTE, a Society incorporated pursuant to the laws of Nova Scotia

hereinafter "JFI"

Whereas the parties hereto entered into a Memorandum of Understanding dated the 20th day of December, 2006 outlining their respective roles and responsibilities with respect to the management of the Joggins Fossil Cliffs;

And whereas CREDA has recently entered into agreements with the Minister of Tourism, Culture and Heritage, the Minister of Natural Resources and the Municipality of the County of Cumberland in relation to the roles and responsibilities of CREDA and those parties in relation to the occupation and management of the palaeontological and natural history components of the Joggins Fossil Cliffs site (the "agreements");

And whereas the parties hereto are desirous of confirming their respective roles and responsibilities in relation to the above noted agreements;

The Signatories hereto have reached consensus as to the following:

1. JFI shall be responsible for carrying out the duties and responsibilities undertaken by CREDA in the above noted agreements, and in all aspects shall act as CREDA's agent, including in the financial management of the relevant operating funds as designated to CREDA for the project.

2. JFI agrees to provide timely and ongoing reports to CREDA with respect to its activities in relation to the Joggins Fossil Cliffs site, and in particular, its activities pursuant to the above noted agreements.

3. That in all other respects the Memorandum of Understanding dated December 20th, 2006 is hereby confirmed.

Dated this 28th day of November, 2007.

The Cumberland Regional Economic Development Association	Witness (CREDA)
PER:	
The Joggins Fossil Institute	Witness (JFI)
PER:	

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MEMORANDUM OF ASSOCIATION

AND BY-LAWS

OF THE

JOGGINS FOSSIL INSTITUTE ASSOCIATION

MEMORANDUM OF ASSOCIATION
AND BY-LAWS
OF THE
JOGGINS FOSSIL INSTITUTE ASSOCIATION

1. The name of the Society is the Joggins Fossil Institute Association, also referred to as the "Society".

2. On a volunteer and non-profit basis, the Society will seek to achieve the following objects:

   a) To manage the Joggins Fossil Cliffs Site and Centre, a place where World Heritage values are protected, respected, understood and presented, so that the story of these values and other cultural and natural values can be told to the world, and future generations;

   b) To hold for the benefit and education of humanity a collection and manage a geographic site representative of the Carboniferous period;

   c) To ensure the site and collection is conserved, safely studied and exhibited and to provide for the advancement of scientific research;

   d) To acquire by way of grant, gift, purchase, bequest, devise or otherwise real and personal property to use and apply such property to the realization of the objects of the Joggins Fossil Institute Association;

   e) To buy, own, hold, lease, mortgage, sell and convey such real and personal property as may be necessary or desirable in the carrying out of the objects of the Joggins Fossil Institute Association; and

   f) To do all such other things as may be provided by the Societies Act, R.S.N.S. 1989, c. 435.

PROVIDED that nothing herein contained shall permit the Society to carry on any trade, industry, or business and the Society shall be carried on without purpose of gain to any of the members and that any surplus or any accretions of the Society shall be used solely for the purposes of the Society and the promotion of its objects.

3. The activities of the Society are to be carried on in Cumberland County.

4. The Registered office of the Society is: 35 Church Street, P.O. Box 546, Amherst, Nova Scotia B4H 4A1.

We the several persons who names, addresses and occupations are subscribed, desire to be formed into a Society, in pursuance to this Memorandum of Association.

Dated at AMHERST, Nova Scotia, this 13 day of July, 2006.

NAMES	ADDRESSES AND OCCUPATIONS
John Kellegrew [signature]	RR#3, 215 Hastings Road Amherst, N.S B4H3Y1 Buisnes Owner
Gerald Read [signature]	RR#6 Amherst 34 Nappan Rd. B4H 3Y4 Business owner
LAING FERGUSON [signature]	Retired Professor of Geology 31 Queens Rd Sackville, NB
LARRY LATTA [signature]	Retired V-P Daimlerchrysler Canada Inc 5532-RR#2, Amherst N.S.
SCOTT SWINDEN [signature]	Executive Director, N.S. NATURAL RESOURCES 3 CREST RD. HALIFAX, NS B3M 2W1
JOHN REID [signature]	COUNCILLOR MUNICIPALITY OF CUMBERLAND 59 CHARLES ST JOGGINS N.S. B0L-1A0
DANIEL BURKE [signature]	2 OCEANVIEW DR AMHERST NS AMHERST TOWN COUNCILLOR
DALE FAWTHROP [signature]	26 CLARENCE ST. AMHERST NS. Account Manager
Darlene Stevenson [signature]	RR1 Debert, N.S. B0M1G0
Kenneth Adams [signature]	14 ATHOL STH. RD RR#2 SOUTHAMPTON, B0M 1W0 DIRECTOR/CURATOR FUNDY GEOLOGICAL MUSEUM
BOB BOOK [signature]	2 BERMUDA AVE., HALIFAX B3N 1E9 DIRECTOR OF DEVELOPMENT - TOURISM DIVISION DEPT. OF TOURISM, CULTURE & HERITAGE
Todd Keith [signature]	67 Newcastle St. Dartmouth NS, B2Y 3M6 Park Planner, Parks Canada Agency
NEAL CONRAD [signature]	40 DUSTAN ST. DARTMOUTH N.S. B2Y 3T8 DIRECTOR, COMMUNITY & RURAL DEV. N.S. OFFICE OF ECONOMIC DEVELOPMENT.
BERNICE VANCE [signature]	42 Charles St, Joggins NS B0L 1A0 Employment Officer

Witness to the above signatures:

[signature]

of Advocate Harbour

in the County of Cumberland and
Province of Nova Scotia

LIST OF FIRST DIRECTORS
OF THE
JOGGINS FOSSIL INSTITUTE ASSOCIATION

The following are to serve as first directors from the date of incorporation until the close of business at the first annual general meeting.

John Kellegrew	RR3, 215 Hastings Rd., Amherst, NS B4H 3Y1
Gerald Read	RR6, 34 Nappan Rd., Amherst, NS B4H 3Y4
Laing Ferguson	31 Queens Rd., Sackville, NB E4L 4G4
Scott Swinden	3 Crest Road, Halifax, NS B3M 2W1
John Reid	59 Charles Street, Joggins, NS B0L 1A0
Daniel Burke	2 Oceanview Dr., Amherst, NS B4H 3Y6
Dale Fawthrop	26 Clarence St., Amherst, NS B4H 3P1
Darlene Stevenson	RR1, Debert, NS B0M 1G0
Kenneth Adams	14 Athol Stn. Rd., RR2, Southampton, NS B0M 1W0
Bob Book	2 Bermuda Ave., Halifax, NS B3N 1E9
Todd Keith	67 Newcastle St., Dartmouth, NS B2Y 3M6
Neal Conrad	40 Dustan St., Dartmouth, NS B2Y 3T8
Bernice Vance	42 Charles St., Joggins, NS B0L 1A0

DATED at Amherst
Nova Scotia this 13th day
of July, 2006.

Gerald Read
(Signed)

BY-LAWS

OF THE

JOGGINS FOSSIL INSTITUTE ASSOCIATION

TABLE OF CONTENTS

I. DEFINITIONS

1. In these Articles, unless there be something in the subject or context inconsistent therewith, and subject to the **Societies Act:**

   1.1 "Act" means the Societies Act, R.S.N.S. 1989 c. 435;

   1.2 "Association" means the Joggins Fossil Institute Association;

   1.3 "CREDA" means the Cumberland Regional Economic Development Association;

   1.4 "Member" means both a member of the Society and of the Board of Directors;

   1.5 "Registrar" means the Registrar of Joint Stock Companies appointed under the Nova Scotia Companies Act;

   1.6 "Society" means the Joggins Fossil Institute Association;

   1.7 "Special Resolutions" means a resolution passed by not less than three-quarters of such members entitled to vote as are present, in person, at a meeting of the Society for which notice specifying the intention to propose the resolution has been duly given.

II. MEMBERSHIP

2. The subscribers to the Memorandum of Association and such other persons as shall be admitted to membership in accordance with these By-laws, and none others, shall be members of the Society and of its Board of Directors, and their names shall be entered in the Registrar of Members accordingly. Specifically, the membership of the Association and its Board of Directors shall consist of not more than twelve (12) persons, to be chosen as follows:

   a) One (1) member being a municipal councillor, to be proposed by the Municipality of the County of Cumberland;

   b) One (1) member to be proposed by her Majesty the Queen, in the right of the Dominion of Canada (the federal government), and who shall be a non-voting member;

   c) Two (2) members to be proposed by her Majesty the Queen, in the right of the Province of Nova Scotia (the provincial government), and who shall be a non-voting member;

   d) One (1) member who is a permanent and full-time resident of that geographical area known as "District 9" of the Municipality of the County of Cumberland;

e) Two (2) members who are a permanent and full-time residents of any district of the Municipality of the County of Cumberland, or any of the four municipal units contained therein;

f) Three (3) members-at-large who shall through their abilities and skills bring to the Board experience in areas relevant to the objects of the Society. Nothing shall prohibit the members appointed pursuant to this clause as being employees of the federal or provincial governments, or a municipal unit;

g) One (1) member-at-large from a geological, palaeontological or such other scientific background relevant to the subject matter of the Society's objects;

h) One (1) member-at-large appointed by CREDA.

3. All of the appointments to the Board as outlined in paragraph 2(d),(e), (f),(g) and (h) shall be approved by CREDA, and shall be for a term of two (2) years.

4. A person appointed as a member of the Society may be reappointed, but no person shall be a member for more than six years exclusive of any time served as a member of the Association from its Incorporation until its first Annual Meeting or in serving the unexpired portion of a previous member's term.

5. A person ceases to be a member of the Society:

a) if appointed pursuant to paragraphs 2(d) or (e), ceases to be a resident of the area defined therein;

b) that person is deceased or has submitted a written resignation to the Society;

c) that person is convicted of an indictable offence, while serving as a director, or has been so convicted within the five (5) years proceeding his/her appointment;

e) unless there are extenuating circumstances found to constitute a reasonable explanation for their absence by a majority of the Board, that person is absent, without cause, from two (2) consecutive meetings of the Association;

f) unless appointed pursuant to clause 2(b) and (c), that person changes their occupation or position from that held at the time of his/her appointment, and said change, in the absolute discretion of a majority of directors, will cause that person to less effectively carry out the duties of director; and

g) if appointed pursuant to Article 2(a),(b), (c) or (h), and the appointing body provides the Board with notice of its desire to designate an alternate appointee.

6. The Board may, by majority vote, remove any director before the expiration of his or her term, with or without just cause.

7. If the position of any member of the Society becomes vacant prior to the expiry of his or her term, a replacement shall be appointed in the same fashion as set out in Clause 2, that appointment to be effective immediately for the unexpired portion of the previous member's term.

8. In the event that the Municipality of the County of Cumberland, or her Majesty the Queen, fail to propose a member pursuant to paragraphs 2 (a),(b), and (c) or 7 above, CREDA shall nominate the necessary number of members to create a full Board of twelve (12) persons.

III FISCAL YEAR

9. The fiscal year of the Society shall be the period of one year or part thereof ending March 31st in any year.

IV BOARD OF DIRECTORS

10. The Board of Directors shall be the membership of the Society as determined by paragraph 2 of these By-laws.

V. POWERS OF DIRECTORS

11. The management of the activities of the Society shall be vested in the directors who, in addition to the powers and authorities by these Articles or otherwise expressly conferred upon them, may exercise all such powers and do all such acts and things as may be exercised or done by the Society.

12. The Directors shall have the power:

    a) to take such steps as they think fit to carry out any agreement or contract made by or on behalf of the Society;

    b) to pay the cost, charges and expenses preliminary and incidental to the promotion, formation, establishment and registration of the Society;

    c) to purchase or otherwise acquire, for the Society any property, rights or privileges that the Society is authorized to acquire, and at such price and generally on such terms and conditions as they think fit;

d) to pay for any property, rights, or privileges acquired by the Society at their discretion;

e) subject to the approval, by special resolution of the Members, to secure fulfilment of any contracts or engagements entered into by the Society by mortgaging or charging all or any of the property of the Society, in such manner as they think fit;

f) to appoint, remove or suspend, at their discretion, such experts, professionals, managers and employees of the Society, as they think fit, and to determine their powers and duties, and establish their salaries and remuneration;

g) to authorize any person or persons to accept and hold in trust for the Society any property belonging to the Society or in which it has an interest;

h) to institute any legal proceedings by the Society or its officers concerning the affairs of the Society and also to defend any legal proceeding against the Society or concerning the affairs of the Society and also to allow time for payment or satisfaction of any debts due or any claims or demands made by or against the Society;

I) to refer any claims or demands by or against the Society to arbitration;

j) to make and give receipts, releases, and other discharges for money payable to the Society for claims and demands of the Society;

k) the signing officers of the Society shall be the Officers for the time being, and such other person or persons authorized by the members. A minimum of two signatures shall be required on all cheques issued on behalf of the Society;

l) to delegate to one or more of the directors, officers, employees or Special Purpose Committees of the Society as are designated by the Board all or any of the powers conferred on the Board to such extent and in such manner as the Board determines at the time of each such delegation;

m) to establish Special Purpose Committees consisting of representatives of the Board and/or of advisory groups, community organizations, businesses, and individuals who have involvements and interests in the objects of the Society, to deal with specific matters as the Board determines from time to time;

n) to remunerate Directors, Officers, and Special Purpose Committee members for such expenses incurred and at such rates as the Board may from time to time decide, but in no case shall there be any honorariums paid.

VI. MEETINGS

13. Meetings of the Board of Directors shall be held as often as the business of the Society may require and shall be called at the request of the Chairperson, the Executive Director, or any three directors of the Society.

14. Notice of any meeting of the Board, stating the day, hour, and place of meeting, shall be given either orally or in writing to each director no later than 72 hours before the meeting is to take place. For further clarity, Saturday and Sunday shall not be counted in the computation of time pursuant to this clause.

15. Notice of any meeting of the Board at which it is intended to request the passage of a Special Resolution must contain, in addition to the date, time and place of the meeting, a copy of the Special Resolution to be introduced. The notice must be personally delivered, mailed to the last recorded mailing address of the member, or faxed to the last known fax number of the member, not less than three business days before the meeting is to take place. Notice personally given may be confirmed in writing by the person delivering the notice. Notice given by mail shall be deemed to have been received at the time when the notice would be received in the ordinary course of post and a written statement from the person mailing the notice as to the date of mailing is sufficient confirmation of delivery. Notice given by fax shall be deemed to have been received the same day as transmitted.

16. Non-receipt of any notice by any director shall not invalidate the proceedings at any meeting of the Board of Directors.

17. No business requiring a vote of the members of the Board of Directors shall be transacted at any meeting unless the quorum of five (5) members is present.

18. Nothing shall prevent a member from attending a meeting via teleconferencing.

19. Every member other than those appointed pursuant to clause 2(b) and (c) shall have one vote and no more.

20. Any questions, motions and regular resolutions arising at any meeting of the Board of Directors shall be decided by a majority of votes. The Chairperson of the meeting shall have a vote, but any motion or resolution that results in an equality of votes, including the vote of the Chairperson, is not carried and shall be deemed to be defeated.

21. Notwithstanding any of the foregoing provisions of these Articles, a resolution in writing, other than a Special Resolution, signed by all the directors entitled to vote on that resolution at a meeting of the directors or a committee of directors is as valid as if it had been passed at a meeting of the directors or a committee of directors.

22. A director who is a party to, or who is a close relative of a person, or is a director of a

company or partner with a person who is a party to, a material contract or proposed material contract with the Society, shall disclose to the Board the nature and extent of that interest. Any such contract or proposed contract shall be referred to the Board for approval even if the contract is one that, in the ordinary course of the Society's business would not require approval by the Board, and a director interested in a contract so referred to the Board, shall not vote nor participate in the discussion of any resolution to approve the contract.

23. The Chairperson of the Board of Directors in his or her absence, the Vice-Chairperson or, in the absence of both, any director appointed from among those directors present shall preside as Chairperson at meetings of the Board.

24. Where a Municipality, a Province or the Government of Canada is contributing funds to assist the Society, representatives of any department or agency of the body so contributing, designated by that body, may attend upon invitation of the Board the meetings of the Board as observers.

25. An Annual Meeting of the Society shall be held within six (6) months after the end of each fiscal year of the Society.

26. At each Annual Meeting, the following items of business shall be dealt with:

Minutes of preceding Annual Meeting;
Consideration of annual reports of the Officers;
Consideration of the financial statements, including balance sheet and operating statement and the report of the auditors thereon;
Election of Directors and Officers for the coming year;
Appointment of Auditors.

VII. OFFICERS AND THEIR DUTIES

27. The Officers of the Society shall be a Chairperson, a Vice-Chairperson, a Treasurer, and a Secretary. The offices of the Treasurer and Secretary may be combined, or may be separately held.

28. The Officers are to be elected by the Board of Directors, from among its members, at the Annual Meeting of the Society to hold office until the next Annual Meeting of the Society.

29. The Chairperson shall direct the activities of the Board of Directors in its supervision of the activities of the Society and the Chairperson shall perform such duties as may be assigned by the Board of Directors from time to time. A director appointed pursuant to Article 2 (b) or (c) shall not be entitled to act as Chairperson, nor act as a member of the Executive Committee.

30. The Vice-Chairperson shall, at the request of the Chairperson or the Board of Directors and subject to its discretion, perform the duties of the Chairperson during his or her absence, illness or incapacity or during such period as the Chairperson or the Board may request.

31. The Secretary of the Society shall keep a book containing minutes of all meetings and shall perform such other duties as may be assigned by the Board of Directors.

32. The Treasurer of the Society shall keep a book showing receipts and expenditures of the Society and the Treasurer shall keep and manage the funds and accounts of the Society and shall render a detailed account, at all times requested, of all receipts and expenditures of the Society and perform such other duties as may be assigned by the Board of Directors from time to time.

33. The Board may appoint a recording secretary, not a member of the Board, who shall cause minutes to be recorded, prepared and entered into books or records designed for that purpose and who shall perform such other tasks as may be assigned from time to time by the Board of Directors.

34. All officers shall be subject to removal as officers by Special Resolution of the Board at any time, with or without cause.

VII. PROTECTION OF DIRECTORS, OFFICERS AND OTHERS

35. Every director and officer of the Society in exercising his or her powers and discharging his or her duties shall act honestly and in good faith with a view to the best interests of the Society and exercise the care, diligence and skill that a reasonably prudent person would exercise in comparable circumstances. Subject to the foregoing, no director or officer shall be liable for the acts, receipts, neglects or defaults of any other director or officer or employee, or for joining in any receipt or other act for conformity, or for any loss, damage or expense happening to the Society through the insufficiency or deficiency of title to any security in or upon which any of the funds of the Society are invested, or for any loss or damage arising from the bankruptcy, insolvency or tortious acts of any person with whom any of the finds, securities or effects of the Society are deposited, or for any loss occasioned by any error of judgement or oversight on his or her part, or for any other loss, damage or misfortune whatever that happens in the execution of the duties of his or her office or in relation thereto; provided that nothing herein shall relieve any director or officer from the duty to act in accordance with the Act and any regulations thereunder or from liability for any breach thereof.

36. Subject to the limitations contained in the Act, the Society shall indemnify a director or officer, a former director or officer, or a person who acts or acted at the Society's request as a director or officer of a body corporate of which the Society is or was a shareholder or creditor, and his or her heirs and legal representatives, against all costs, charges, and

expenses including an amount paid to settle an action or satisfy a judgement, reasonably incurred by him or her in respect of any civil, criminal or administrative action or proceeding to which he or she is made a party by reason of being or having been a director or officer of the Society or that body corporate, if:

a) he or she acted honestly and in good faith with a view to the best interests of the Society; and

b) in the case of a criminal or administrative action or proceeding that is enforced by a monetary penalty, he or she had reasonable grounds for believing that his or her conduct was lawful.

37. The Society may purchase and maintain insurance for the benefit of any person referred to in paragraph 35 against such liabilities and in such amounts as the Board from time to time determines.

IX. EXECUTION OF INSTRUMENTS

38. Contracts requiring signature of the Society may be signed by:
   a) any two of the Chairperson of the Board, the Vice Chairperson, the Secretary or the Treasurer;

and all contracts so signed shall be binding upon the Society without any further authorization or formality. The Board of Directors shall have power from time to time by resolution to appoint any officer or officers, or any person or persons, on behalf of the Society either to sign contracts generally or to sign specific contracts.

39. The corporate seal of the Society may be affixed to contracts, documents and instruments in writing signed as aforesaid or by any officer or officers, person or persons, appointed as aforesaid by resolution of the Board of Directors but any such contract is not invalid merely because the corporate seal is not affixed thereto.

40. The term "contracts" as used in this by-law shall include deeds, mortgages, charges, conveyances, transfers and assignments of property real or personal, immovable or moveable, agreements, releases, receipts, and discharges for the payment of money or other obligations, conveyances, transfers and the assignment of stocks, bonds, debentures, or other securities and all documents and instruments in writing.

X. BOOKS OF ACCOUNTS AND AUDIT OF ACCOUNTS

41. The Directors shall cause proper books of account to be kept at the office of the Society or with the Treasurer. All business and accounting matters, together with a proper-record of all receipts and expenditures shall be maintained together with a record of all assets and liabilities of the Society. The books and records of the Society may be inspected by any

member at any reasonable time within two days prior to the annual general meeting at the registered office of the Society.

42. The Society shall, at each annual meeting, appoint an auditor or auditors to hold office until the next annual meeting, who shall be the same auditor as appointed by CREDA under its by-laws. The first auditors of the Society may be appointed by the Board of Directors at any time before the first annual meeting and the auditors shall hold office until the new auditors are appointed for the next annual meeting.

43. None of the following persons shall be eligible for appointment as auditor of the Society:

a) Members and Officers of the Society; or

b) Partners, family members or employees of an Officer or Member of the Society.

44. The remuneration of the auditors shall be fixed by the Directors.

45. The duties of the Auditor shall be to, at least once a year, audit the accounts and books of the Society and examine the accuracy and correctness thereof.

46. The auditors shall have the right of access, at all times, to the books and accounts and accounting procedures of the Society and shall be entitled to require from the directors and officers and employees of the Society any information and explanations as they deem necessary for the performance of their duties as auditors. The auditors may attend any general meeting of the Society and to make any statement or explanation regarding the accounting and books as they deem fit.

47. The auditors shall make a report to the Annual Meeting on the results of the audit and the report shall be a written report which shall state:

a) whether or not they have obtained all the information and explanations they have required; and

b) whether, in their opinion, the balance sheet referred to in the report is properly drawn up so as to exhibit a true and correct view of the state of the Society's affairs. The auditor's report must be a written report and must be attached to the balance sheet and shall be read before the Society's annual meeting and shall be open to inspection by any member.

48. If any accounts of the Society fail to disclose the amount of any loan made during the period to which the accounts relate, then it shall be the duty of the auditors to include in their report a statement giving particulars of all such payments and transactions.

49. Every account of the Directors, when audited and approved by an annual meeting, shall be

conclusive unless an error is discovered within three months after such approval. Whenever any such error is discovered within that period the account shall forthwith be corrected and thenceforth be conclusive.

50. If only one auditor is appointed then all the provisions contained herein shall relate to that auditor only.

XI. MISCELLANEOUS

51. The Society shall file with the Registrar with its Annual Statement a list of its directors with their addresses, occupations, and dates of appointment of election, and within fourteen days of a change of directors, notify the Registrar of the change.

52. The Society shall file with the Registrar a copy in duplicate of every special resolution within fourteen days after the resolution is passed.

53. The borrowing powers of the Society shall be exercised by special resolution of the members,

XII. REPEAL AND AMENDMENT OF BY-LAWS

54. On thirty (30) days written notice to its members, the Society has power to repeal or amend any of these By-laws by a special resolution passed in the manner prescribed by these By-laws.

\\Swordfish\cumberland\USERS\kdouglas\JFIA Board\By-Laws\JFIA Bylaws - final .wpd

NOVA SCOTIA

Tourism, Culture and Heritage
Office of the Minister

World Trade and Convention Centre, 1800 Argyle Street, PO Box 456, Halifax, Nova Scotia, Canada B3J 2R5
Telephone 902 424-4889 Fax 902 424-4872 • www.gov.ns.ca

NOV 28 2007

Ms. Rhonda Kelly
Executive Director
Cumberland Regional Economic Development Association
35 Church Street
PO Box 546
Amherst, NS B4H 4A1

Dear Ms. Kelly:

In response to your request that the Department of Tourism, Culture and Heritage provide operational funding to the Joggins Fossil Centre, the Department is pleased to provide the Cumberland Regional Economic Development Association operating capital for the Centre.

Subject to budget appropriation for the 2008-2009 fiscal year, the operating capital will support the fiscal period of April 1, 2007 through March 31, 2008 and will be a maximum of $250,000 to be paid in two installments. The payment schedule will be as follows:

- On or before April 15, 2008 - $125,000; and
- Within one (1) week of the provincial budget being passed by the Nova Scotia Legislature - the balance of $125,000.

The operating capital shall be used for the operating costs of the Joggins Fossil Centre, including labour, materials, promotion and operating expenses.

Should you have any questions regarding the funding, please contact Bill Greenlaw, Executive Director, Heritage Division, at (902) 424-4986 or greenlbe@gov.ns.ca. We look forward to continuing our successful relationship well into the future.

Sincerely,

Bill Dooks
Minister

cc: Kelliann Dean, Deputy Minister
Bill Greenlaw, Executive Director, Heritage

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to clarify the role anticipated for the Joggins Fossil Institute in the implementation of on-site collection of fossils from within the nominated property, including the relationship with the implementation of the *Special Places Protection Act*, including the Heritage Research Permits."

STATE PARTY RESPONSE:

The *Special Places Protection Act* as described on pages 85 – 86 (and included in full as Appendix G:1) of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007) provides for the regulation of fossil collecting for the province of Nova Scotia.

Current Status

In keeping with the strict controls of this provincial legislation and to ensure that the nominated property is managed, protected and presented for future generations, the Joggins Fossil Institute's policy regarding fossil collecting is, at this time, conservative in that a Heritage Research Permit is required for all excavation of and collecting of fossils (see attached application form for a Heritage Research Permit) at the nominated property. Uncontrolled collecting of fossils by persons not in possession of a Heritage Research Permit (HRP) is prohibited.

The Joggins Fossil Institute has collaborated with the Nova Scotia Department of Tourism, Culture and Heritage to establish an agreement regarding the management of the protected site and includes definitions of roles related to fossil collecting (DTCH_CREDA_AGREE.pdf). Specifically, the Joggins Fossil Institute will act on site to assist the Nova Scotia Department of Tourism, Culture and Heritage in assessing and processing Heritage Research Permit applications. The final authority to issue collecting permits remains at present with the provincial government.

In addition to collaboration related to assessing permits, the Joggins Fossil Institute has prepared a management plan for the nominated property (Appendix C of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007). Management priorities related to fossil collecting include: providing education and training related to identifying and collecting fossils; providing information to the public regarding the significant natural heritage at the Joggins Fossil Cliffs and the legislation that is in place to ensure that the property is protected for future generations; continued community engagement through development of the "Friends of the Fossil Cliffs" volunteer program; and to conduct and support scientific research – through the JFI Science Advisory Committee, the

JFI Science and Education Coordinator, and through collaboration with the international research community. Furthermore, the interpretive staff working at the Joggins Fossil Centre and on the nominated property provide support for visitors in terms of providing first-hand information about the natural heritage at Joggins and also serve to monitor fossil collecting on the property.

Anticipated Enhanced Role for the Joggins Fossil Institute

In recognition of the conservative nature of the current legislation, The Nova Scotia Department of Tourism, Culture and Heritage – Heritage Division is working with the Joggins Fossil Institute to review guidelines for palaeontology research permits that will support avocational and educational collecting at the nominated property. These guidelines will be finalized by the spring of 2008 (as per attached letter DTCH_LETTER.pdf). It is anticipated that the Institute will have a key role to play in supporting the management of avocational fossil collecting at the nominated property as both erosion rates and visitor impacts must be monitored to provide adequate information regarding the future potential to engage visitors in an active collecting program whose primary focus is on education and awareness building. The Joggins Fossil Institute will also support the process of disposal / distribution of fossils that may be deemed surplus to the provincial fossil collection and could potentially be used for educational purposes.

Attachments

1. HRP_Palaeo.pdf	Heritage research permit application form
2. DTCH_LETTER.pdf	Letter regarding timelines for future work related to fossil collecting processes and disposal of crown assets
3. DTCH_CREDA_AGREE.pdf	Agreement between CREDA and the Department of Tourism, Culture and Heritage.

NOVA SCOTIA

Department of Tourism, Culture & Heritage

Heritage Division
Special Places Protection Act, 1980

Application for
Heritage Research Permit
(Palaeontology)

(Original becomes Permit when approved by the Executive Director of the Heritage Division)

Permit No. . . . .

The undersigned . . . .

of . . . .

representing (institution) . . . .

hereby applies for a permit under section 8 of the Special Places Protection Act to carry out palaeontological investigations

from . . . . to . . . .

at . . . .

general location . . . .

specific location(s) (cite UTM designations where appropriate . . . .

. . . .

and as described separately in accordance with the attached Description of Project.

I certify that I am familiar with the provisions of the Special Places Protection Act of Nova Scotia, and that I will abide by the terms and conditions listed below.

Date . . . . Signature of applicant . . . .

Approved: Date . . . . Executive Director . . . .

Description of Project

The proposed project is to be described under the following headings:

(a) Scope and objectives of investigations
(b) Significance of proposed project
(c) Proposed research plan and methodology
(d) Relation of proposed project to previous work or other work in progress.
(e) Anticipated crew size, names of crew and relevant experience
(f) Schedule of field work and analysis
(g) Projected conservation requirements and proposed conservation measures
(h) Financial and other support applied for, or already granted, in support of proposed project.
(i) Curriculum vitae of applicant
(j) Previous permits awarded to applicant

Terms and Conditions

1. Permits shall be valid only in the calendar year in which issued. Applications for extensions should be submitted in the same manner as the original permit.
2. Before the end of the calendar year each permit holder shall provide the Executive Director with a written preliminary report on the results of his investigations
3. Upon completion of analysis the permit holder shall provide the Executive Director with a written final report on their investigations, in such format and detail as the Executive Director requires.
4. All materials recovered become the property of the Province of Nova Scotia and must be delivered upon request to the Museum or to any other public institution, the Executive Director may designate. Such materials must be cleaned, numbered and recorded on standard field record forms. Materials required for research purposes must be recorded on an official loan form signed by an official representative of the Nova Scotia Museum.
5. Upon completion of his investigations, each permit holder shall restore the sites he has excavated as nearly as possible to their former condition, to the satisfaction of the owner.
6. Permits shall be issued on the understanding that the investigations are to be conducted for the sole purpose of recovering information and materials for scientific or historical study, by the applicant or qualified persons under his direct supervision, and conforming to the best scientific standards within the applicant's ability.
7. Permits shall normally be issued only to persons affiliated with responsible public institutions, on the understanding that the information and materials collected shall be properly recorded, preserved, and made available for scientific study and public observation. Applicants not professionally affiliated with a recognized public institution must provide the names of two referees who can evaluate and comment on the applicant's ability to undertake the proposed project.
8. A permit shall be valid only if the applicant can demonstrate that the owner of the land on which palaeontological work is to be carried out has given permission for such work to commence (this shall include permission from the Department of Natural Resources where investigations are proposed on Crown lands). A permit ceases to be valid if the permit holder has reason to believe that the consent of the owner has since been withdrawn.
9. A person designated by the Executive Director may at any time inspect a permit, or any investigation being conducted under a permit, or any materials recovered under the authority of a permit.
10. The Executive Director may cancel a permit at any time and the permit shall, upon cancellation, cease to be in force.
11. Cultural material recovered under the Terms and Conditions of this permit may not be exported from Canada without possession of a Cultural Property Export Permit as required by the Cultural Property Import and Export Act administered by the Secretary of State for Canada.

NOVA SCOTIA

Tourism, Culture & Heritage
Heritage Division
Executive Director's Office

1747 Summer Street
Halifax, Nova Scotia
B3H 3A6

Tel: (902) 424-7344
Fax: (902) 424-0560

Our File Number:

November 26, 2007

Ms. Rhonda Kelly
Executive Director
Cumberland Regional Economic Development Association
35 Church Street, PO Box 546, Amherst
Nova Scotia B4H 4A1

Dear Ms. Kelly:

Thank you for meeting with us on November 14, 2007 to discuss outstanding issues related to the Joggins UNESCO nomination. We fully understand the need to clarify our time lines with respect to fossil collection and management.

Since our meeting, staff have met to review proposed guidelines for palaeontology research permits that will better serve those involved in avocational and educational collecting. We are committed to finalizing these guidelines by the spring of 2008 in time for the official opening of the Joggins Fossil Centre.

In addition, within one year of the first meeting of the Joggins Fossil Institute Scientific Advisory Committee we commit to establish a process to dispose of fossils deemed surplus to the provincial collection to the Joggins Fossil Institute to be used for educational purposes.

We look forward to these developments both to support the operations of the Joggins Fossil Centre and to enhance the protection and promotion of our fossil heritage.

Sincerely,

Bill Greenlaw

Bill Greenlaw
Executive Director

THIS AGREEMENT made the 28th day of November, 2007.

BETWEEN:

HER MAJESTY THE QUEEN in right of the Province of Nova Scotia, as represented by the **MINISTER OF TOURISM, CULTURE AND HERITAGE** (hereinafter "Minister")

OF THE FIRST PART

- and -

THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION, a Society incorporated pursuant to the Societies Act, with head office in Amherst, Nova Scotia (hereinafter "CREDA")

OF THE SECOND PART

WHEREAS the Joggins Fossil Cliffs is a site of world wide significance due to its fossil record, particularly in relation to the Carboniferous period;

AND WHEREAS the Minister, with the approval of the Governor in Council, has designated the Joggins Fossil Cliffs, shown on Schedule "A" attached hereto, as a protected site (the "Protected Site"), pursuant to the *Special Places Protection Act* ("*SPPA*");

AND WHEREAS CREDA, together with other parties, has nominated the Protected Site for designation as a UNESCO World Heritage Site;

AND WHEREAS the local community and regional governmental and developmental agencies believe the development of the Protected Site as a scientific and heritage tourism destination will bring benefits to the community, the region and the Province as a whole;

AND WHEREAS it is recognized that any development must be balanced with proper management and protection of the Protected Site;

AND WHEREAS CREDA together with other parties have formulated and are implementing a project which will simultaneously develop the Protected Site as an internationally recognized destination and pursue the designation as a UNESCO World Heritage Site;

AND WHEREAS the Minister supports the efforts of CREDA to pursue the designation of the Protected Site as a UNESCO World Heritage Site;

In consideration of the mutual promises contained in this Agreement, the Parties covenant and agree as follows:

1.0 PROTECTED SITE AND JOGGINS FOSSIL COLLECTION

1.1 The Parties agree that CREDA may undertake, on the Protected Site, activities related to scientific research, tourism and education purposes with the Minister's written approval. CREDA acknowledges that the Minister's approval does not authorize CREDA to undertake activities on any private lands forming part of the Protected Site without the consent of the landowners.

1.2 CREDA agrees to submit the final Site Management Plan, including provisions that address the Protected Site, to the Minister for final approval by April 2008.

1.3 CREDA shall at all times administer, manage and control the Protected Site in accordance with the Site Management Plan approved by the Minister, and shall not implement any changes to the Site Management Plan related to the Protected Site without the Minister's written approval.

1.4 CREDA agrees to establish and maintain a Scientific Advisory Committee for the Protected Site that will include permanent representation by the Curator of Geology and by the Manager of the Special Places Program of the Department of Tourism, Culture and Heritage.

1.5 The Parties acknowledge that the authority to protect all fossil resources in the Province rests with the Minister.

1.6 CREDA agrees that all fossil collecting will be undertaken in accordance with the provisions of the *SPPA* and the heritage research permits process set out by the Minister.

1.7 CREDA agrees that it will oversee the employment of a qualified palaeontologist. The Minister agrees to share heritage research permit applications for the Protected Site with the CREDA palaeontologist for his or her review and comments.

1.8 CREDA acknowledges that the final authority to issue heritage research permits rests with the Minister.

1.9 The Minister agrees that the Joggins fossil collection should be maintained intact for display and interpretation at the Joggins Fossil Centre wherever reasonably possible and for as long as the Joggins Fossil Centre is able to demonstrate operational sustainability with appropriate space to house and care for the fossil collection.

1.10 CREDA acknowledges that all fossils collected under the provisions of the *SPPA*, and/or since the *SPPA* was introduced, belong to the Province as part of the Provincial Collection.

1.11 CREDA agrees that all fossils from the Provincial Collection loaned to CREDA by the Province will be subject to the terms and conditions of Nova Scotia Museum loan agreements as determined by the Minister. CREDA agrees that it will execute a Nova Scotia Museum loan agreement prior to receiving any fossils to be loaned to CREDA by the Province.

1.12 CREDA agrees that all fossils from the Provincial Collection shall be managed as provided for in the provisions of the Collection Management Policy and Procedures of the Nova Scotia Museum.

1.13 CREDA agrees to comply in all respects with the *Canadian Museum Association Code of Ethics Guidelines (1999)* to ensure the integrity of the fossil collection.

1.14 The Minister may, at any time, upon giving notice to CREDA, impose additional conditions or restrictions in respect of the fossil collection or on any approvals referred to in this Agreement.

2.0 CONFIDENTIALITY

2.1 CREDA and the CREDA palaeontologist shall keep private, treat as confidential, and not make public or divulge during as well as after the term of this Agreement, any heritage research permit applications, as well as any information or material to which CREDA and the CREDA palaeontologist become privy as a result of receiving and reviewing heritage research permit applications for the Protected Site (collectively referred to as "Confidential Information").

2.2 CREDA agrees that it will safeguard the Confidential Information and will not further disclose it to any other party.

2.3 CREDA agrees that it will use the Confidential Information only for the purpose of reviewing heritage research permit applications and providing comments on the applications to the Minister, and not for any other purpose.

2.4 CREDA acknowledges that the Confidential Information may include personal information protected under the *Personal Information International Disclosure Protection Act* ("*PIIDPA*"). CREDA undertakes to comply with and be bound by *PIIDPA*.

2.5 CREDA agrees that following the review of a heritage research permit application, all copies of the Confidential Information will be promptly returned to the Minister, or securely destroyed by CREDA.

2.6 CREDA shall make the Confidential Information accessible only to the CREDA palaeontologist and not to any other employees, and shall ensure that the CREDA palaeontologist enters into a confidentiality agreement with the Minister prior to receiving any heritage research permit applications for the Protected Site.

2.7 CREDA shall notify the Minister if the CREDA palaeontologist is changed, and CREDA shall ensure that any new CREDA palaeontologist enters into a confidentiality agreement with the Minister prior to receiving any heritage research permit applications.

2.8 CREDA will immediately notify the Minister if CREDA knows or suspects that the Confidential Information may have been compromised or knows or suspects that any requirement of this Article 2.0 may have been breached.

2.9 The sharing of heritage research permit applications with the CREDA palaeontologist pursuant to Article 1.7 may be terminated by the Minister if, in the sole opinion of the Minister, CREDA or the CREDA palaeontologist has breached or failed to comply with any of the terms of this Agreement or the confidentiality agreement.

3.0 TRAINING AND OTHER OPPORTUNITIES

3.1 The Minister may provide training to CREDA with respect to the acquisition, documentation, preservation, use and disposition of the fossil collection.

4.0 CONTRACT OF SERVICES

4.1 The Parties agree that this Agreement is a contract for the performance of a service and that CREDA is an independent organization and neither it nor its employees, nor any third parties providing services to CREDA, whether or not for payment, shall be deemed to be an employee, servant or agent of the Minister.

4.2 The Parties agree that CREDA will make its own agreements and payments with respect to Worker's Compensation and other employment related issues

4.3 The Parties agree that CREDA shall comply with all laws and standards including all applicable labour and occupational health and safety legislation.

5.0 TERM AND TERMINATION

5.1 This Agreement shall be effective as of the date of signing and shall continue in effect for a period of ten (10) years unless terminated in accordance with the provisions of this Agreement.

5.2. The Parties may renew this Agreement only in writing and on such terms and conditions as the Parties find mutually acceptable.

5.3 This Agreement may be terminated by the Minister if, in the opinion of the Minister, CREDA has breached or defaulted or failed to comply with any of the terms and conditions of the Agreement and CREDA has failed to remedy the same after being given fifteen (15) days notice to remedy the breach, default or failure.

5.4 Either party may terminate this Agreement by providing one hundred and twenty (120) days written notice to the other Party of the intention to terminate.

5.5 Notwithstanding the preceding paragraphs of this section, the Minister may terminate this Agreement without notice to CREDA, if CREDA files a petition in bankruptcy, is adjudged bankrupt, becomes insolvent or takes the benefit or protection of any statute for bankrupt or insolvent debtors.

5.6 The Minister shall not be liable to CREDA for any damage, cost or expense, nor shall CREDA be entitled to any compensation from the Minister, in the event this Agreement is terminated in accordance with the terms of this Article 5.0.

6.0 LIABILITY

6.1 CREDA agrees that neither the Minister or the Province or any officer or employee of the Province shall be liable for any injury including death to any person, or for the loss of, or damage to, any property, that is caused in any way by its performance or non-performance of its obligations under this Agreement or that is related in any way to the operation of the Joggins Fossil Cliffs Centre unless the injury, loss or damage is caused by the negligence of an officer or employee of the Province while working within the scope of his or her employment.

6.2 CREDA agrees that it shall at all times indemnify and save harmless the Province, its Ministers, officers, employees and agents from and against all claims, demands, losses, costs, damages, actions, suits or other proceedings of any kind based upon injury to or death of a person or damage to or loss of property arising from any wilful or negligent act, omission or delay on the part of CREDA, its servants or agents.

6.3 Articles 6.1 and 6.2 shall survive the termination of this Agreement.

7.0 INSURANCE

7.1 CREDA shall at its own expense, shall purchase and maintain in full force during this Agreement insurances to protect itself, the Province of Nova Scotia ("Nova Scotia"), their successors and assigns and their respective directors, officers, employees, agents and servants involved in the operation of the Joggins Fossil Cliffs Centre and in the performance of this Agreement for the purposes and risks outlined herein and as set out in Schedule "B" attached hereto.

7.2 Such insurance shall provide coverage for all risks and shall protect Nova Scotia, CREDA, their successors and assigns, and their respective officers, directors and employees from all claims arising out of liability for property damage, bodily injury including death and personal injury.

7.3 All policies shall be issued by financially sound insurers licensed to carry on business in Canada and shall be subject to approval by Nova Scotia. Insurers shall not cancel or materially change the policy without 90 days prior written notice to Nova Scotia.

7.4 Certified copies of all insurance policies or related documentation, in form and content acceptable to Nova Scotia, shall be delivered to Nova Scotia prior to the opening of the Joggins Fossil Centre. Certificates of insurance evidencing renewal or replacement insurances, in form and content acceptable to Nova Scotia, shall be provided to Nova Scotia not later than fifteen (15) days prior to the expiration of existing policies. Upon request from Nova Scotia or its authorized representative, certified copies of any policy or policies shall be provided promptly.

7.5 All insurance policies shall include a provision whereby Nova Scotia (or its nominee) may, but will not be obligated to, assume direction and control of the insurance policy in the event the CREDA or any of its successors or assigns defaults in its obligations in connection with the project.

8.0 NOTICE

8.1 Notice to the Minister shall be directed to:

Nova Scotia Department of Tourism, Culture and Heritage
World Trade and Convention Centre, 6th Floor
P.O. Box 456, 1800 Arglye Street
Halifax, Nova Scotia, B3J 2 R5
Telephone - (902) 424 - 4889
Fax - (902) 424 - 4872

8.2 Notice to CREDA shall be directed to:

Cumberland Regional Economic Development Association
35 Church Street
P.O. Box 546
Amherst, Nova Scotia, B4H 4A1

ATTENTION: Executive Director
Telephone - (902) 667 - 3638
Fax - (902) 667 - 2270

8.3 Either Party may designate a new address for notices under this Agreement, which shall be provided in writing to the other Party.

8.4 Every notice given hereunder shall be given either in writing personally delivered or posted by prepaid mail or by facsimile transmission. If posted, notices shall be deemed to have been received by the intended recipient thereof, and shall be effective upon the 5th business day of the government next following the date of posting.

9.0 INTERPRETATION

9.1 This Agreement shall be construed and interpreted in accordance with the laws of the Province of Nova Scotia.

9.2 This Agreement may not be assigned in whole or in part without the prior written consent of the Minister, which consent may be withheld for any reason.

9.3 Any waiver by the Parties hereto of any breach of this Agreement by the other, whether such waiver be direct or implied, shall not be construed as a continuing waiver of or consent to any subsequent breach of this Agreement by the other.

9.4 This Agreement, including the preamble and the schedules, shall constitute the whole agreement between the Parties and no representation or statement not expressly contained herein shall be binding upon either Party.

9.5 If any term or provision of this Agreement shall be found to be illegal or unenforceable, this Agreement shall remain in full force and effect and such terms or provision shall be deemed removed from the Agreement.

9.6 This Agreement may only be altered by means of a written memorandum signed by all Parties, and the said memorandum shall be supplemental to and shall be deemed to form part of this Agreement.

9.7 This Agreement shall not be changed, modified or discharged orally.

IN WITNESS WHEREOF the Parties have hereunto set their hands and affixed their seals on the day and year first above written.

SIGNED, SEALED AND DELIVERED in the presence of	)	**HER MAJESTY THE QUEEN in right of the Province of Nova Scotia**
Witness	)	Minister of Tourism, Culture and Heritage
	)	**THE CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION**
Witness	)	PER: __________ c/s
	)	PER: __________ c/s

SCHEDULE "B"

INSURANCE

1. General Liability Insurance for liabilities arising out of property damage, personal injury and bodily injury including death resulting from any activity connected with this Agreement and with the existence, management, maintenance and operation of the Joggins Fossil Centre. All such policies shall name as Additional Insureds Nova Scotia, their successors and assigns, and their respective directors, officers and employees. This insurance will include the following provisions:

- policy limit of liability of $2 million per occurrence (can be structured as primary plus supplementary layers or primary plus Umbrella and/or Excess)
- Sudden & Accidental Pollution coverage for all insured perils
- nil deductible for Bodily Injury
- maximum deductible all other occurrences of $10,000 per occurrence, except Sudden & Accidental Pollution ($100,000 each claim)
- contingent employers liability
- personal injury liability
- broad form occurrence property damage
- fire fighting expense liability
- non-owned automobile liability
- incidental aircraft and water craft coverage (if applicable)
- cross liability and separation of interest with respect to each Insured
- Nova Scotia, CREDA and their respective directors, officers and employees included as Additional Insureds
- breach of any of the terms or conditions of the policy, or any negligence or wilful act or omission or false representation by an Insured or any other person, shall not invalidate the insurance with respect to Nova Scotia
- primary insurance without right of contribution of any other insurance carried by Nova Scotia

- 90 days prior written notice of material change or cancellation from Insurer to Nova Scotia

2. Automobile Liability Insurance insuring all licensed vehicles owned, leased or operated by CREDA. CREDA must ensure that evidence of comparable coverage is provided by all contractors, subcontractors and workmen or tradesmen working at the site. This insurance will include the following provisions:

   - policy combined limit of liability of $2.0 million per occurrence
   - overall limit of liability of $2 million per occurrence (can be structured as primary plus supplementary layers or primary plus Umbrella and/ or Excess)
   - maximum deductible of $10,000 per occurrence

3. Umbrella and Excess Liability Insurance with respect to, and following the form of, the Commercial General Liability or Comprehensive General Liability and Automobile Liability insurances. This insurance will include the following provisions:

   - overall limit of liability of $2 million per occurrence (can be structured as Primary plus supplementary layers and Umbrella and/or Excess, or primary plus Umbrella and/or Excess)
   - "drop-down" provision for impaired or exhausted aggregates in underlying insurances (automatic reinstatement or aggregate limits in underlying insurance acceptable alternative)

4. Directors & Officers Liability Insurance covering the directors and officers of the corporation. This insurance will include the following provisions:

   - policy limit of liability of $1 million each claim
   - Corporate Reimbursement maximum deductible of $100,000 per claim, nil for directors and officers

CONFIDENTIALITY AGREEMENT

MADE BY Cumberland Regional Economic Development Association. (CREDA)
(Print Name)

in favour of

HER MAJESTY THE QUEEN in right of the Province of Nova Scotia, as represented by the **MINISTER OF TOURISM, CULTURE AND HERITAGE** (hereinafter "Minister")

WHEREAS by agreement dated November 28/07, the Minister and the Cumberland Regional Economic Development Association ("CREDA") entered into an agreement respecting the Joggins Fossil Cliffs Protected Site (the "Joggins Agreement");

AND WHEREAS under the Joggins Agreement, the Minister agreed to share heritage research permit applications for the Joggins Fossil Cliffs Protected Site with a palaeontologist employed by CREDA for his or her review and comments;

AND WHEREAS under the Joggins Agreement, the Minister requires CREDA to obtain from the palaeontologist who will receive and review heritage research permit applications, an agreement made in favour of the Minister respecting confidentiality;

THEREFORE I, Cumberland Regional Economic Development Association hereby agree as follows:
(Print Name)

1. I will keep private, treat as confidential, and not make public or divulge during as well as after the term of this Agreement, any heritage research permit applications, as well as any information or material to which I become privy as a result of receiving and reviewing heritage research permit applications (collectively referred to as "Confidential Information");

2. I will safeguard the Confidential Information and will not further disclose it to any other party;

3. I will use the Confidential Information only for the purpose of reviewing heritage research permit applications and providing comments on the applications to the Minister, and not for any other purpose;

4. I acknowledge that the Confidential Information may include personal information protected under the *Personal Information International Disclosure Protection Act* ("*PIIDPA*"). I undertake to comply with and be bound by *PIIDPA*;

5. Following the review of a heritage research permit application, all copies of the Confidential Information will be promptly returned to the Minister, or securely

destroyed by CREDA;

6. I will not make the Confidential Information accessible to any other employees of CREDA;

7. I will immediately notify the Minister if I know or suspect that the Confidential Information may have been compromised or know or suspect that any requirement of this agreement may have been breached; and

8. The Minister will have the right to terminate the sharing of heritage research permit applications with me if, in the sole opinion of the Minister, CREDA or I breach or fail to comply with any of the terms of this agreement or the Joggins Agreement.

Agreed to this 28th day of November, 2007.

Kathy Douglas	)	Rolly
Witness Signature	)	Signature
Kathy Douglas	)	Rhonda Kelly
Witness Printed Name	)	Printed Name

Schedule A

JOGGINS FOSSIL CLIFFS PROTECTED SITE

ALL that certain tract of land and land covered by water as shown on a Plan of JOGGINS FOSSIL CLIFFS PROTECTED SITE at Joggins in the County of Cumberland, Province of Nova Scotia, on file at Department of Natural Resources Office at Halifax under Field Plot P- 044/04 and being more particularly described as follows:

BEGINNING at the northeastern point at the top of the cliff or bank (in its natural state) on the eastward side of Chignecto Bay, on the west side of the mouth of Downing Cove;

THENCE southwesterly and following the various courses of the top of the cliff or bank (in its natural state) and extending across the mouth of all tributaries on the eastward side of Chignecto Bay, to the northwestern point of Ragged Reef Point;

THENCE due grid north seaward to a point being located at a perpendicular distance of 500 metres northerly from the top of the cliff or bank, on the eastward side of Chignecto Bay;

THENCE in a generally northeasterly direction remaining parallel to and 500 metres perpendicularly distant from the top of the cliff or bank on the eastward side of Chignecto Bay, to a point being located due grid north from the PLACE OF BEGINNING;

THENCE due grid south to the PLACE OF BEGINNING.

CONTAINING an approximate area of 689 hectares.

THE ABOVE DESCRIBED PARCEL having a seaward boundary lying 500 metres perpendicularly distant from the top of the cliff or bank and having a landward boundary that will follow parallel to the top of the cliff or bank, as its location varies over time.

Joggins Fossil Institute

Arrangements for Involvement of Private Land Owners

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to confirm the arrangements for involvement of private landowners (who own the cliff faces and beaches above the mean high-water mark within the nominated property) in the management of the property and their participation in fossil collection programmes."

STATE PARTY RESPONSE:

"The Fossil Cliffs are Joggins' gift to the World"

Bill Fairbanks
Attorney, Private Landowner, and Member of the "Fossil Cliffs Project – Steering Committee, Winter 1998
as cited from
The Joggins Fossil Cliffs World Heritage Site Designation Initiative
Community Consultation Process & Action Plan
Appendix F:3 Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007)

The Joggins Fossil Institute and its partners have recognized the importance of engaging private landowners in contributing to sustainable management and protection of the Joggins Fossil Cliffs. In the process of designating the Joggins Fossil Cliffs as a "protected site" under the *Special Places Protection Act* (Appendix G:1 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007)) the provincial Department of Tourism, Culture and Heritage and the Joggins Fossil Institute collaborated in advising all private landowners of the intention to designate the property and provided opportunities for consultation. Furthermore, while the community of Joggins developed a land use planning and zoning bylaws, the Joggins Fossil Institute and the Municipality of the County of Cumberland formed an advisory committee with participation by private landowners (Appendix G:4 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007)).

The tradition of involving the community and more specifically landowners with property adjacent to the nominated property is supported formally through the membership of the Joggins Fossil Institute Board of Directors membership, whereby a member of the board who resides in Cumberland County must also be a private landowner. In addition, the Joggins Fossil Institute's Science Advisory Committee membership includes an opportunity for local participation to ensure that communication with the community is direct and focuses on addressing community issues.

Historically, private landowners have been willing participants in the stewardship and promotion of the Joggins Fossil Cliffs. Examples of involvement have included:

- lease agreements for access to the property and to support visitor infrastructure (including parking areas and signage programs)
- permission to access property to conduct research and surveys, and
- participation as board members and on action teams.

In turn, the Joggins Fossil Institute and its partners have recognized the generous contributions and collaboration of landowners through formal acknowledgement ceremonies and provision of complimentary educational and promotional resources.

Although all fossils belong to the province of Nova Scotia, permission to access fossils (if on private property) must be attained from the landowner. In the case of Joggins, active excavation of the cliffs to collect fossils is not included as a management strategy. The constant erosion of the cliffs by natural forces regularly exposes fossils and releases them from the cliffs fall to the beach. Visitor management strategies deter people from venturing close to the cliffs – where risk of rock fall is high and where more scientifically significant fossils may be located. Moreover, there are only small sections of the beach that would be considered to be below the mean high-water mark and therefore privately owned.

The history of landowner involvement in the management of the Joggins Fossil Cliffs has been positive to date, the Joggins Fossil Institute will continue to actively implement specific programs that provide the opportunity for landowners to be engaged in the stewardship of the nominated property and in turn communicate the social, psychological and economic benefits of protecting the natural heritage at the Fossil Cliffs. Programming may include, a beach users forum, beach management issues seminars, public consultation at "low tide day", opportunities to participate in education and research programs, and free newsletter subscriptions. Dialogue and feedback between landowners and the Joggins Fossil Institute is maintained through landowner/resident membership on the Board of Directors.

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "… to confirm the intentions to mark the boundaries of the nominated property and to provide and maintain information and safety signage, including restrictions on fossil collection within the nominated property at the access points to the site, and offsite."

STATE PARTY RESPONSE:

Marking Boundaries of the Property

The property boundaries have been defined by topographic features visible in the landscape and are described in Section 1.E(i) on pages 13 to 15 and depicted graphically in Appendix I: Map 1 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007). The landward boundary of the property is defined by the top of the cliff or by the back of the beach. This boundary is in constant flux due to the continual natural erosion process and thus cannot be physically marked on the ground. Similarly, the seaward boundary is in the intertidal area and could not have marking assigned to it. The northern and southern boundaries (Downing Cove and Ragged Reef Point) are clearly visible topographic features. In collaboration with the Nova Scotia Department of Natural Resources, the Joggins Fossil Institute has positioned metal survey pins (benchmarks) and calculated geographic coordinates using global positioning system technology at the northern and southern extent (with permission of private landowners) of the nominated property (Figure 1).

Figure 1. Nova Scotia Department of Natural Resources survey team establishing geographic coordinates and locating a benchmark for southern property boundary at Ragged Reef Point.

The intention of the Joggins Fossil Institute is to maintain the existing survey pins at the northern and southern extents of the property and provide boundary description and signage at public access points to the property. The signage will provide a description of the property boundary as well as information on safety, the significance of the natural heritage and restrictions regarding land use activities.

Existing Signage and Access Points

Currently there is only one publicly advertised access point (Bell's Brook) to the nominated property. An additional access point exists at Lower Cove however this access is through private property and is not promoted to visitors. These two access points, Bells Brook and Lower Cove Beach, have signs indicating safety considerations and provide information about the property including restrictions on activities (Figures 2 a and 2b below).

Figure 2a and 2b. Lower Cove Beach and Bell's Brook signage.

Way finding signs point visitors to the property from the main highway access to the Bell's Brook access point – the way finding signage does not direct the public to access the property at Lower Cove however there is a secondary road that runs adjacent to the beach at Lower Cove that is primarily used by local residents.

The Bell's Brook access point is currently is under lease from a private landowner. This access has a wooden stairway, interpretive signage (see Figure 3 below), signage regarding restriction of activities and also safety signage as indicated in Figure 2.

Figure 3. Signage and access way at Bell's Brook.

Additional information regarding the significance of the property's natural heritage is also currently in place at the parking area (off site) that support the Bell's Brook access point (Figure 4).

Figure 4. Interpretive and safety sign at the Bell's Brook parking area.

Future Plans for Public Access and Signage

The Bell's Brook access point will no longer available to the public (stairs will be removed and the lease with the private land owner will be terminated under mutual agreement) when the new access point from the Joggins Fossil Centre (via the "dugway") is constructed and available for public use (Spring 2008). Therefore, the only publicly advertised pedestrian access point to the property will be through the newly constructed visitor centre and via the "dugway".

As indicated in Appendix E:4 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007), a key element in the development of a comprehensive approach to visiting the nominated property (to provide guided tours from Lower Cove south to the new visitor centre) is the necessity to get visitors from the new Visitor Centre to the beach and cliffs at Lower Cove approximately 4 km away. This is problematic in that the best access point at the Lower Cove Bridge has virtually no land area to provide for parking or other amenities. Further, the access is on the west side of the road requiring visitors approaching from Joggins to turn around on the highway or in a private driveway and park on the narrow shoulder of the road to face southward. Additionally, little space is available on the preferred south side of the bridge forcing parking to the north side and pedestrians to cross the narrow bridge with no dedicated pedestrian walkway. Increasing numbers of visitors brought to the site by the new Centre would make the situation intolerably congested and inherently unsafe. An alternative site for parking and turnaround needed to be found and it is close by at the former grindstone quarry at the north end of Lower Cove Beach (Figure 5). This access point is also on publicly owned property.

The proposed access point (Figure 5) will have parking facilities, interpretive and safety signage and will also have a gate to restrict vehicle traffic. The 'Grindstone Beach' site is ideally situated to provide a number of useful amenities. It provides a safe location to safely turn around a bus travelling from the Centre site to the cliffs. It has sufficient land area to provide for parking of private vehicles off the highway. It is a convenient beach access point with a low scarp at the water's edge that makes a ramped barrier-free access (for people with limited physical abilities) to the beach in this area possible.

Figure 5. Planned access at the grindstone beach – Lower Cove

New Signage Program

All public access points will have a new signage program (Figures 6 and 7). Signage information will include safe beach access/tide times, indications of restricted activities, and safety warnings (see attached file with detailed text and graphics: standard sign public access.pdf). If the nominated property is inscribed on the World Heritage list, information will also be included regarding UNESCO and world heritage (see images below). Exterior signage will be presented in both English and French. The Joggins Fossil Institute will consult with private landowners to propose establishing basic signage (as per Figure 2a) that indicates that the property is protected.

Additional offsite signage (there will be no signage on the nominated property) has been described in Appendix E:5 of the Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List (January, 2007). The Joggins Fossil Institute operations coordinator will be responsible for maintaining exterior signage for the property. The Joggins Fossil Institute custodian will continually monitor public access points to ensure that signage is maintained.

Figure 6. New signage program for public access areas (attached file for details).

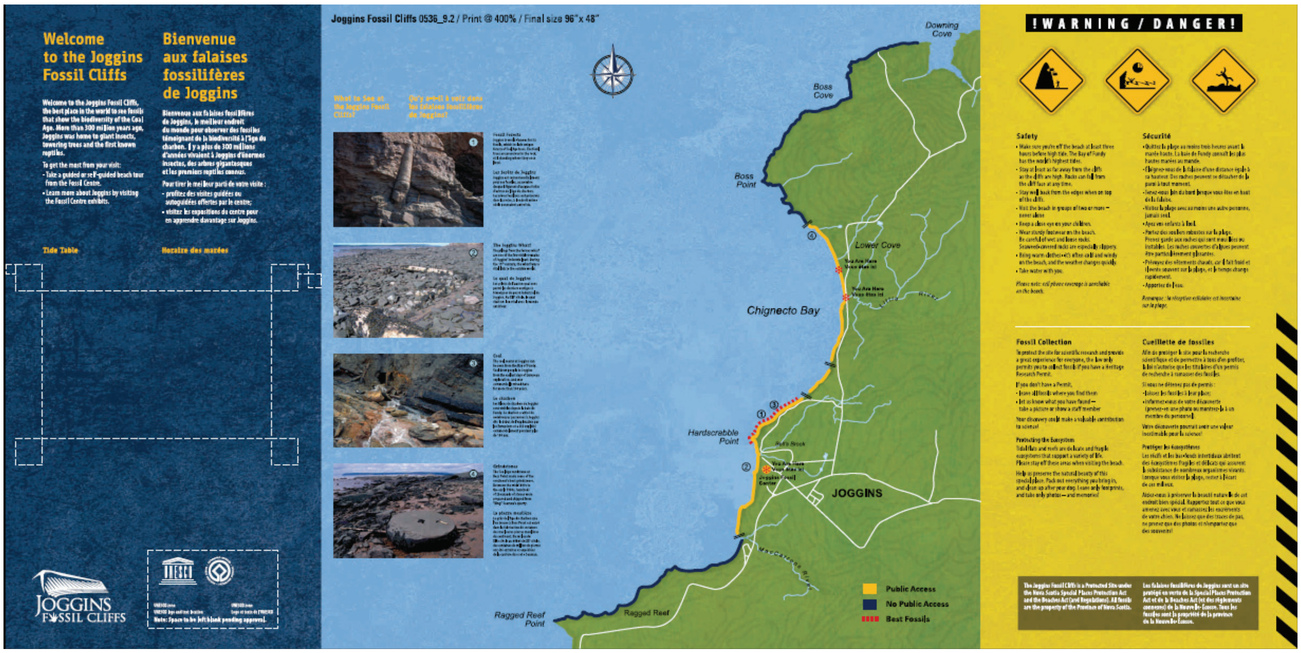
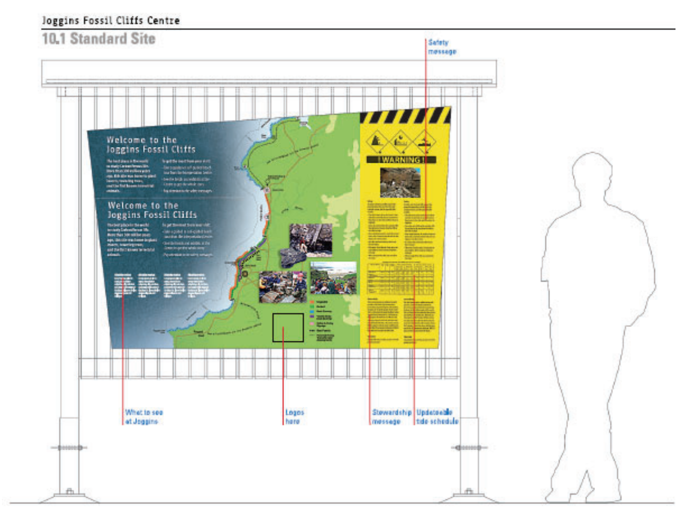


Figure 7. Schematic design for standard signs at all public access areas.



Attachments

1. Standard Sign Public Access.pdf — Detailed image of text and graphics for standard signs at all public access points.

Welcome to the Joggins Fossil Cliffs

Welcome to the Joggins Fossil Cliffs, the best place in the world to see fossils that show the biodiversity of the Coal Age. More than 300 million years ago, Joggins was home to giant insects, towering trees and the first known reptiles.

To get the most from your visit:

- Take a guided or self-guided beach tour from the Fossil Centre.
- Learn more about Joggins by visiting the Fossil Centre exhibits.

Bienvenue aux falaises fossilifères de Joggins

Bienvenue aux falaises fossilifères de Joggins, le meilleur endroit du monde pour observer des fossiles témoignant de la biodiversité à l'âge du charbon. Il y a plus de 300 millions d'années vivaient à Joggins d'énormes insectes, des arbres gigantesques et les premiers reptiles connus.

Pour tirer le meilleur parti de votre visite :

- profitez des visites guidées ou autoguidées offertes par le centre;
- visitez les expositions du centre pour en apprendre davantage sur Joggins.

Tide Table

Horaire des marées

JOGGINS FOSSIL CLIFFS

UNESCO zone
UNESCO logo and text location

UNESCO zone
Logo et texte de l'UNESCO

Note: Space to be left blank pending approval.

What to See at the Joggins Fossil Cliffs?

Qu'y a-t-il à voir dans les falaises fossilifères de Joggins?

Fossil Forests

Joggins is world-famous for its fossils, which include unique forests of Coal Age trees. The fossil trees are preserved in the rock, still standing where they once lived.

Les forêts de Joggins

Joggins est connu mondialement pour ses fossiles, au nombre desquels figurent d'uniques forêts d'arbres de l'âge du charbon. Les arbres fossilisés sont préservés dans la roche, à l'endroit même où ils poussaient autrefois.

The Joggins Wharf

The pilings from the former wharf are one of the few visible remains of Joggins' industrial past. During the 19th century, the wharf was a vital link to the outside world.

Le quai de Joggins

Les pilotis de l'ancien quai sont parmi les derniers vestiges à témoigner du passé industriel de Joggins. Au XIXe siècle, le quai était un lien vital avec le monde extérieur.

Coal

The coal seams at Joggins can be seen from the Bay of Fundy. Coal drew people to Joggins from the earliest days of European exploration, and was commercially mined here for more than 100 years.

Le charbon

Les filons de charbon de Joggins sont visibles depuis la baie de Fundy. Le charbon a attiré de nombreuses personnes à Joggins dès le début de l'exploration par les Européens et a été exploité commercialement pendant plus de 100 ans.

Grindstones

The Coal Age sandstone at Boss Point made some of the continent's best grindstones. Between the mid-1800s to the early 1900s, hundreds of thousands of stones were prepared and shipped from "King" Seaman's quarry.

La pierre meulière

Le grès de l'âge du charbon que l'on trouve à Boss Point est entré dans la fabrication de certaines des meilleures pierres meulières du continent. Du milieu du XIXe siècle au début du XXe siècle, des centaines de milliers de pierres ont été extraites et expédiées de la carrière du « roi » Seaman.

! WARNING / DANGER !

Safety

- Make sure you're off the beach at least two hours before high tide. The Bay of Fundy has the world's highest tides.
- Stay at least as far away from the cliffs as the cliffs are high. Rocks can fall from the cliff face at any time.
- Stay well back from the edges when on top of the cliffs.
- Visit the beach in groups of two or more – never alone
- Keep a close eye on your children.
- Wear sturdy footwear on the beach. Be careful of wet and loose rocks. Seaweed-covered rocks are especially slippery.
- Bring warm clothes--it's often cold and windy on the beach, and the weather changes quickly.
- Take water with you.

Please note: cell phone coverage is unreliable on the beach.

Sécurité

- Quittez la plage au moins deux heures avant la marée haute. La baie de Fundy connaît les plus hautes marées au monde.
- Éloignez-vous de la falaise d'une distance égale à sa hauteur. Des roches peuvent se détacher de la paroi à tout moment.
- Tenez-vous loin du bord lorsque vous êtes en haut de la falaise.
- Visitez la plage avec au moins une autre personne, jamais seul.
- Ayez vos enfants à l'œil.
- Portez des souliers robustes sur la plage. Prenez garde aux roches qui sont mouillées ou instables. Les roches couvertes d'algues peuvent être particulièrement glissantes.
- Prévoyez des vêtements chauds, car il fait froid et il vente souvent sur la plage, et le temps change rapidement.
- Apportez de l'eau.

Remarque : la réception cellulaire est incertaine sur la plage.

Fossil Collecting

To protect the site for scientific research and provide a great experience for everyone, the law only permits you to collect fossils if you have a permit.

If you don't have a permit,

- leave all fossils where you find them
- let us know what you have found – take a picture or show a staff member

Your discovery could make a valuable contribution to science!

Protecting the Ecosystem

Tidal flats and reefs are delicate and fragile ecosystems that support a variety of life. Please stay off these areas when visiting the beach.

Help us preserve the natural beauty of this special place. Pack out everything you bring in, and clean up after your dog. Leave only footprints, and take only photos – and memories!

Cueillette de fossiles

Afin de protéger le site pour la recherche scientifique et de permettre à tous d'en profiter, la loi n'autorise que les titulaires d'un permis de recherche à ramasser des fossiles.

Si vous ne détenez pas de permis :

- laissez les fossiles à leur place;
- informez-nous de votre découverte (prenez-en une photo ou montrez-la à un membre du personnel).

Votre découverte pourrait avoir une valeur inestimable pour la science!

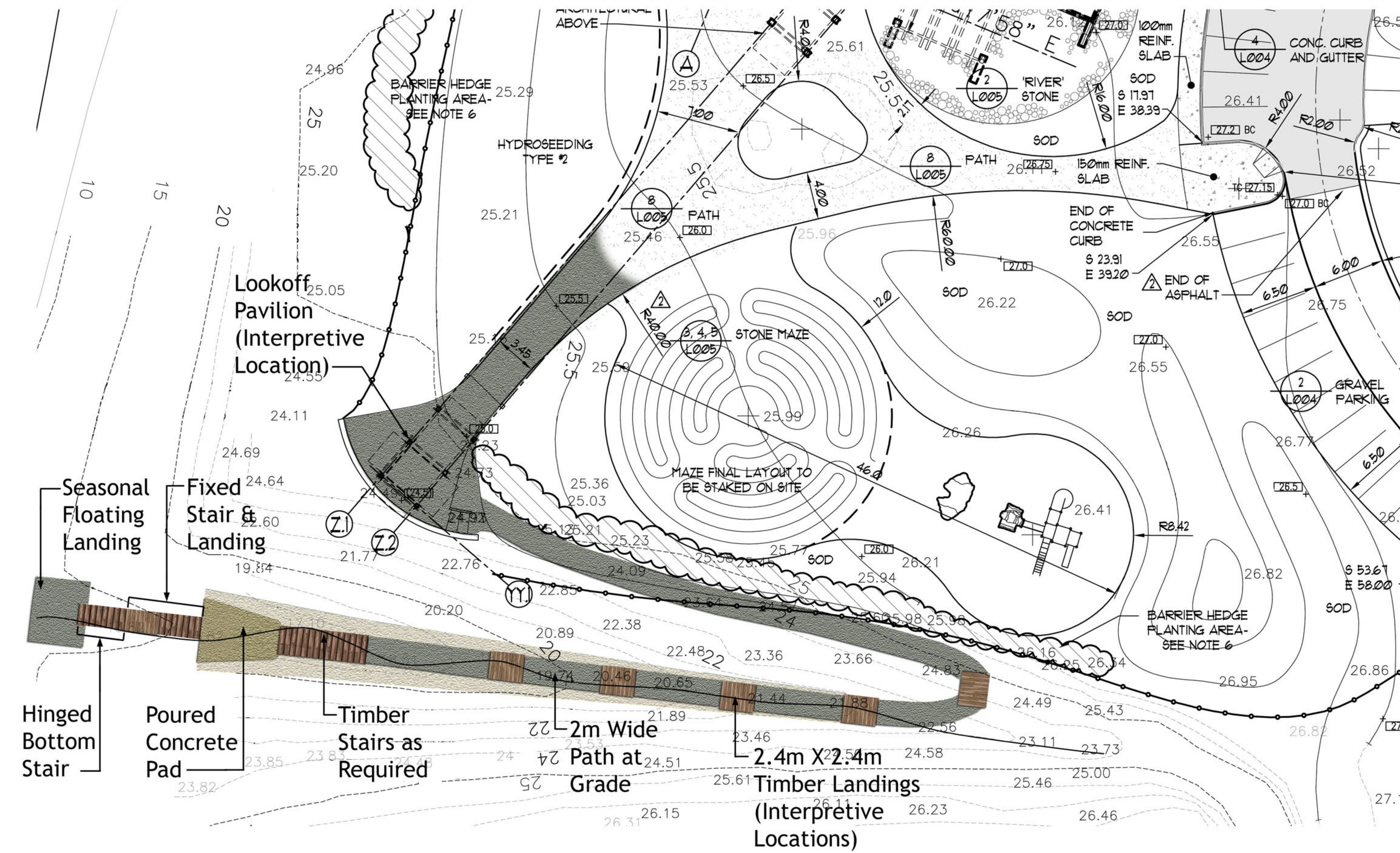
Protéger les écosystèmes

Les récifs et les bas-fonds intertidaux abritent des écosystèmes fragiles et délicats qui assurent la subsistance de nombreux organismes vivants. Lorsque vous visitez la plage, restez à l'écart de ces milieux.

Aidez-nous à préserver la beauté naturelle de cet endroit bien spécial. Rapportez tout ce que vous amenez avec vous et ramassez les excréments de votre chien. Ne laissez que des traces de pas, ne prenez que des photos et n'emportez que des souvenirs!

The Joggins Fossil Cliffs is a Protected Site under the Nova Scotia Special Places Protection Act and the Beaches Act (and Regulations). All fossils are the property of the Province of Nova Scotia.

Les falaises fossilifères de Joggins sont un site protégé en vertu de la Special Places Protection Act et de la Beaches Act (et des règlements connexes) de la Nouvelle-Écosse. Tous les fossiles sont la propriété de la province de la Nouvelle-Écosse.



Proposed Beach Access at Dugway

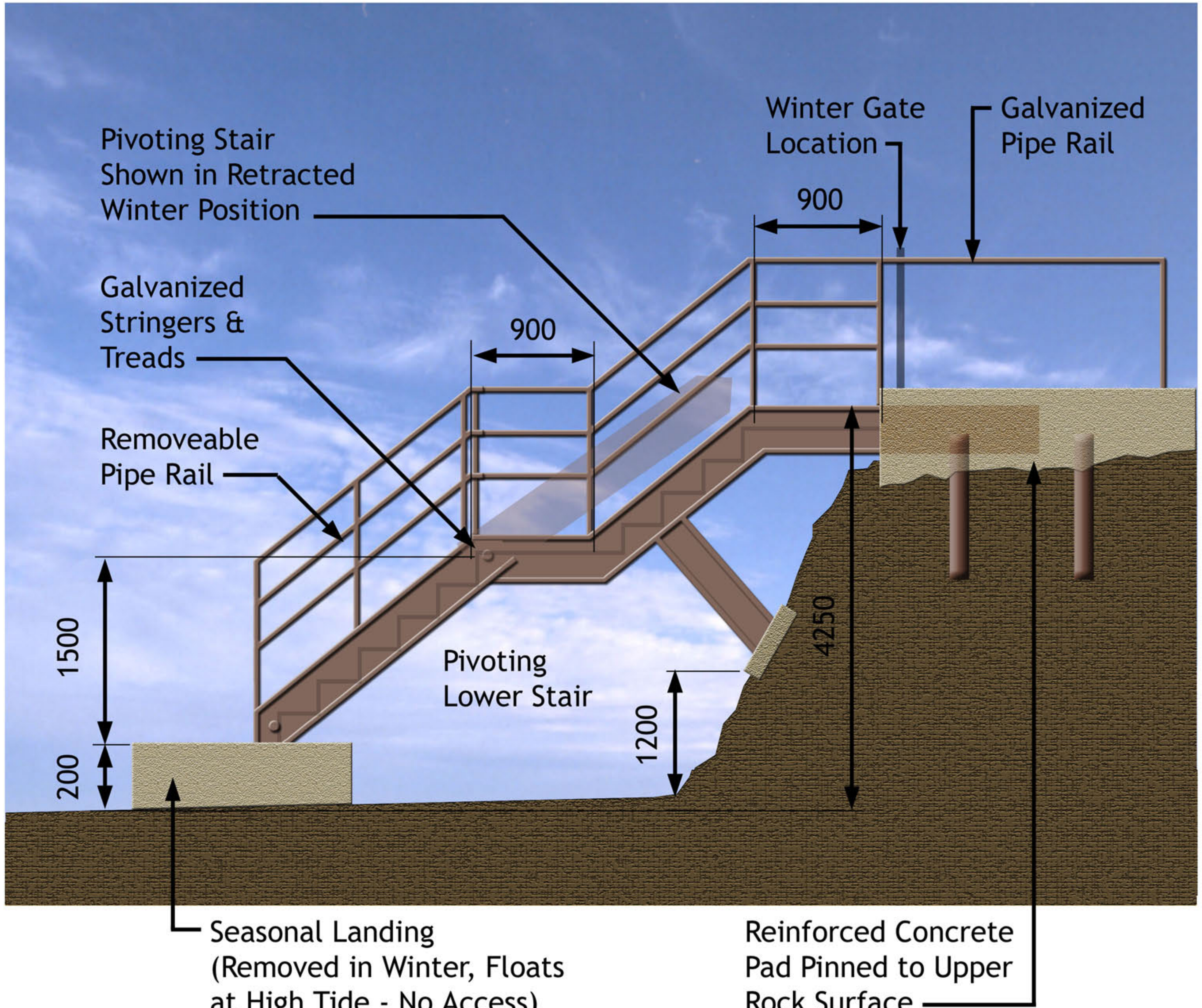
0 1 2 5 10m

- Plan Dimensions in Metres
- Spot Elevations in Metres Above Geodetic Datum

22 November 2007

whwarchitects

JOGGINS FOSSIL CLIFFS



22 November 2007

Joggins Fossil Cliffs

Proposed Beach Access at Dugway

Dimensions in Millimetres, Diagram is not to Scale

whwarchitects

Joggins Fossil Institute

Community Process to Develop Nomination

THE WORLD CONSERVATION UNION (IUCN) REQUEST OF THE STATE PARTY:

> "…to submit details of community process that has been undertaken to develop the nomination since inception."

STATE PARTY RESPONSE:

This summary is intended to provide an overview of the significant collaboration and community engagement activities respecting the Joggins Fossil Cliffs (JFC) nomination initiative. Hard copy documentation that provides details of the community collaboration were provided to the IUCN evaluation team during the mission to the Joggins Fossil Cliffs (October 2007) and additional copies are attached (see attachments below).

Included within the comprehensive document are the following sections:

I. Evolution of Organizational Structure
II. Community Consultation Sessions: 1998 – 2007
III. Newsletters
IV. Media Releases

Organizational structure

The Evolution of Organizational Structure in Section I provides an overview of the chronological development of governance structure for the JFC nomination initiative from 1996 to the current operational model. The attached documentation detailed illustrates that, the governance structure evolution has consistently maintained community and stakeholder involvement. Furthermore, each stage of governance development was adapted in response to the contextual needs of JFC initiative activities at any given time. A total of seven governance structures have been implemented since 1996 including the following:

1) 1996 – 2000 Ad-Hoc Committee
2) 1998 – 1999 Steering Committee – Community Consultation Process and Action Plan (Full Report included as Appendix F:3 in Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007)
3) 2001 – 2003 Joggins Fossil Cliffs Steering Committee
4) 2003 Transitional Steering Committee
5) 2003 – 2004 Joggins Fossil Cliffs Sub-Committee
6) 2004 – 2007 Joggins Fossil Cliffs Advisory Board
7) 2007 – present Joggins Fossil Institute Association

As detailed in Section I, each governance structure has functioned as a sub-committee of the Cumberland Regional Economic Development Association (CREDA). The current Joggins Fossil Institute Association is also registered independently as a not-for-profit society under the Nova Scotia Registry of Joint Stock Companies.

Community consultation sessions

Section II details community consultation from 1998 to 2007 for the Joggins Fossil Cliffs initiative. The subject matter within the consultation process has included, though not necessarily limited to; World Heritage Site nomination process, site protection and management, site development, community economic development, and potential initiative impact (short and long term). All sessions held have been interactive, providing viable and relevant community input.

Communications: media releases and newsletters

Sections III and IV provide documentation respecting communications. Copies of Joggins and relevant CREDA newsletters are included in Section III while Section IV profiles media releases.

Additional Information

The Joggins Fossil Institute has maintained a web page that is updated regularly to provide information regarding the nomination process and the nominated property (see www.jogginsfossilcliffs.net). In addition to communicating using the worldwide web, the Joggins Fossil Institute has worked collaboratively with neighbouring Cape Chignecto Provincial Park to develop and implement a communications plan (see Full Report included as Appendix E:3 in Nomination of The Joggins Fossil Cliffs for Inscription on the World Heritage List, January 2007).

Attachments

1. JFI_Calder1.pdf	Calder, J.H. 2006. (Mineral Resources Branch Report of Activities 2005, Nova Scotia Department of Natural Resources, Report ME 2006-1) The Joggins Carboniferous Section: A Progress Report on World Heritage Nomination.
2. JFI_Calder2.pdf	Calder, J.H. 2007 (Mineral Resources Branch Report of Activities 2006, Nova Scotia Department of Natural Resources, Report ME

	2007-1) Chronicle of a World Heritage Nomination: The Joggins Fossil Cliffs, Nova Scotia, Canada.
3. JFC_community_collaboration.pdf	CREDA (2007 unpublished), Community Consultation and Engagement.

The Joggins Carboniferous Section: A Progress Report on World Heritage Nomination

J. H. Calder

Introduction

The initiative to seek UNESCO World Heritage status for the celebrated coastal section of Carboniferous (late Mississippian and early Pennsylvanian) strata at Joggins has been pursued actively since 1998, locally driven by the Cumberland Regional Economic Development Association (CREDA). In 2004 and 2005, several milestones were reached on the road to World Heritage nomination. These include naming the site to Canada's Tentative List, dedication of funding by the Province of Nova Scotia and by the Atlantic Canada Opportunities Agency, hiring of Senior Project Manager Jenna Boon, a former resident of Joggins, and selection of the development consortium, headed by WHW Architects of Halifax. The work being undertaken involves a co-operative that comprises numerous agencies, government departments and community groups (Table 1), co-ordinated by the Senior Project Manager, reporting to an Advisory Board of senior community, municipal and government representatives.

The Tentative List

From November 2003 to May 2004 the Government of Canada, represented by Parks Canada, carried out an evaluation of 125 sites in Canada for which they had received proposals as potential World Heritage sites in either the cultural or natural categories. Subsequent to presenting the case to the review panel, Joggins was named to the short list of sites (the Tentative List, UNESCO, 2005) that Canada will formally nominate to the World Heritage Bureau of UNESCO, the United Nations Educational, Scientific and Cultural Organization. The importance of this achievement cannot be overstated, as failure to be named to the Canada's Tentative List would have spelled the end of the pursuit of World Heritage status.

The case presented included a comprehensive comparative analysis of global terrestrial Pennsylvanian sites (Falcon-Lang, 2002). The concept of proclaiming one site as representative of a particular stage of earth history is intrinsically at odds with the ecological heterogeneity of the planet since the establishment of terrestrial biomes at least since the late Paleozoic (Falcon-Lang and Calder, 2004), but is a concept that underpins the World Heritage evaluation of fossil sites in particular (Thorsell, 1994; Wells, 1996). A philosophical and practical discussion of these issues, using Joggins as a case study, was presented in Falcon-Lang and Calder (2004), and subsequently at a special session of the 2006 Annual Meeting of the Geological Association of Canada (Calder, 2006).

Table 1. Agencies collaborating on the Joggins World Heritage initiative.

Atlantic Canada Opportunities Agency
Cape Chignecto Provincial Park
Community representatives
Cumberland Economic Development Association
Emergency Health Services
Emergency Measures Organization
Human Resources Development Corp.
Joggins-River Hebert Development Association
Joggins Volunteer Fire Department
Municipality of the County of Cumberland
Nova Scotia Office of Economic Development
Nova Scotia Department of Natural Resources
Nova Scotia Department of Tourism, Culture and Heritage
Parks Canada
Royal Canadian Mounted Police

Calder, J. H. 2006: *in* Mineral Resources Branch, Report of Activities 2005; Nova Scotia Department of Natural Resources, Report ME 2006-1, p. 1-4.

Defining and Protecting the Site

The property to be nominated as a World Heritage Site comprises the coastal cliffs and foreshore from Downing Head in the north to Ragged Reef Point in the south, a linear distance of 10 km that includes some 15 km of coastline (Fig. 1). In October 2005, surveyors of the Land Services Branch, Nova Scotia Department of Natural Resources (DNR), established benchmark survey points at both landmarks to formally delineate the site (Fig. 2). The property encompasses exposures of the Mabou and Cumberland groups, including the Shepody, Claremont, Boss Point, Joggins, Springhill Mines and part of the Ragged Reef formations. Together, these formations span approximately 15 million years of Earth history (Gradstein *et al.*, 2004).

The integrity of Crown and private property adjacent to the coastline is protected by provincial legislation, and further protected through land-use bylaws currently being developed by the Municipality of Cumberland County, under the direction of Municipal Planner Jim Coughlin.

Infrastructure

Development of infrastructure that supports management and interpretation of the site, as well as long-term economic development, will be undertaken before submission of the nomination to UNESCO. Central to this development will be the construction of a $4.5 million interpretive, research and management centre, to be constructed at the site of the old Joggins No. 2 colliery, overlooking the cliffs at the foot of Main Street. In February 2005, the Province of Nova Scotia committed $1.1 million towards this end, and funding from the Atlantic Canada Opportunities Agency ensued in the amount of $350,000.

Interpretation

Conveying the significance of this celebrated geological site to the general public is an important component of site development. The visitor experience is being developed by the Montreal firm Design + Communication under the supervision of the Development and Infrastructure Committee chaired by Mary-Jo MacKay, Nova Scotia Department of Tourism, Culture and Heritage, and with the close collaboration of the author in the capacity of Scientific Advisor. Site-wide interpretive interventions are being developed in concert with Vollick, McKee, Petersmann & Associates of Halifax.

Governance and Management

A unique governance model for this prospective World Heritage Site is being developed under the direction of Senior Project manager Jenna Boon. Central to establishing the integrity of the site is the protection of the fossil record under the *Special Places Protection Act* and the *Beaches Protection Act*. The Operational Governance and Management Action team has drafted Board and Operational Policies in addition to a Site Management Plan. This team is working closely with a sub-committee to develop an emergency response plan and safety program for the site.

Communication and Marketing Strategy

MT&L Public Relations, a consulting firm from Halifax, has been contracted to develop a communication and marketing strategy for the site. Their work will entail conducting a communication audit, developing a design brief, and providing the branding and visual identity, graphics standards manual and advertising tool kit. The communication and marketing strategy will be integrated with the interpretive and infrastructure design, and also will support the graphic design required for the nomination dossier itself.

Nomination Timeframe

The nomination document is in preparation by the author (DNR), and will incorporate the management plan for the site being developed by Jenna Boon (CREDA) and Todd Keith (Parks Canada). The timetable for World Heritage nominations commences with submission of the

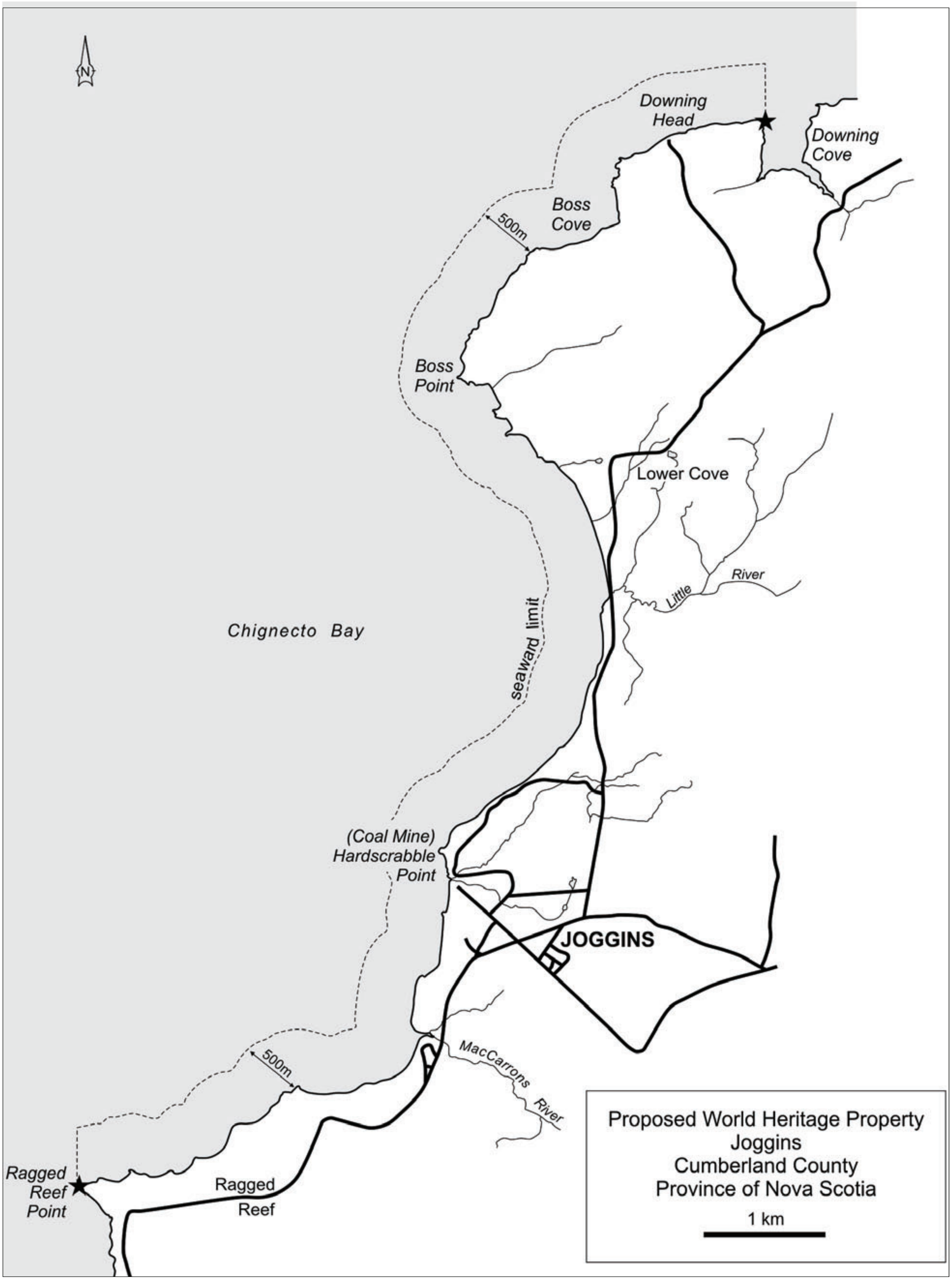


Figure 1. Map of the proposed World Heritage Property at Joggins, Cumberland County.

Figure 2. DNR surveyor Jeff Hingley, with Sandy Cameron, establish a benchmark near Ragged Reef Point (see Fig. 1 for location).

nomination dossier on the first day of February of each calendar year. As a natural site, the Joggins nomination will be assessed by the World Conservation Union (IUCN), Gland, Switzerland, over the following 15 month period, including a site visit by IUCN evaluators. Recommendations subsequently are made to the World Heritage Committee for deliberation at their annual meeting in June-July of the year following the nomination submission. The working timetable for submission of the nomination for Joggins is February 1, 2007, which would entail a decision at the June-July 2008 session of the World Heritage Committee.

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Chronicle of a World Heritage Nomination: The Joggins Fossil Cliffs, Nova Scotia, Canada

J. H. Calder

Introduction

A timeline of the initiatives that lead ultimately to the nomination of a property for inscription on the UNESCO World Heritage List comprises distinct, incremental phases as support and confidence in the nomination grow both locally and internationally. Although the steps required and the path followed by each World Heritage Site will be unique, reflecting the circumstances of each site and the jurisdictions in which they reside, some of these are broadly applicable to other nominations and may prove to be instructive as a case study, complementary to the detailed advice provided in the Operational Guidelines for World Heritage (UNESCO, 2005). In this paper, an analysis of the steps toward World Heritage nomination is documented for the Joggins Fossil Cliffs (Fig. 1), nominated by Canada in 2007 as a natural site.

This analysis draws on the author's perspective as advocate, scientific advisor, and senior author of the World Heritage nomination, spanning its inception through submission to the World Heritage Centre in Paris.

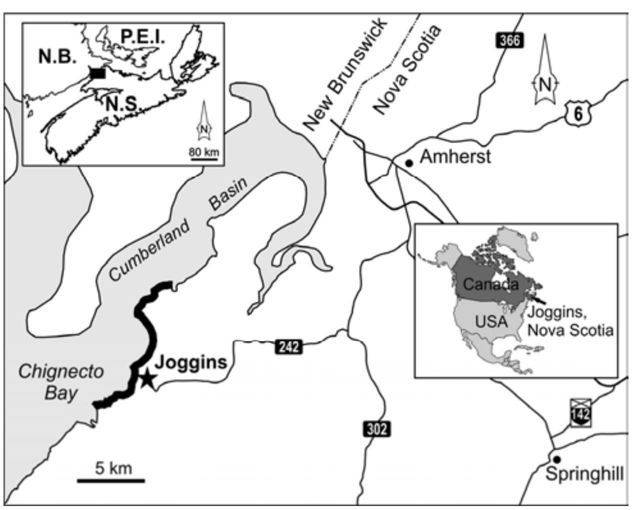

Figure 1. Map showing the location of the Joggins Fossil Cliffs.

The Joggins Fossil Cliffs

The nomination of the Joggins Fossil Cliffs (NTS 21H/09; Fig. 2) was submitted in 2007 under the aegis of Criterion viii of the Operational Guidelines (UNESCO, 2005) as "an outstanding example in the world of a stage of earth history, including the history of life …", specifically as the iconic site of the Carboniferous "Coal Age" that fuelled the Industrial Revolution, and which bears witness to the first reptiles in earth history. These first reptiles marked the adaptation of vertebrate life to land, and were the earliest representatives of the amniotes, a group that includes reptiles, dinosaurs, birds and mammals. The case for inscription rests primarily on three pillars (Fig. 3): (1) the seminal role that Joggins has played in science; (2) the terrestrial fossil record, which is doubly significant because of its ecological context; and (3) the grand exposure of the geological record in the cliffs on the Bay of Fundy coast (see Appendix for the full Statement of Outstanding Universal Value).

The site has been well established in scientific literature since its discussion in the pages of *The Origin of Species* by Darwin (1859), and has come to be known as the "Coal Age Galapagos" (Calder, 2006). Fully 101 years before ratification of the World Heritage Convention, Sir Charles Lyell, founder of modern geology, proclaimed the cliffs to be "the finest example in the world" of the rocks and fossils of the 'Coal Age' (Lyell, 1871).

The Road to World Heritage at Joggins: A Case Study

The timeline of bringing forward the nomination of the Joggins Fossil Cliffs (Fig. 4) spans 16 years from the time that possibility of World Heritage inscription was first recommended and investigated. It is fair, however, to consider 'Mile Zero' on the road as the formal legislative

Calder, J. H. 2007: *in* Mineral Resources Branch, Report of Activities 2006; Nova Scotia Department of Natural Resources, Report ME 2007-1, p. 1-9.

Figure 2. Photograph of the Joggins Fossil Cliffs at low tide.

protection of the site under the laws of the Province of Nova Scotia in 1970 and 1980. Milestones along the path to World Heritage nomination are indicated on Figure 5. Particularly instructive are: (1) the sequential order of these milestones, some of which were critical to moving the nomination forward; and (2) the time span between milestones and of the stages in the nomination process.

Component Stages

The nomination of Joggins gained consensus and experienced an increase in commitment incrementally, commensurate with increased assurance that the site is indeed likely to be formally nominated and that the nomination is likely to be successful. Much of the process of developing a World Heritage nomination, therefore, involves confidence building.

The path to nomination can be seen as comprising the following component stages (see Fig. 4):

1. Protective designation.
2. Awareness building and commemoration.
3. Studying the potential for World Heritage inscription.
4. Consensus building (culminating with commitment from government and naming to Tentative List).
5. Consultation with the community (including consensus building above).
6. Formation of a broad-based steering committee.
7. Preparation and strategic development of the case.
8. Commitment from government: (a) in principle; and (b) financially.
9. Planning for site management.
10. Infrastructure planning and development.
11. Nomination assembly and critical review within the country, culminating in its formal submission to the World Heritage Bureau.

Subsequent stages include:

- Evaluation by the World Conservation

Figure 3. Joggins is recognized for its fossil content, unmatched exposure and the contribution it has made to the history of scientific thought.

Union (IUCN), or in cases of cultural sites, by International Council on Monuments and Sites (ICOMOS)
- Decision (World Heritage Committee).

These stages fall into three categories of relative timing:

1. Intermittent and/or longer term (several years: e.g. consensus building).
2. Concentrated, short term (several months up to two years: e.g. tentative list evaluation, nomination assembly).
3. Concurrent with other stages (e.g. infrastructure planning and development).

Protective Designation

The Joggins coastal section was first protected under legislation of the Province of Nova Scotia in 1970 (*Historical Objects Protection Act*, succeeded in 1980 by the *Special Places Protection Act*). This important action, undertaken by visionary Director of the Nova Scotia Museum, J. Lynton Martin, formally established the intrinsic value of the site to the province, and fomented subsequent action on site development and management.

Awareness Building and Commemoration

In 1989, the author began to seek commemorative designation of the cliffs which would incrementally build awareness and support at home for World Heritage nomination. A proposal was made to the Chief Scientist (R. P. Riddihough) of the Geological Survey of Canada (GSC) that the federal government formally recognize Joggins as the site of the first field project of the GSC on its 150th Anniversary in 1992. The commemoration in turn assisted the community in securing funds for a building to house a new fossil centre for the Donald Reid collection, built at the site of the monument on Main Street. From its opening in 1993 through 2006, the Joggins Fossil Centre, privately run by the Donald Reid family, fulfilled the role of site interpretation, a remarkable example of community stewardship.

Studying the Potential for World Heritage Inscription

Under the Canada-Nova Scotia Tourism

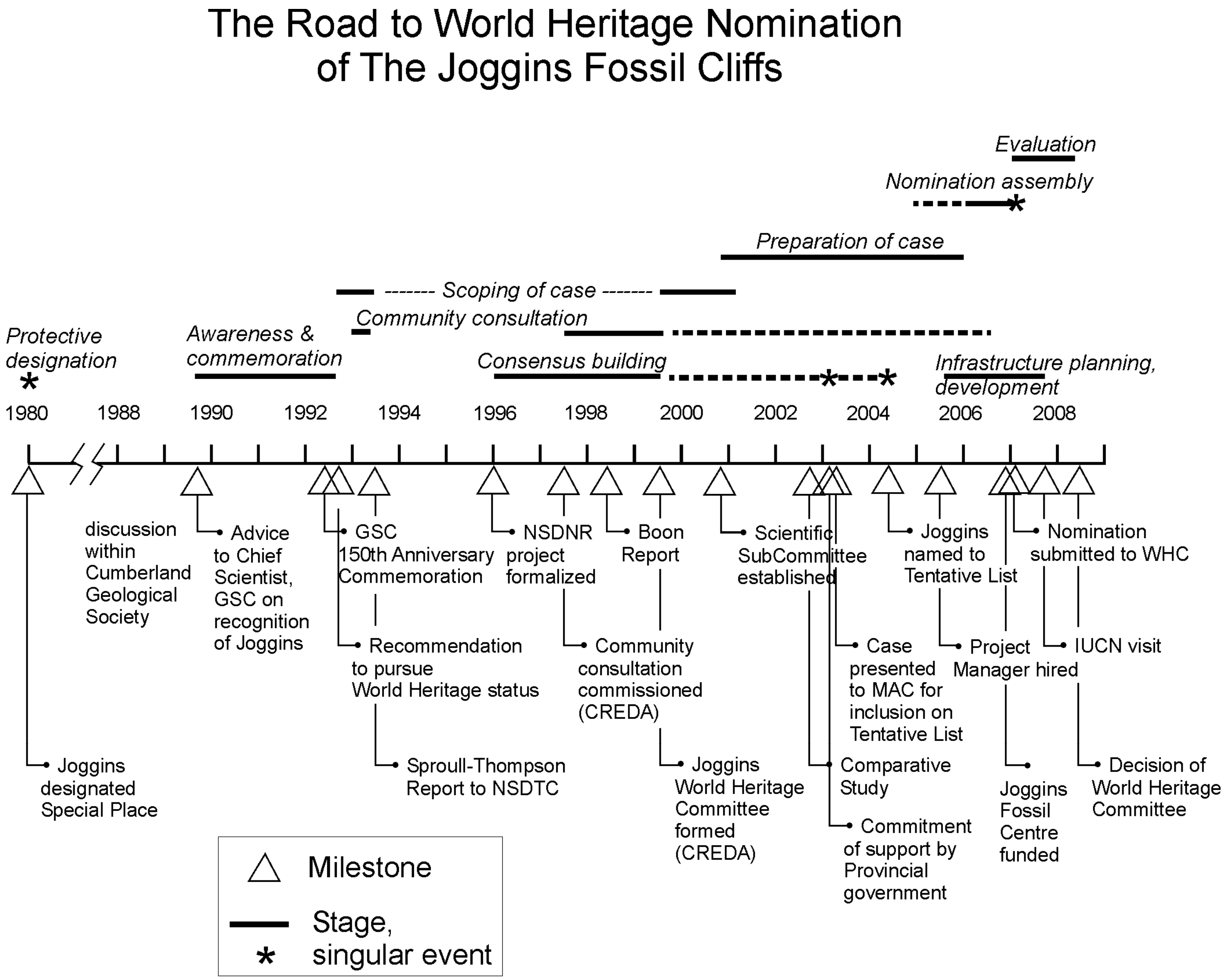

Figure 4. Timeline of the effort to nominate the Joggins Fossil Cliffs as a UNESCO World Heritage Site.

Development Agreement for 1992-1995, a tourism development and management plan for the cliffs was commissioned by the Nova Scotia Department of Education and Culture (Nova Scotia Museum, under the direction of Robert Frame and Robert Ogilvie), and undertaken by Janet Sproull-Thompson for consultants Jacques Whitford and Associates.

In a letter of November 18, 1992, the author made the following recommendations to the consultant (here abridged) to:

1. Involve local people in the process.
2. Expand the area protected under the *Special Places Act*.
3. Consider a full-scale interpretive centre, associated library and research centre, and possibly an affiliated paleontological institute.
4. Emphasize enduring international significance, including earliest reptiles.
5. Consider the great potential of natural sites as a sustainable economic driver; link development at Joggins with the Fundy Geological Museum at Parrsboro.
6. Nominate the cliffs as a World Heritage Site.

With the submission 15 years later of the nomination of the Joggins Fossil Cliffs to UNESCO, all six recommendations have been acted upon.

In-depth study of the potential and nomination process was undertaken by the author in concert with the formation of the first Joggins World Heritage planning committee in 1999, co-ordinated by the Cumberland Regional Economic Development Association (CREDA), under the leadership of Rhonda Kelly, its Executive Director.

Consensus Building

Building confidence among key government agencies in the prospect of the cliffs as a World Heritage site was an important, albeit largely informal process. In 1996, the Nova Scotia Department of Natural Resources approved a formal initiative, 'Economic Development of Fossil Sites in Nova Scotia'. Central to this initiative was the World Heritage nomination of Joggins, to be undertaken jointly with relevant government agencies, including the Nova Scotia Museum.

An informal working group of international scientists collaborated to fill gaps in the scientific literature throughout the duration of the nomination timeline, providing an important bridge between historic and current research at the site, and raising the significance of the site within the scientific community.

Consultation with the Community

The Sproull-Thompson report, although limited in its justification for World Heritage inscription, would serve as an important catalyst within the community. The report was brought to the attention of the Cumberland Regional Economic Development Association (CREDA) by Joggins resident Mark Boon in 1997, triggering a second round of community consultation led by Boon with the support of CREDA, and leading ultimately to CREDA's co-ordinating role. Consultation continued as a component of developing a management strategy for the site as a Special Place (undertaken by Robert Ogilvie, Nova Scotia Museum), concurrently with the World Heritage initiative.

Formation of a Broad-based Committee

A milestone in the pathway to nomination was the formation of a steering committee facilitated by CREDA, (under the direction of Executive Director Rhonda Kelly), who brought together community and government representatives to formally investigate the World Heritage potential of Joggins. The leadership shown by CREDA facilitated discussion among various government agencies on neutral ground, and ensured that the community was actively engaged.

Following the naming of Joggins to Canada's Tentative List, this committee evolved in 2005 into an overseeing Advisory Board, comprising community leaders and senior representatives of municipal, provincial and federal government agencies, and ultimately, with the formation of the Joggins Fossil Institute Association, into its Board of Directors.

Preparation and Strategic Development of the Case

With the formation of the steering committee, exploration of the case was undertaken in depth. Development of the justification for inscription, a key component of the formal nomination document, was undertaken by a Scientific Subcommittee, formed in 2000 and chaired by the author.

During this time, a comparative analysis of global sites with which Joggins ultimately would be compared was commissioned by CREDA under the supervision of the scientific chair and undertaken by Howard Falcon-Lang, University of Bristol, England. Although not mandatory prior to 2005, a comparative analysis was nonetheless considered to be essential in securing a place for Joggins on the Tentative List for Canada for two reasons: (1) Joggins was not expressly named in the indicative list of fossil sites prepared in the briefing paper by Wells (1996) to the IUCN, and (2) documentation in possession of the federal agency responsible for World Heritage in Canada (Parks Canada Agency) was known by the Scientific Subcommittee to be inadequate.

Commitment from Government

Consensus for World Heritage nomination was formally recorded in a memorandum of understanding by Deputy Ministers of three key departments of the Nova Scotia government: (1) Natural Resources, (2) Tourism, Culture and Heritage, and (3) the Office of Economic Development. The catalyst for this memorandum of understanding was the presentation of the case to the Ministers' Advisory Committee of the federal government for the inclusion of Joggins on the Tentative List for Canada. The naming of Joggins to the Tentative List was pivotal to the nomination initiative, and by confirming its future nomination to UNESCO this was a key step in galvanizing government support.

Financial commitment by municipal, provincial and federal governments to infrastructure development was achieved in 2006, on the eve of the submission of the nomination dossier. This commitment was secured largely by the efforts of the project manager (Jenna Boon) and CREDA Executive Director (Rhonda Kelly), with the influential support of the Joggins Fossil Cliffs Advisory Board. The formation of the Advisory Board, with representation of key agencies by senior government officials, was strategically important to securing government support in matters of finance and policy.

Planning for Site Management

Although work on the management of the cliffs was intermittent, it spanned virtually the entire timeline of the nomination. Background research for management of the site as a Special Place and prospective World Heritage Site began in 1991 by Robert Ogilvie and Robert Grantham, curators (respectively) of Special Places and Geology with the Nova Scotia Museum. Work on developing a management plan for the site as a Special Place paralleled formation of the World Heritage planning committee in 1999, and was adapted by the project manager (Jenna Boon), with input from Parks Canada Agency (Todd Keith), to conform to the Operational Guidelines for World Heritage (UNESCO, 2005).

Management at the site will fall to a not-for-profit society, the Joggins Fossil Institute Association, a model similar to that employed at the Dorset and East Devon Coast World Heritage Site, England. The Institute will be empowered to act on behalf of the province in matters pertaining to protection and stewardship of the site.

Infrastructure Planning and Development

Infrastructure at the site in support of interpretation for visitors and for site stewardship and management was conspicuous by its absence, the role being largely fulfilled by the privately operated Joggins Fossil Centre of the Reid family. Planning and development of infrastructure was co-ordinated by the project manager, and the content was directed by the scientific advisor. Although infrastructure planning was undertaken relatively late and required simultaneous attention of the project manager and scientific advisor to both the nomination dossier and interpretation development, it provided the opportunity to ensure that the interpretation message paralleled and supported that of the nomination.

The need to have a person dedicated to bringing together the disparate components required before Joggins could be assessed as a potential World Heritage Site was identified by the steering committee once Joggins had been named to Canada’s Tentative List. A contract position was created within CREDA for a project manager and was filled in 2005 by Jenna Boon, who is also a former resident of the community. The manager filled the key role of overseeing contracts for infrastructure and nomination support, co-ordinating land-use planning with the municipal government, securing funding commitment from all levels of government, and ensuring that the community remained informed of progress.

Assembly, Review and Submission of the Nomination

Preparation of the nomination began with the work of the Scientific Subcommittee in late 2000. The scientific advisor served as senior author, ensuring that the strategic message of outstanding universal value that is central to the case for World Heritage inscription formed the spine of the nomination dossier. Preparation of the nomination dossier required close co-operation between the scientific advisor in the capacity of lead author and the project manager, who co-authored the nomination and who bore the task of bringing to the nomination the disparate components required from various working groups and agencies.

Critical review of the nomination dossier was undertaken over the course of several critiques by World Heritage staff of Parks Canada Agency, to ensure that the documentation reflected, and would meet or exceed, expectations of the World Heritage

Committee during the review process. As part of this critical review, the main body of the dossier and key maps were submitted for preliminary technical analysis by the World Heritage Bureau, Paris, four months prior to its formal submission.

Evaluation (by WHC and IUCN)

Once the nomination is formally submitted for the annual deadline on 1 February 2007, a process is set in motion that culminates 17 months later with the decision of the World Heritage Committee at its annual session in June of the following year. In the interim, the nomination is evaluated by the World Conservation Union (IUCN), which conducts a site visit later in the year that the nomination is submitted.

Recommendations

1. *Preliminary assessment*. Early on in the process of considering a site for World Heritage nomination, it is crucial to evaluate the potential of the site to succeed. The most likely candidate for this role is an academic or scientific authority familiar with the site and its global context.
2. *Strategist*. It is equally crucial that the scientific authority be aware of UNESCO Operational Guidelines, available at http://whc.unesco.org/en/resources, in order to develop and advise on the best strategic course for the nomination, identifying strengths and weaknesses in the forthcoming nomination. As the guidelines constantly evolve, it is important that a close working relationship be forged with the World Heritage representative for the country.
3. *Authoritative advocate*. Continuity of scientific authority throughout the preliminary consideration and formal nomination process is a particular challenge, given the pressures on authorities affiliated with academic institutions that require competitive publication output. Recently retired authorities, or those affiliated with government agencies, may be better positioned to fulfill this role, supported by colleagues at academic institutions.
4. *Comparison and collaboration* with authorities who developed the strategic case for inscribed World Heritage Sites in the same category is highly recommended. Access to the nomination review and recommendations for all inscribed sites are available at http://whc.unesco.org/.
5. *Community support* is essential, as few sites globally are uninhabited, either within their boundaries or surrounding areas. Communities must be comfortable with the requirements and changes that will attend World Heritage inscription, and can fulfill important roles as stewards of the site. Furthermore, political support for the nomination in many countries will be sensitive to the level of community support. Therefore, community participation should be established as early in the process as possible.
6. *Endorsement by government*. With community support and assurance of the authority that the site meets UNESCO requirements for World Heritage inscription, government agencies and political representatives must formalize their collective support, ultimately leading to the inclusion of the site on the Tentative List, which each country is required to file with the World Heritage Bureau.
7. *Operational funding*. Governments and their agencies that represent the country at the level of managing the nominated property must accept in principle that it is incumbent upon them to dedicate annual operational funds in order to protect and manage the site in perpetuity.
8. *Lead agency/secretariat*. As the nomination process proceeds, the complexity of the project increases due to the need for simultaneous co-ordination and communication between agencies, as well as the need to raise to World Heritage standards any areas in the stewardship of the site that are deficient. Ideally, one agency should be designated as the co-ordinator of the nomination, while taking care not to alienate colleagues and sister agencies that will be required to play a role in site stewardship if the site is inscribed. An alternative model entails formation of an intra-agency secretariat, which may also leverage dedicated funding for its operations.
9. *Project co-ordination and facilitation*. Once the decision to proceed with the nomination is agreed upon by the responsible agencies, a project co-ordinator should be appointed or named in order to facilitate communication between agencies and individuals and to ensure that input by various working groups to the nomination author(s) adheres to required timelines.

10. *Ongoing nomination authority*. It is essential that the long-term role of strategist and authority be maintained to ensure that the nomination follows its strategic path to establishing the site's outstanding universal value and stewardship in perpetuity for future generations.

Conclusions

The nomination of a property for inscription on the World Heritage list is a lengthy process that inevitably begins with the passion of one or more individuals that must be conveyed ultimately to the world. Equally required is the knowledge that the road is long. Although various persons and agencies will serve key roles at different stages of the nomination process, it is essential to maintain core expertise for the nomination strategy throughout its development. Involvement of the community at an early stage is of paramount importance, and financial commitment by government agencies responsible for site management is a prerequisite of a successful nomination.

Appendix: Justification (Statement of Outstanding Universal Value) from the World Heritage Nomination of the Joggins Fossil Cliffs

The coastal cliffs at Joggins reveal the most complete fossil record in the world of terrestrial life in the Pennsylvanian "Coal Age" of earth history. Nowhere is this record of the evolution of life on land and biodiversity in the tropical "Coal Age" - encompassing plant, invertebrate and vertebrate life - rendered more evocatively. The magnificently exposed succession of sedimentary layers preserves the fossils *in situ*, providing environmental context that is unrivalled in the world. The fossil record includes the two defining, iconic elements of the "Coal Age": fossil forests of the "coal swamps" and the first reptiles, which as the earliest amniotes are the oldest known representatives of reptiles, birds and mammals. The origin of amniotes, the first vertebrates to achieve the capacity to reproduce on land, was one of the most significant events in the history of life on earth, an evolutionary milestone first recorded with certainty at Joggins. No other locality in the world has provided as much knowledge of the nature of early amniotes or more informative specimens for linking them to more primitive groups of Palaeozoic tetrapods, and to the world in which they lived. Through the power of the Bay of Fundy tides, which are unsurpassed in the world, ongoing discovery is ensured at this site of outstanding universal value.

This dramatic setting is home to what Sir Charles Lyell, founder of modern geology, described as "the finest exposure in the world" of the rocks and fossil record of the Pennsylvanian "Coal Age" of earth history. The fossil record of Joggins has figured in the first debate on evolution, and remains pivotal to understanding the terrestrial origins of vertebrate life, including our own species. This uniquely representative chapter of the earth's history has been the subject of the research and writings of some of the world's most influential scientists since the mid-nineteenth century. Joggins has figured in such seminal works as *Principles of Geology* by Lyell and *The Origin of Species* by Charles Darwin, and has come to be known as a 'Coal Age Galapagos'.

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ENGAGEMENT & COLLABORATION

JOGGINS FOSSIL CLIFFS

Evolution of Organizational Structure

Joggins Organizational Structures

Overview

1996 - 2007

The following section provides an overview of the evolution of organizational structure for the Joggins Fossil Cliffs development spanning from 1996 until current governance model. Throughout this evolution the priority of community and stakeholder involvement has remained consistent.

The complexity and mandate of each has evolved from the informal beginnings to the current Joggins Fossil Institute Association which has formal bylaws and is registered as a Not-for-Profit Society under the Nova Scotia Registry of Joint Stocks. The following list provides a summary of each 'group' in chronological order. Where applicable, additional information has been included in the subsequent pages of the section, it is important to note that all identified organizational structures fall under the auspices of CREDA as 'sub-committees'.

A) Ad Hoc Committee - Joggins: 1996 - 2000
This group began reviewing documentation and eventually potential for long term development of the Joggins Fossil Cliffs in 1996. Initiated by the community with support from the Cumberland Regional Economic Development Association, its composition included community, CREDA staff and provincial government stakeholders. Active participants ranged from 8 - 10 members at any one point in time.

B) 'Boon Report' Steering Committee: 1998 - 1999
Comprised of community members with resource staff support from CREDA, this group assisted in the facilitation and development of the 'Boon Report' - a process and resulting document which actively sought (and achieved) community input, support and 'buy-in' for the long term development of the Joggins Fossil Cliffs as a site for excellence in interpretation, preservation, and education, as well as a potential community economic 'generator' for the region. The level of excellence sought was in the context of a possible nomination as a World Heritage Site. Community membership ranged from 4 - 6 members (including CREDA resource staff support). The report included recommendation respecting organizational structure.

C) Joggins Fossil Cliffs Steering Committee: 2001 - 2003
The Joggins Fossil Cliffs Steering Committee provided and expanded the organization model to 'steer' the anticipated development in Joggins. It incorporated three subcommittees; i) scientific ii) logistics

/infrastructure iii) economic /tourism development. Each subcommittee was chaired by a steering committee member who reported back accordingly. The expanded governance model enabled increased community and stakeholder engagement/involvement which served to strengthen support and interest. Early in 2003 the model was further refined to include communications and to better define roles of both the scientific and infrastructure subcommittees in the context of furthering the UNESCO World Heritage application process as well as the overall site development.

D) Transitional Steering Committee: 2003
The Joggins Fossil Cliffs Steering Committee evolved into a transitional Team whose mandate was broadened to include a comprehensive review of the existing governance model for the purpose of realigning to better meet the opportunities (and challenges) presented by long term development.

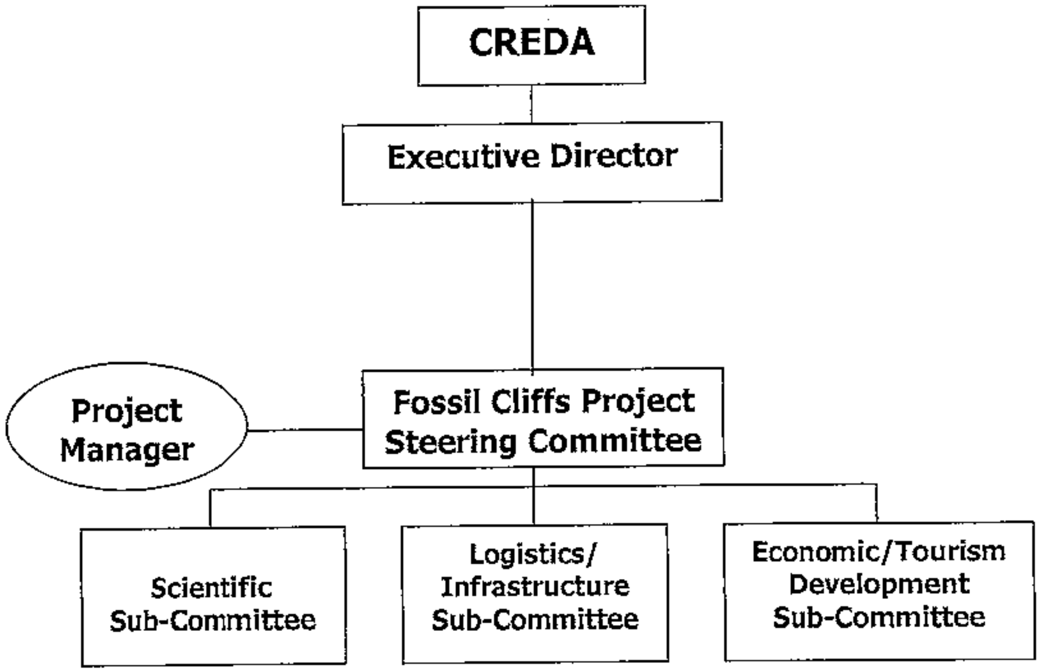
E) Joggins Fossil Cliffs Subcommittee: 2003 - 2004
Established late in 2003, the structure included a 'Committee of Chairs' which represented each of the six newly established action teams including a) Nomination Dossier b) Management Response c) Business Plan d) Site Logistics and Infrastructure e) Marketing/Communication f) Community Development. Each component within the structure had a clearly articulated mandate. The new structure also enabled substantial community and key stakeholder engagement which facilitated significant progress in all relevant areas of activity.

F) Joggins Fossil Cliffs Advisory Board: 2004 - 2007
The Advisory Board evolved from the cumulative work of the Joggins Fossil Cliffs Subcommittee. Its establishment and mandate finalized the essential link with all three levels of government along with community engagement. Under its auspices a Senior Project Manager was hired and five distinct working groups were established to facilitate Nomination Dossier development/submission and the requisite parallel overall governance, management, site development and marketing.

G) Joggins Fossil Institute Association: 2007 - present
The work of the former Advisory facilitated the establishment of the Association which has overseen the physical site development and will be the policy board which directs the long term operation of the Joggins Fossil Institute Research and Interpretive Centre. A registered Not-for-Profit Association under the Nova Scotia Society's Act currently functions as a subcommittee of CREDA through a signed Memorandum of Understanding.

Joggins Fossil Cliffs Project
Organizational Model

(June 22, 2001)



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CUMBERLAND REGIONAL
ECONOMIC DEVELOPMENT
ASSOCIATION

February 24, 2003

MEMORANDUM

TO: Joggins Fossil Cliffs Steering Committee

FROM: Mark Boon, Co-Chair
Rhonda Kelly, Co-Chair

SUBJECT: Steering Committee Restructuring

Further to our last meeting, this memo is intended to provide members with information regarding potential restructuring of the JFC Steering Committee and its functions.

After much discussion with resource staff and funding partners, it is apparent that a complete restructuring at this point may not serve to further our efforts. Indeed, time and efforts would perhaps be best spent reaffirming and better defining the roles of the Infrastructure and Scientific Sub-Committees in the context of the overall project and the UNESCO application process.

Further, our efforts should be focused upon securing stronger government support, coordination and partnership to ensure consistency as we move forward.

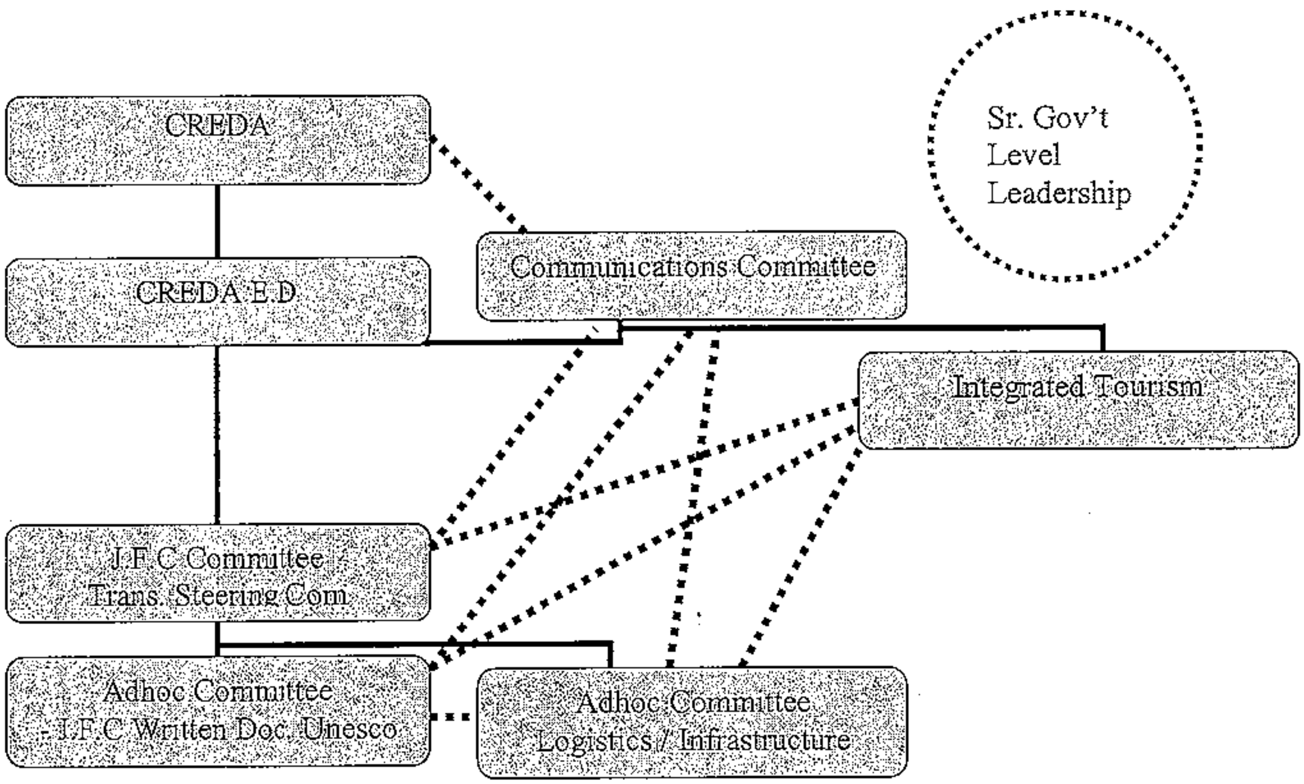
As previously indicated, the Communications Sub-Committee will be broadened to better coordinate CREDA's communications activities generally, as Joggins is one of several projects which requires this type of support. Tourism will be handled in a similar manner incorporating several initiatives which play a role in our regional integrated approach.

With the above in mind, the "reorganization" component of Thursday's agenda will further detail the above and serve as a review of the overall role of the Steering Committee.

Many thanks.

J.F.C Transitional Organizational Model

(Transitional until such time that role/direction of levels of Sr. Gov't is established)



As part of the ongoing activities of the Joggins Fossils Cliffs Steering Committee it is understood that members (collectively and individually) function based upon the following "*Premise*":

To develop the Fossil Cliffs in Joggins as:

(a) an integral part of an integrated tourism plan for the Region,
(b) a protected site as per the legislation for the Province of Nova Scotia,
(c) a W.H.Site, as per the parameters set forth by UNESCO

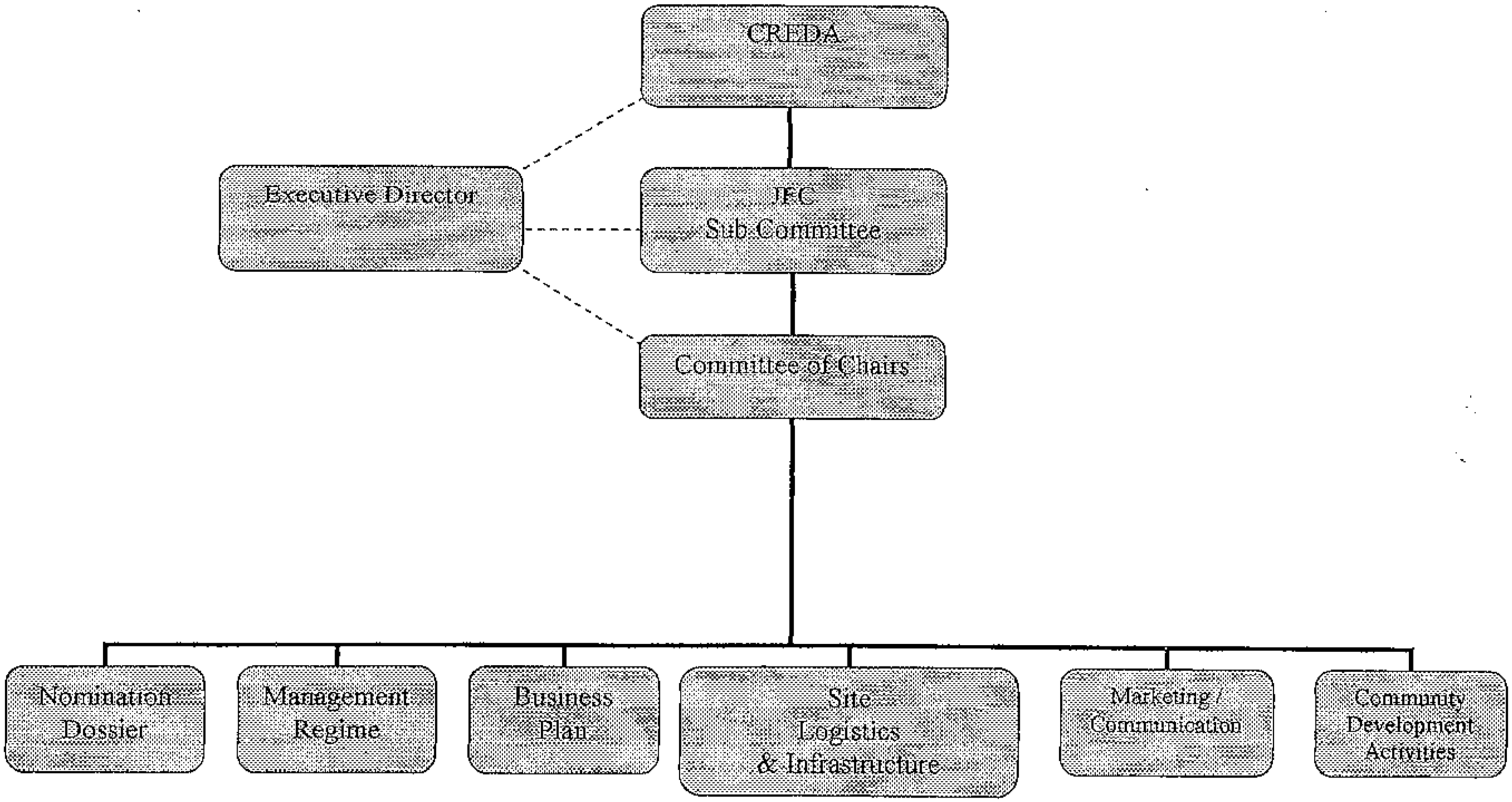
In this regard, it is accepted that:

- no merit value is assigned to either (a),(b) or (c),
- all factors (a), (b) or (c) are deemed important,
- all factors are interdependent, inter-related and inter-connected.

It is also recognized and accepted that:

-(a) the following constituencies will play a part in the process of development: local, area, regional residents,
- (b) various levels of government - local, regional, provincial, federal ("Top Down - Bottom up approach").
- (c) it may be necessary to involve corporate and/or private business
- the degree of involvement of (a), (b) and (c) depends on factors such as: need, timing, availability of resources, appropriateness etc."

Operational Model
Joggins Fossil Cliffs Sub Committee



Dec 03

Mandates

I. **JFC Sub-Committee**
Mandate: To provide overall leadership and direction relevant to the Joggins Fossil Cliffs as a work heritage site and / or protected site.
Reports to: CREDA Board of Directors.

II. **Committee of Chairs**
Mandate: To coordinate the activities / priorities relative to the development of the Joggins site while ensuring the efficient and effective use of time and resource. This will be accomplished through ongoing communications / coordination / reporting respecting each action committee thus ensuing the JFC sub-committee fulfills its mandate with prescribed timelines as appropriate.
Reports to: JFC Sub-Committee

III. **Action Committees**
The chair of each Action Committee is responsible to report to the Committee of Chairs on a regular, designated basis. Activities undertaken by each Action Committee must have prior approval of the JFC sub-committee and directly link to the over all mandate of the sub-committee.

A. Nomination Dossier
Mandate: To develop / coordinate the preparation of the Nomination Dossier for potential eventual presentation to UNESCO which encompasses all relevant requirements for World Heritage Site application and successfully portrays the awe inspiring global significance of the site.

B. Management Regime
Mandate: To collaboratively develop, in partnership with senior government personnel a relevant and realistic management model for Joggins Fossil Cliffs as a World Heritage Site.

C. Business Plan Development
Mandate: To develop a strategic business plan which addresses capital development and long term operational requirements which include a detailed action plan as well as financial requirements. Inherent to this will be securing of funding partners.

D. Site Logistics& Infrastructure
Mandate:
(1) To plan and facilitate matters pertaining to the overall site (protected area / WHS) and adjoining area including, but not limited to the following:

- Geographic boundaries
- Overall site planning and development
- Fossil collection policy
- National Historic Site Designation

(2) To facilitate the development and implementation of the following:

- Appropriate/relevant land use bylaws/zoning requirements
- Key infrastructure requirements

E. Marketing / Communications

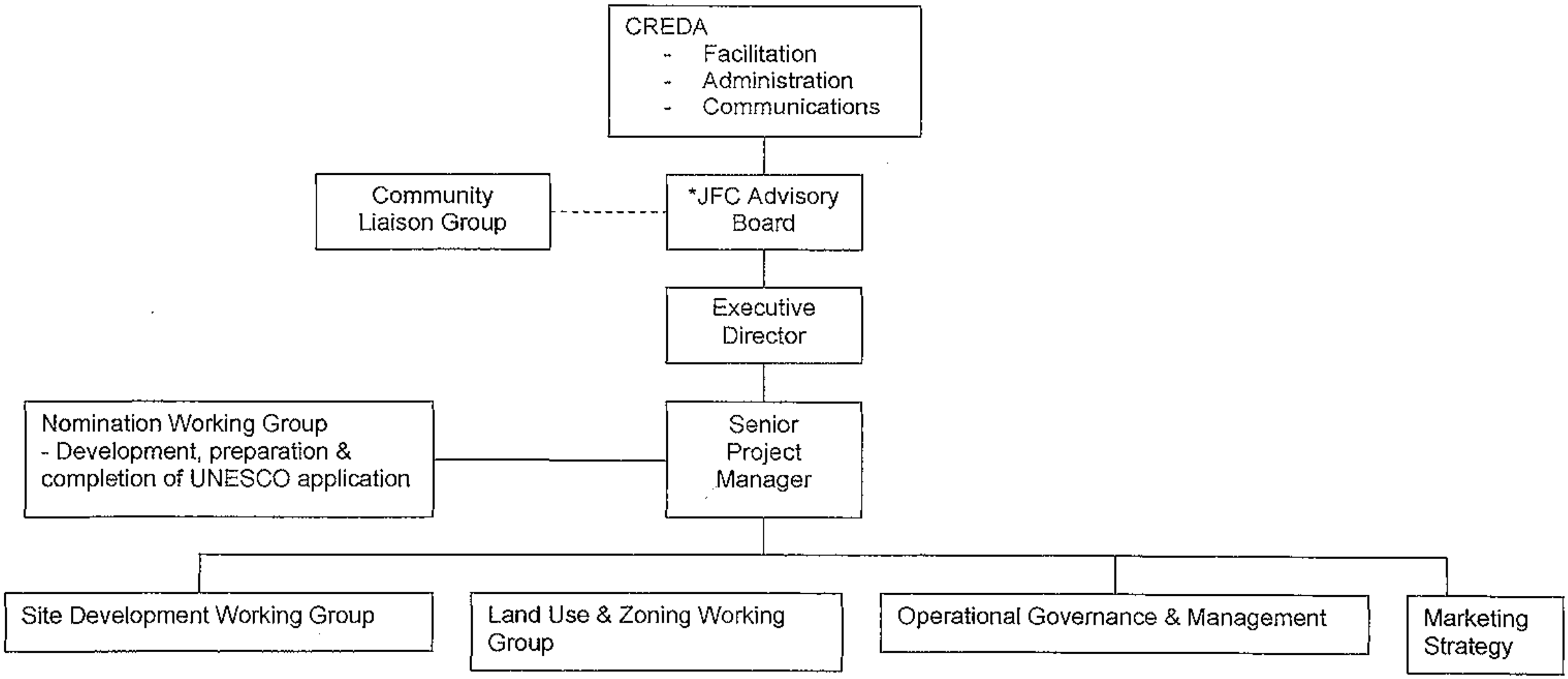
Mandate: To develop and implement communications / marketing strategies relative to matters such as, but not necessarily limited to , the following:

- Development of the JFC project
- Development of the governance model
- Positioning of Joggins within the overall development of an integrated Tourism Plan
- Facilitate the communications consultation process

F. Community Development Activities

Mandate: To work cooperatively with community groups / individual in the development of the community in the context consistent with the global expectations of a World Heritage Site.

DRAFT – JFC Project Development Governance Structure

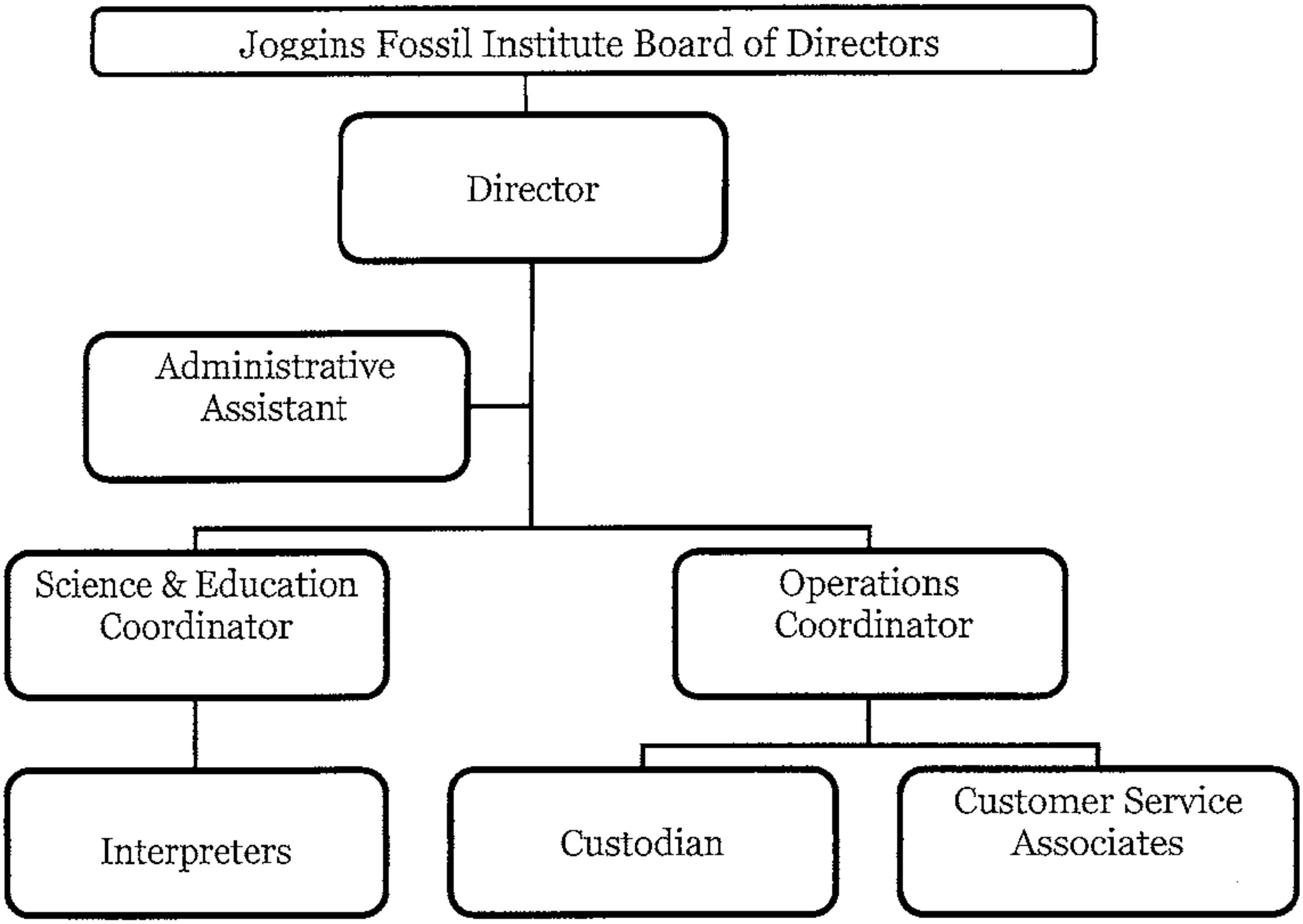


*JFC Advisory Board – proposed representation

- CREDA
- Community
- Municipal Government
- DNR
- TC&H
- OED
- Parks Canada
- ACOA
- Corporate/Private (TBD at a later date)

Note: Governance structure and mandates to be reviewed quarterly.

9/10/2004


Joggins Fossil Institute Board of Directors
Director
Administrative Assistant
Science & Education Coordinator
Operations Coordinator
Interpreters
Custodian
Customer Service Associates

Community Consultation

Community Consultation Sessions
1998 – 2007

__1998__:

- February 16th - First community consultation under the auspices of the Boon Report. Discussion and community input.
- April 20th - Follow-up meeting respecting the Boon Report. Included review of 'Report's findings to date' as well as additional community input.

__1999__:

- November 15th – Review of Boon Report, Organization Structure and gathering community input to facilitate next step in initiative.

__2000__:

- November 2nd – Review of UNESCO criteria and related boundary expansion for Special Places designation under the Provincial Special Places Act. Opportunity for community to give input respecting process and interest.

__2001__:

- February – Open meeting with River Hebert/Joggins Area Development Association for the purpose of input respecting site management and future development.
- June 5th – Community meeting to acquire input respecting vision development for both a Site Management Plan and future development at the site.

__2002__:

- April – Community update/input session regarding Dugway Access engineering and site geotechnical analysis and conceptual plan development.
- May 30th – Environmental Design Management (EDM – Ross Cantwell) community input session to facilitate site concept plan development.

__2003__:

- January 30th – Review/presentation of EDM Tourism Concept Plan. Questions as well as input from the community which assisted in determining next step.
- June 23rd – Community input information session respecting potential entrepreneurship opportunities for community members in the context of the proposed site development.
- October 20th – Second entrepreneurship session (follow-up to June 23rd).

2004:

- June 15th – Review of geotechnical/engineering assessment for Dugway Site; review of Joggins' recent inclusion on Canada's tentative list. Community consultation respecting current status, and input regarding next steps. Also call for volunteers for community beautification Committee.

2005:

- February 18th – First major funding announcement of $1.1 million in trust for Capital Development at the Joggins Fossil Cliffs. Session included informal community networking/input.
- May 30th – Project update, introduction of senior Project Manager, review of project status including call for proposal for Architectural/Design Team. Community input re next steps. Also request for community participation in upcoming "Imagine the Cliffs " visual arts contest.
- September 8th – Community engagement/input respecting building and interpretative design (facilitated by WHW Architects).
- November 21st – Open House/input session respecting the development of a Municipal Planning Strategy Plan for the Joggins Area (facilitated by the Municipality of the County of Cumberland).

2006:

- January 30th – Community presentation and discussion respecting the new Joggins Fossil Cliffs Interpretive facility along with the overall Fossil Cliffs Development Plan. Opportunity for questions and input by the community.
- April 24th – Land use planning session as facilitated by the Municipality of the County of Cumberland (community questions, concerns and input).
- December 18th – Completion of funding announcement. Community networking and input.

2007:

- March 22nd – Community Open House with all key stakeholders present. Opportunity for questions, input and networking.

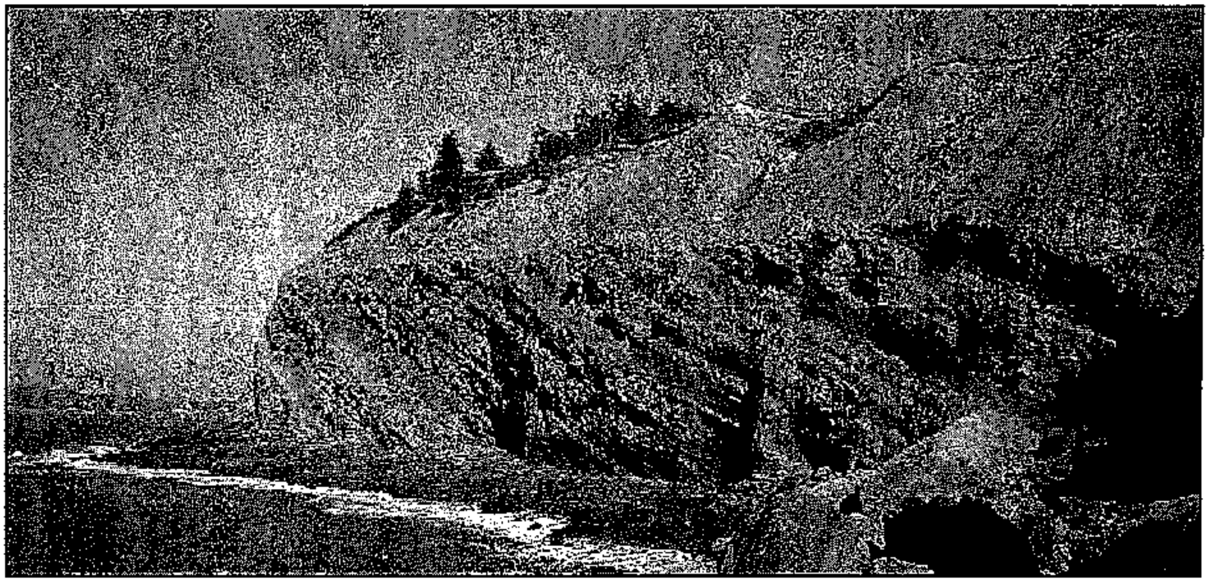
Newsletters

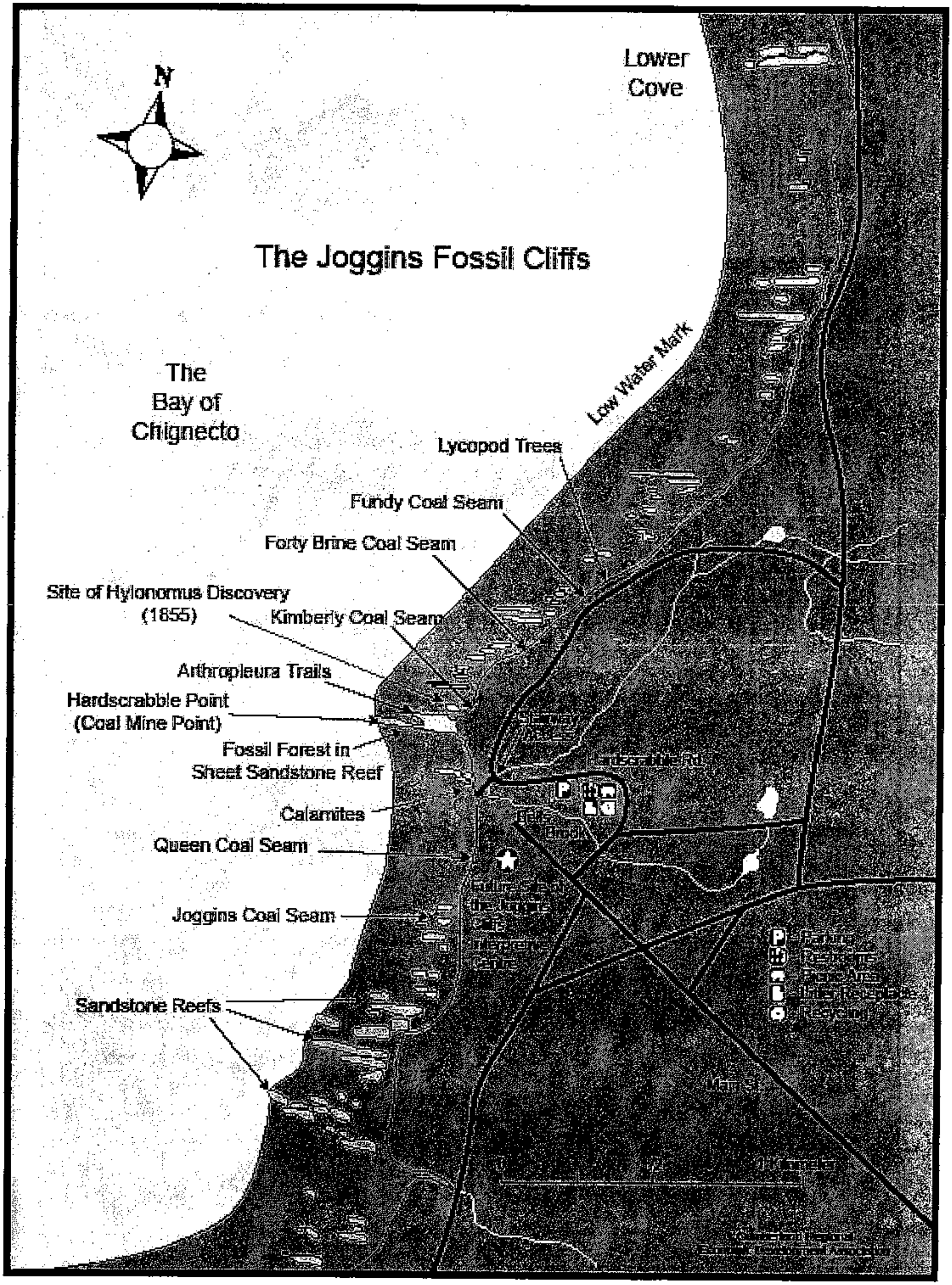
Welcome to the Joggins Fossil Cliffs NOVA SCOTIA

"A Walk Into the Past"

Located on the upper Bay of Fundy, home of the world's highest ocean tides, is the shoreline community of Joggins, Nova Scotia. This seacoast village experiences the awesome powers of the Atlantic Ocean as its waters rise and fall in excess of 15 metres (50 feet) twice daily. These great tidal forces, combined with efforts of area coal miners, led to an amazing discovery of fossils in the seacoast cliffs at Joggins. With careful observation, visitors can discover the fossils on the beach and in the multi-hued layers of the cliffs. The way to the Fossil Cliffs is well marked and parking is located approximately 100 metres from the edge of the cliff. A short walk from the parking lot leads to a flight of stairs that will take you down onto the Fossil Cliffs beach. Visitors should make inquiries as to tide times before venturing too far along the beach.

The Joggins Fossil Cliffs became world famous in the mid 1800's when Sir Charles Lyell and Sir William Dawson, during one of their excavations of a fossilized tree trunk, observed small bones in the interior of the tree. The fossilized bones were of the oldest known reptile, *Hylonomous Lyelli*. This fossil provided the first evidence that terrestrial animals had lived during the 'Coal Age'. This discovery and the discovery of plant and animal fossils became invaluable evidence to support the theory of Evolution and to serve as a palaeontological reference point where animals first began to live on land. The fossils at Joggins also provided important scientific reference for Sir Charles Darwin's theory of evolution published in his famous book, "On The Origin of Species."

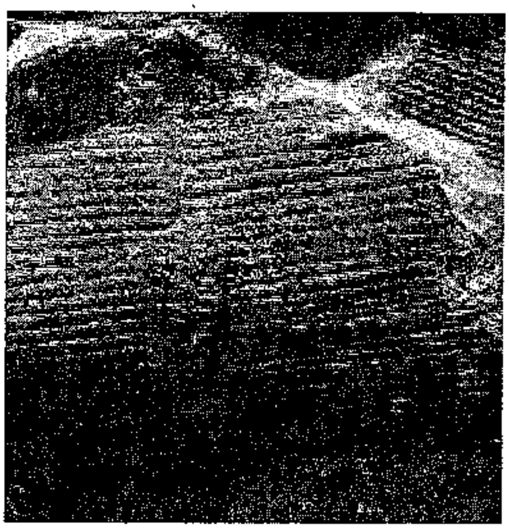



N
Lower Cove
The Joggins Fossil Cliffs
The Bay of Chignecto
Low Water Mark
Lycopod Trees
Fundy Coal Seam
Forty Brine Coal Seam
Site of Hylonomus Discovery (1855)
Kimberly Coal Seam
Arthropleura Trails
Hardscrabble Point (Coal Mine Point)
Fossil Forest in Sheet Sandstone Reef
Calamites
Queen Coal Seam
Joggins Coal Seam
Sandstone Reefs

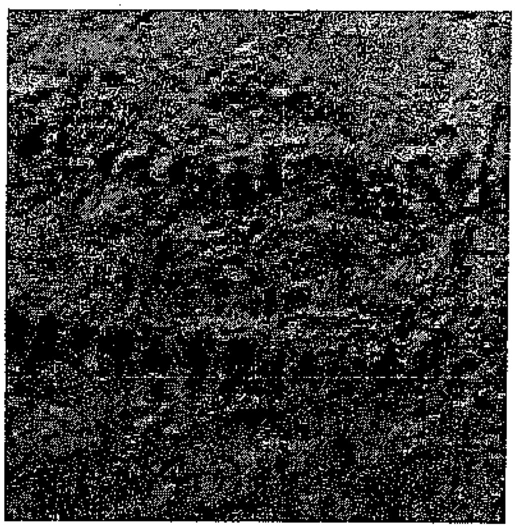
The Fossils you are most likely to come across on the beaches of the Joggins Fossil Cliffs are *Lepidodendron*, (large scale trees) *Sigillaria*, (a smaller form of scale tree) *Calamites* (seed ferns) and numerous animal track ways etched in the stone.

Lepidodendrales or scale trees (left) are ancient members of the Lycopod family of vascular plants. These ancient trees were dominant during the Carboniferous period and populated many of the swampy areas with their sometimes 30 - 40 metre-high trunks. Fossils of giants like *Lepidodendron* as well as the smaller *Sigillaria* are often found and easily recognizable by their scaly texture. Many *Lycopods* also had root organs called *Stigmaria* that once anchored their trunks into the wet soil of 'Coal Age' Joggins. These roots are also often found fossilized and share the scaly profile of the *Lepidodendrales*.

Pteridosperms or seed ferns (right) are ancient ferns from the carboniferous period that ranged in size from shrubs to miniature trees. These plants would have accounted for a significant portion of the undergrowth in the carboniferous forest. Although seed ferns look very much like 'true' ferns today, they are different in having a seed-type life cycle, bearing walnut-sized seeds that grew directly on their foliage. Fossils of ferns and seed ferns like *Mariopteris* are easily recognizable by their leafy patterns. It is believed that seed ferns were completely extinct by the time of the Mesozoic era which saw the rise of the dinosaurs.



Calamites (left) were one of the biggest carboniferous 'horsetails ferns' of the forest. Growing to 30 metres in height these ancestors of modern horse tails were common in the carboniferous swamp. Like modern day bamboo, *calamites* usually grew in clusters or thickets. Originally *calamites* were the name given to the ribbed markings on the side of their trunk but now the entire plant is known by that name. These ribbed markings make *calamites* fossils easy to identify and are among some of the more numerous fossils to be found at Joggins.



Track-ways (right) are an example of what are called trace fossils, meaning that they show evidence of the existence of a passing animal life form but do not contain fossilized remains of that creature. There are numerous types of trackways that may be found at Joggins; including those of *Belinurus* (horseshoe crabs) and *Arthropleura*, a giant millipede-like arthopod. Trace fossils can be spotted by being on the lookout for orderly patterns on the surface of rocks that resemble those that would be made by a living creature today.

Footprints (left) are another example of trace fossils but are generally more easily recognizable to human eyes because of their distinctive shape. Usually these footprints were made by amphibians or reptiles scurrying over soft ground or mud and leaving their imprints. It is not uncommon to find multiple sets of footprints in the same area and several unidentified bird-like prints have also been found.

The Joggins Fossil Cliffs are Protected under the Nova Scotia Special Places Protection Act.

In 1972, the Province of Nova Scotia designated the Joggins Fossil Cliffs as a Protected Site. A **Heritage Permit** is required to explore for or excavate fossils from or in the cliffs, reefs, bedrock and large stones on the Joggins shore and to recover fossils from this site. These fossils remain the property of the Province of Nova Scotia. Like most great things in life, fossil discoveries are best when shared with others. If you make a find that you think seems unique please bring your fossil to the Joggins Fossil Centre and/or the other institutions listed below:

Fundy Geological Museum
162 Two Islands Rd.
Parrsboro, Nova Scotia
Canada
B0M 1S0
Phone: (902) 254-3814
Toll Free: 1-866-856-DINO
Fax : (902) 254-3666

or the

Nova Scotia Museum of Natural History
1747 Summer St.
Halifax, Nova Scotia
Canada
B3H 3A6
Phone: (902) 424-6512
Fax: 902-424-0560

Safety and Enjoyment

The Fossil Cliffs of Joggins are beautiful, however they are inherently dangerous. Here you have the world's most powerful tides and towering cliffs of unstable sedimentary rock that are constantly eroding and crumbling to the beach below. However, if you are aware of potential hazards and associated safety recommendations, then you can enjoy your experience at the Joggins Fossil Cliffs with little or no danger.

A few safety measures to keep in mind:

- Stay away from the cliff edges. The cliffs are actively eroding and unstable. Ensure you are aware of the over hangs above and a hard hat should be worn if you venture close to the cliffs.
- Be careful of the cobblestones beaches and reefs. Wet, loose and/or seaweed covered rocks underfoot are a hazard. Wear appropriate footwear. Avoid walking on seaweed and wet loose rocks.
- Check the tide charts for the area. Try to leave the beach about two hours before high tide. The best time to visit the site is from mid-tide to mid-tide (approximately between three hours to low-tide and three hours to high tide).
- The weather can be extreme on the beach. Dress in layers and consider carrying a bottle of water with you.
- Cell phone coverage on the Joggins shore can be spotty. It is a good idea to let someone know when you are expected to be off the beach.
- It is also a good idea to use the "buddy system" (travelling in pairs) while exploring the Joggins Fossil Cliffs.
- Ensure that children are under adult supervision.

Brought to you by: Cumberland Regional Economic Development Association & the Joggins Fossil Cliffs Project

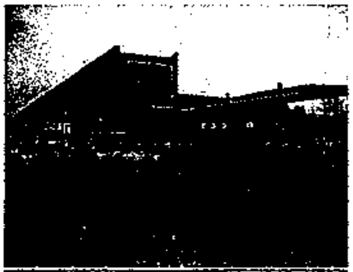
CREDA Joggins Fossil Cliffs NOVA SCOTIA

For more information, please visit: **www.fossilcliffs.net**
or call CREDA at: **(902) 667-3638**

CREDA NEWS

FALL 2006/WINTER 2007

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION



The Joggins Fossil Cliffs Interpretive Centre (above) will open Summer 2007.

Inside this issue:

Millions invested in Joggins Fossil Cliffs- Don Reid donates personal collection to new Centre

Joggins– Santa Claus arrived a week early for Joggins and area residents who packed the St. Thomas Aquinas Parish Hall on December 18 for an historic and long-anticipated announcement. Nearly $7 million in new federal and provincial capital is being invested to help create a world-class tourism and heritage site at the Joggins Fossil Cliffs.

The investments will help build an interpretive centre to showcase what is considered the world's richest and most significant Coal Age fossil site. Canada's New Government, through the Atlantic Canada Opportunities Agency (ACOA) is invested more than $4.8-million in the new centre. The Nova Scotia Department of Tourism, Culture and Heritage will invest $1.8-million.

"Our investment of over $4.8-million will boost Atlantic Canada's eco-tourism potential," said Bill Casey, MP for Cumberland-Colchester-Musquodoboit Valley on behalf of the Honourable Peter MacKay, Minister of Foreign Affairs and Minister of ACOA.

The provincial investment is in addition to $1.1-million provided in December 2005 to help leverage other funding, bringing the total provincial contribution up to $2.9-million.

"The Joggins Fossil Cliffs are a tremendous resource for Nova Scotia in terms of preserving our heritage and sharing it with the world," said Len Goucher, Minister of Tourism, Culture and Heritage. " Our investment will help develop a unique tourism experience and contribute to the efforts to get UNESCO World Heritage Site designation."

CREDA is leading the project and, with the support of the municipality of the county of Cumberland, has contributed $921,600.

"A key element of success for this project is community involvement, support and stewardship of the Joggins Fossil Cliffs site," said CREDA Executive Director Rhonda Kelly.

(..continued on page 2)

High-Speed Broadband Expansion Begins on Northumberland Shore

Northport– The expansion of high-speed broadband access to all of Nova Scotia has begun in a cluster of rural Cumberland County communities from Tidnish to Port Howe. Premier Rodney MacDonald and Richard Hurlburt, Minister of Economic Development delighted a large crowd of local residents and school children when they visited Northport Elementary School on January 3 to officially launch the pilot project for Nova Scotia.

Seaside Communications of Sydney will work with the provincial government, local communities and CREDA to develop a viable business model that can be used in other rural areas of the province. Seaside President Irving Schwartz said he was confident they could begin connecting the first wireless customers by February.

The Office of Economic Development is providing $430,000 to cover project expenses, and will lead the pilot, in partnership with representatives from the Cumberland County communities and CREDA, which submitted the successful bid for the pilot project. The business model developed here will be used to deliver broadband to the other unserved areas of Nova Scotia by 2009.

Cumberland County Repopulation Strategy Released

Placing more emphasis on education within Cumberland County will help encourage young people to stay or return as well as help build understanding of different cultures to foster immigration, says the recently completed Cumberland County Repopulation Strategy. The strategy includes a number of action items related to culture awareness and education, youth attraction, settlement services, social supports, and infrastructure. It also takes a look at the County's labour force with an eye to planning for future needs.

The study was facilitated by Mount Allison University's Rural and Small Town Programme and initiated by CREDA, with Steering Committee support from all five municipal units as well as key regional development partners. The study was carried out over a seven month period and focused on retaining and attracting young people and working toward attracting immigrants to the area.

Community meetings were held in Amherst, Springhill, Parrsboro, Oxford and Pugwash. Students at each of the County's seven high schools also added input.

Although 5000 people moved to Cumberland County between 1999 and 2004, 5,500 left the County. At the same time, the County received 83 new immigrants. Most of the people who moved into Cumberland County were between the ages of 45 - 64, typically not the ages to have young families with them.

The study found that although the County's workforce is stable at the moment, most workers are between the ages of 35 - 44. This aging workforce indicates that there will be a need to replace a number of people in the coming decade.

Key Recommendations

- Establish a multi-cultural organization and English Second Language (ESL) training
- Address the perception that immigrants would "take jobs away" from local people
- Introduce cultural diversity issues to elementary and junior high schools
- Invite settled immigrants to participate in school programs
- Create more Youth Town Councils like the one in Parrsboro
- Offer a wider variety of post-secondary training locally
- Develop a database of young people who have moved away to let them know of happenings and job opportunities locally
- Promote entrepreneurship and succession planning, building on experience gained by youth from outside local communities
- Survey youth who have moved away to determine what might be done locally to make the area more attractive
- Establish Settlement Teams in local communities. These teams would be responsible for establishing a single point of contact within each municipality where newcomers could access information about the community as well as regional information like health care, school services, government services, and more.

Study participants also noted the need for social supports for newcomers, appropriate and affordable housing, more daycare service and more widespread family resources, cleaning up or removing derelict properties, better access roads to rural areas, and the availability and provision of high speed internet and broadband..

Governments invest $7-million in Joggins Fossil Cliffs

Continued from page 1...

Once completed in 2007, the centre will house the best collection in the world of carboniferous fossils, thanks to local collector Don Reid. The always modest Reid received a standing ovation when it was announced that he was donating his entire collection to the Joggins Fossil Institute. Reid has been displaying his personal collection at his own centre in Joggins, but he plans to shut it down when the new one opens.

"When I first started I didn't know what I was doing," he said. "I still kept collecting because I liked the look of them," Reid said in a recent interview.

Jenna Boon, Senior Project Manager, said Reid's collection is vital to the project. In fact, she said, the interpretive centre has been designed around it.

The green design interpretive centre will feature a vegetation roof and will utilize a wind tower and solar panels to provide alternative energy sources. Once completed, the centre is expected to employ approximately 10 people on a full or part time basis. Based on existing visitor statistics, estimated initial visitation is 40,000 annually.

Bay of Fundy Tourism wins Green Award

The Bay of Fundy Tourism Partnership sailed away from the Tourism Industry Association of Canada annual conference in Jasper, Alberta, as the winner of a prestigious national award for sustainable tourism. The award, sponsored by Parks Canada and the Globe & Mail, recognizes the Bay of Fundy Tourism Partnership's innovative eco-business program.

"This year our membership (which includes accommodations, attractions and adventures around the Bay in Nova Scotia and New Brunswick) voluntarily adopted a green business program that includes comprehensive on-site environmental reviews of their businesses," notes Bay of Fundy co-chair, David Beattie. "The objective of the program is to reduce our environmental impacts on the Bay by reducing pollution and waste, conserving water and energy, and protecting its natural beauty."

The Eco-Efficiency Centre (an educational and environmental management outreach centre of Dalhousie University's Faculty of Management) designed and delivered this customized green business program for this group of Bay of Fundy Tourism Business operators in Nova Scotia and New Brunswick. Tourism business operators participating in the program in Cumberland County included: Cape Chignecto Provincial Park, Driftwood Park Retreat, Cape d'Or Lighthouse (all in the Advocate area) as well as the Fundy Geological Museum, Gillespie House Inn and Evangeline Tower Bed and Breakfast in Parrsboro.

The Eco-Business Program augments the current *Bay of Fundy Recommended Experiences* quality program and presents practical ways for Fundy tourism businesses to incorporate best environmental management practices into their day-to-day operations on an ongoing basis. The Eco-Efficiency Centre's Eco-Business program is one of the only programs of its kind in Canada and this award recognizes its applicability to the tourism sector.

In Nova Scotia, the Bay of Fundy Tourism Partnership is supported by the Department of Tourism, Culture and Heritage, the Tourism Industry Association of Nova Scotia, Central Nova Tourism Association, Evangeline Trail Tourism Association (Destination Southwest Nova), CREDA, Colchester and Hants RDAs, as well as by its member businesses.

News from around Cumberland County

Advocate Harbour– Some of Cumberland County's rugged back roads proved to be a good testing ground for a pair of new General Motors pickup trucks recently. GM chose our area to host a portion of a November Canadian press launch for it's new Chevrolet Silverado and GMC Sierra pickup trucks. The junket took the automotive writers from across Canada to the Joggins Fossil Cliffs and to Advocate Harbour where the trucks were actually driven down the steep road to the Lightkeeper's Kitchen. The press junket also visited Springhill, where the Community Centre was used as a staging area, as well as Fox Harb'r Resort.

Pugwash– The Village of Pugwash is heavily involved in planning for the future. The Pugwash Planning Advisory Committee will conduct a public survey of development issues and priorities early in the new year. The survey will be conducted through the Municipality of Cumberland County website. The results will assist the committee as it works with County Planner Jim Coughlin to develop a land use vision, goals, policies and regulations for the Village. Meanwhile, a separate committee with representation from the Village Commission, the business community, and the general public has begun the process of developing a Five-Year Strategic Plan for the community. The process, which is being facilitated by CREDA, will also include several community consultation sessions.

Parrsboro– A Kentville based firm, Bruce Roberts Consulting, has been selected to conduct a Waterfront Development Study and Opportunities Inventory for the Parrsboro Wharf area. The study is being done for the Parrsboro Area Harbour Commission. The Commission is seeking development opportunities that will enhance economic prosperity, contribute to the tourism assets in the area, and compliment the local eco-tourism product without adversely affecting cottagers or the current restaurant operator. Funding for the study is being provided by the Nova Scotia Office of Economic Development, ACOA and the Harbour Commission. The study got underway in November with stakeholders consultations and interviews. The consultants will also conduct a web-based survey of community residents and complete a Site Development Plan. Their recommendations will be presented to the community at a public meeting prior to acceptance by the Harbour Commission. CREDA is responsible for project management.

Oxford– Visitors to Oxford will soon be greeted by new Welcome Signs. Aaron Embree of CREDA is working with the Town on the design of the new signs.

CUMBERLAND REGIONAL
ECONOMIC DEVELOPMENT
ASSOCIATION

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www.creda.net

CREDA Is Quality System Registered to ISO 9001:2000

NHL Training Camp in Cumberland County?

Could Cumberland County be part of the proposed Bluenose League that hopes to convince up to 8 NHL teams to bring their fall training camps to various Maritime towns and small cities each September? There is no reason why not according to Consultant Kevin Cameron, a former professional hockey player and one time president of the Halifax Mooseheads. Cameron was in Cumberland County in November at the invitation of CREDA and the towns of Springhill and Amherst to tour the Springhill Community Centre and the Amherst Stadium, as well as to look at other local amenities such as accommodations and recreational and fitness facilities.

Cameron has been retained by the South West Shore Development Authority to work with the team of people looking to advance the concept of making Nova Scotia, and eventually other parts of the Atlantic region, the hockey equivalent to Florida's Grapefruit League, where major league baseball teams conduct their spring training camps each spring. Frank Anderson of SWSDA says the fact that Yarmouth has successfully hosted the New York Islanders training camp for the past two Septembers is proof to other teams that small rural communities can fulfill their needs. During the camp the Islanders played two exhibition games against the Boston Bruins in Halifax and Moncton. The Ottawa Senators, Toronto Maple Leafs, Montreal Canadiens and Pittsburgh Penguins also played exhibition games in the region this past September.

The group that is pursuing the idea of more camps and exhibition games in the province is in the process of putting together a business plan. They've approached NHL teams and they're also approaching communities in Nova Scotia on the subject of hosting an NHL camp. Its hoped that another three NHL teams will hold their camps in the province in 2007, with more to follow in succeeding years.

Career Resource Centre Fall "Job Fair" A Success

Amherst—The Career Resource Centre (CRC) hosted another very successful Community Job Fair November 8th at the Lion's Community Centre in Amherst.

A total of 20 local employers from manufacturing, retail, tourism and other sectors were represented at the job fair. Four educational organizations were also on-site to assist job seekers in determining options for additional education.

More than 100 people attended the event, which was an excellent opportunity for community residents to meet and talk to the individuals who are responsible for hiring staff.

Not only could the job seeker determine the skills and abilities required by a particular employer, but they also heard first hand what that employer looks for in an employee.

There is strong evidence that these Job Fairs really work. Statistics compiled by the CRC show that at least 11 individuals found employment as a direct result of the contacts they made at the previous Job Fair held in June, 2006.

Located in the Cumberland Economic Resource Centre at 35 Church Street, Amherst the Career Resource Centre is an initiative funded by Service Canada and sponsored by the Cumberland Regional Economic Development Association.

Job seekers explore employment opportunities during the recent CRC Job Fair.

Trained staff is available to assist clients, while services include computers with internet access and software for employment and career research, resumes, and cover letters. The CRC also offers an Employment Opportunities Board that is updated daily, faxing and photocopying of resumes, 7 local and provincial newspapers, Career Counselling and Mentoring Services, periodic workshops, and Portfolio Development Courses.

Resources available include books, magazines, pamphlets, as well as information on educational programs, labour markets and business.

CLIFF NOTES

JOGGINS FOSSIL INSTITUTE NEWSLETTER February 2007

Millions invested in Fossil Cliffs Project

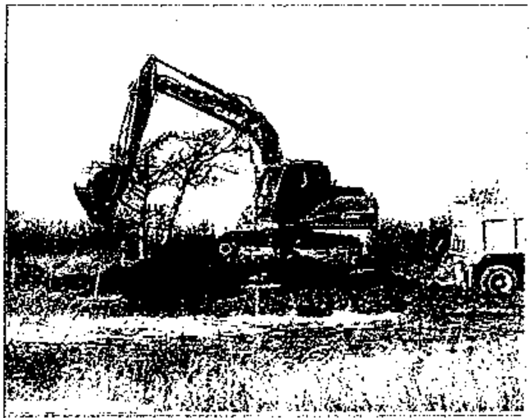
JOGGINS- Santa Claus came a week early for Joggins and area residents who packed the St. Thomas Aquinas Parish Hall on Monday, December 18 for an historic and long-anticipated announcement. Nearly $7 million in new federal and provincial capital is being invested to help create a world-class tourism and heritage site at the Joggins Fossil Cliffs.

The investments will help build an interpretive centre to showcase what is considered the world's richest and most significant Coal Age fossil site. Canada's New Government, through the Atlantic Canada Opportunities Agency (ACOA) is investing more than $4.8-million in the new centre. The Nova Scotia Department of Tourism, Culture and Heritage will invest $1.8-million.

"Our investment of over $4.8-million will boost Atlantic Canada's eco-tourism potential," said Bill Casey, MP for Cumberland-Colchester-Musquodoboit Valley on behalf of the Honourable Peter MacKay, Minister of Foreign Affairs and Minister of ACOA.

The provincial investment is in addition to $1.1-million provided in December 2005 to help leverage other funding, bringing the total provincial contribution up to $2.9-million.

"The Joggins Fossil Cliffs are a tremendous resource for Nova Scotia in terms of preserving our heritage and sharing it with the world," said Len Goucher, Minister of Tourism, Culture and Heritage. " Our investment will help develop a unique tourism experience and contribute to the efforts to get UNESCO World Heritage Site designation."



Work has gotten underway on the Joggins Fossil Cliffs Interpretive Centre (above) scheduled to open this summer.

CREDA is leading the project and, with the support of the municipality of the county of Cumberland, has contributed $921,600.

"A key element of success for this project is community involvement, support and stewardship of the Joggins Fossil Cliffs site," said CREDA Executive Director Rhonda Kelly.

Once completed, the centre will house the best collection in the world of carboniferous fossils, thanks to local collector Don Reid. The always modest Reid received a standing ovation when it was announced that he was donating his entire collection to the Joggins Fossil Institute. Reid has been displaying his personal collection at his own centre in Joggins, but he plans to shut it down when the new one opens.

"When I first started I didn't know what I was doing," he said. "I still kept collecting because I liked the look of them," Reid (pictured below) said in a recent interview.

A Halifax based company, Pomerleau Construction was the successful bidder when tenders for the project closed. WHW Architects of Halifax is the lead architectural and design firm, while Design and Communications Inc. (D+C) of Montreal is the major subcontractor responsible for interpretive planning and design.

MT&L Public Relations Limited was retained to develop a new logo for the Fossil Cliffs site as well as a Marketing and Communications Plan.

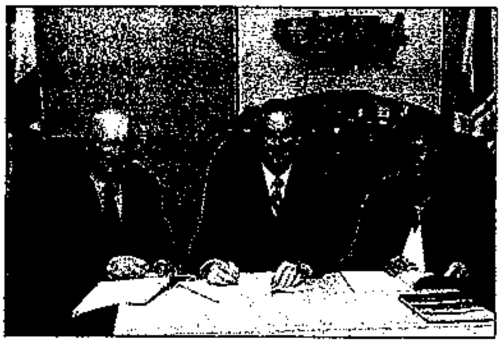
Local fossil collector Don Reid

Joggins Nomination Dossier delivered to World Heritage Centre in Paris

Paris- One of the greatest challenges faced by the project has been the development of the "Nomination for Inscription" also known as the Nomination Dossier. Once Canada placed the Joggins Fossil Cliffs on its Tentative List, work began immediately on developing the document which is a necessary step to achieving World Heritage Site designation. The Nomination Dossier (cover page pictured here) was completed in late January and has been presented to the World Heritage Centre in Paris for review and to ensure that it is complete and that the submitting party has followed the procedures correctly.

The World Heritage Centre then sends it to the appropriate advisory bodies for evaluation. Once a site has been nominated and evaluated, it is up to the intergovernmental World Heritage Committee to make the final decision on its inscription. The committee meets annually to decide which sites will be inscribed on the World Heritage List.

The Nomination Dossier is a 136-page document that could be compared to a scientific textbook in many ways. With 22 binders of appendix materials, the nomination fills a 31.5 by 13.5 by 12 inch oak case that weights, when full, approximately 50 pounds. As UNESCO requires 3 copies of everything, three wooden cases were hand delivered to the World Heritage Centre in Paris by Senior Project Manager Jenna Boon. It was more cost effective to personally deliver the Nomination Dossier than to send it by courier. This also ensured that it was there by February 1st, which was the deadline for submitting nominations for 2007.



One of the final tasks prior to submitting the Nomination Dossier to UNESCO was to have it officially signed by the sponsoring "State Parties" including the Government of Canada and the Province of Nova Scotia. Premier Rodney MacDonald is shown (centre) in the photo above during an official signing ceremony in Halifax on January 23rd. Also pictured preparing to sign are Cumberland County Warden Keith Hunter (left) and CREDA Executive Director Rhonda Kelly.

River Hebert— Premier Rodney MacDonald recently visited participants in the Joggins Fossil Cliffs Essential Skills Development and Training Program held at the River Hebert District High School. The Premier was accompanied by Justice Minister and Cumberland South MLA Murray Scott.

Fifteen participants are involved in the 26-week program which was designed to help individuals gain successful employment in the tourism sector within Cumberland County. Topics being covered include general knowledge of the industry, local knowledge of the community, customer service, communications, and a wide range of professional skills. Specific training related to the Geology of Joggins and the surrounding area will also make up a portion of the curriculum. Students will gain practical experience with a six-week work placement within the tourism industry.

Funding partners for the CREDA initiated project include the Nova Scotia Department of Community Services, Service Canada and the Atlantic Canada Opportunities Agency (ACOA). Delivering partners include Nova Scotia Community College-Cumberland Campus and River Hebert District High School.

The unique partnership with the high school will result in the development of a Student Wellness Centre. Students will help design the centre which will provide them with a relaxing, non-threatening environment where they can get assistance with courses, career planning, health information, and information to assist with other issues. All of the equipment purchased for the tourism training program will be donated to the high school at the end of the program.

Shown above with the Joggins Nomination Dossier are from left to right: Cumberland South MLA Murray Scott; CREDA Executive Director Rhonda Kelly; Jenna Boon, Senior Project Manager; Dr. John Calder, Senior Geologist NS Department of Natural Resources; Premier Rodney MacDonald; and Cumberland County Warden Keith Hunter.

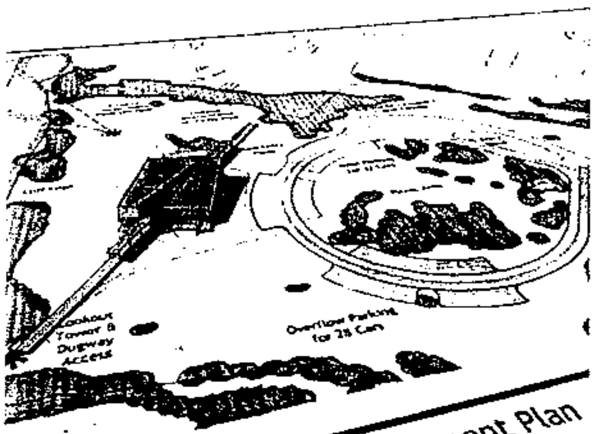
CREDA NEWS

Cumberland Regional Economic Development Association

SPRING 2006

Summer start date anticipated for construction of Fossil Cliffs Interpretive Centre

JOGGINS- After approximately 10 years of development work and planning, construction is scheduled to get underway this summer on a world-class interpretive centre for the Joggins Fossil Cliffs. According to Jenna Boon, Senior Project Manager, the construction drawings for the 13,000 square foot centre should be completed by the end of June. Following this work tenders will be called and ground breaking is scheduled for mid-August 2006.



The overall site development plan for the Joggins Fossil Cliffs (above) shows the location of the Interpretive Centre, parking and beach access at the Dugway site.

The centre, which will open in 2007, will house a gift shop, a lab and 6,000 feet of exhibition space devoted to the significance of the cliffs. The centre is the key component of a $7.5-million project that will also see much improved access to the beach and nomination in 2007 of the Fossil Cliffs and beach area as a UNESCO Natural World Heritage Site.

The green design interpretive centre will feature a vegetation roof and a wind tower to provide electricity. Once completed, the centre is expected to employ approximately 10 people on a full or part time basis. Based on existing visitor statistics, estimated initial visitation is 40,000 annually.

Meanwhile, three summer students have been hired to assist visitors to the Cliffs and conduct research in preparation for UNESCO nomination.

(See Joggins-page 4)

The case to prove that Joggins should become a **World Heritage Site** will be argued on several fronts, including mining history, historical and international interest. The main 'pillars' of the case will be:

-The Site: a dramatic cliff section accessible to the visitor.

-The Fossil Record: the best example in the world of life on land in the 'Coal Age', over 300 million years ago, including standing trees of the ancient wetlands that gave rise to coal deposits, and the oldest example in the world of a fossil reptile.

-The Geological Record: the vast layers of rock in which the fossils are found are the best exposure of coal-bearing rocks from the Coal Age found anywhere in the world.

-The History of Science: interpretation of the cliffs at Joggins and their fossils was used by some of history's most important scientists, including Sir Charles Lyell, founder of the principles of geology and Charles Darwin, who wrote of Joggins in The Origin of Species, the book that defined the theory of evolution.

Woodland Owners Conference a big success

Springhill-Approximately 150 people gathered at the beautiful new Community Centre in Springhill on Saturday, April 8th for the annual Central Woodland Owner Conference. The conference attracted people from all over the mainland with an interest in the future of our privately owned woodlands. Participants were treated to displays of 15 exhibitors, a wonderful home-made lunch provided by the Community Centre Auxiliary and a wide variety of interesting speakers. There were also draws for several great prizes including a GPS unit and a chain saw.

(..continued on page 4)

NEWS BRIEFS

Investment and Trade Canada has approved CREDA's regional application under the Community Investment and Trade (CISP) Program. CREDA has received Youth Internship funding to employ Janet Smith, a recent graduate of St. Mary's University as a Junior Development Officer. Janet is currently working on a Cumberland Community Profile and gathering and assessing data from Statistics Canada. Terms of Reference are being developed for a Sector Strategy Study to determine areas of opportunity for the Cumberland economy appropriate for Foreign Direct Investment.

Repopulation-CREDA and the five municipal units are partnering to develop a regional repopulation strategy for Cumberland County. Key components of the strategy will include youth recruitment and immigration. A repopulation committee has been formed to lead the process, which is being facilitated by the Rural and Small Town Programme at Mount Allison University. The committee is involving communities in helping to formulate the strategy through focus group discussion and by talking with immigrants who have settled in the region.

Downtown Amherst Mural Project– The Downtown Amherst Revitalization Society (DARS) is making plans for a new mural depicting the Great Amherst Mystery. The mural will be initiated this year on a downtown building yet to be announced. It will be the 12th mural undertaken since the Amherst Mural Project began in 1996. Ongoing beautification of the downtown will continue with additional tree sculptures, a sandstone sculpture and new entrance signage.

Parrsboro - The Sustainable Tourism Committee officially unveiled the town's new brand image- ***Parrsboro Rocks*** -before a packed reception on April 24 at the Fundy Geological Museum. The new logo, designed by the consulting firm Impact Performance Group, will now be featured on Parrsboro's promotional material as well as on new "Welcome to Parrsboro" signs at the town's entrances.

Oxford– Service Nova Scotia and Municipal Relations has approved more than $8200 in Community ACCESS-ability Program funding for upgrades to the Capitol Theatre. The funding will help pay for barrier free washrooms, a second stairway to the balcony as well as a wheelchair accessible entrance ramp. CREDA Development Officer Amy Smith was able to obtain the funding for the Capitol Theatre Committee.

CREDA's MISSION

"Creating an environment which facilitates sustainable economic growth in the Cumberland Region in partnership with all municipal units."

Lt. Gen. Roméo Dallaire Honourary Patron of the Pugwash Peace Exchange

Pugwash Peace Exchange launches website

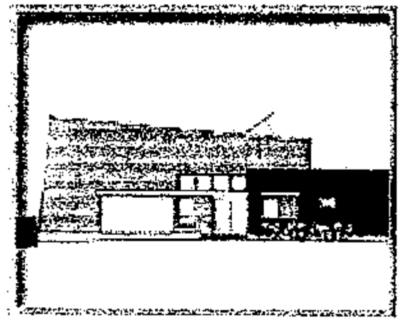
Pugwash– The Pugwash Peace Exchange has reached another milestone with the launching of a website. The website will be used as a major fundraising tool in efforts to construct a 9,000 square foot interpretive, educational and research centre and to refurbish key buildings associated with the first Pugwash Peace Conference hosted by Cyrus Eaton in 1957. The website illustrates the multiple facets of the Peace Exchange from the history of the Pugwash Conferences on Science and World Affairs to the present goals of the project and the people involved, such as their Honourary Patron Lieutenant-General Roméo Dallaire. As well, it outlines upcoming events, news, and provides a "Youth Zone" page. Memberships can be purchased via the website, and donations accepted online. The site was created by Splash Marketing and funding for it's creation was secured by CREDA from the Nova Scotia Office of Economic Development and ACOA. The address is: www.pugwashpeaceexchange.org

Cape Chignecto Provincial Park enters 9th season

Advocate Harbour- Cape Chignecto Provincial Park in Advocate Harbour opened for the 2006 season on Friday, May 12. This marks the ninth season in operation for the 4200 hectare wilderness hiking and camping park that offers some of the best coastal hiking and most spectacular scenery in eastern Canada. With over 60 kilometres of trails, both back and front-country camping, wilderness cabin and bunkhouse, and a visitor centre complete with interpretation and a gift shop the park truly is a Cumberland County gem that continues to attract visitors from all over the world.

Watch for the opening late this summer of Phase Two, the day-use park at Eatonville. When completed, this part of Cape Chignecto will provide two family-accessible trail systems, viewing stations, picnic areas and a completely green solar-powered interpretive/visitor centre to be known as the Three Sisters Interpretive Centre (pictured right). The new trails and viewing stations will allow visitors safe and easy access to view some of the most spectacular scenery the Park has to offer including the Three Sisters sea stacks, Eatonville Harbour, and the raised beach at Squally Point. It's anticipated that Phase Two will be completed and opened in September.

Cape Chignecto Provincial Park is managed and operated by CREDA and a volunteer Management Board through a Management Agreement with the Nova Scotia Department of Natural Resources.



Three Sisters Interpretive Centre

CRC taking its services out to communities

Amherst– The Career Resource Centre (CRC) is now making monthly visits to Parrsboro, Springhill and Pugwash to offer on-site employment assisted services to residents of those communities.

This self-directed assistance is available one Wednesday per month from 11 am to 3:30 pm at the Parrsboro Library CAP Site, the Springhill Library CAP Site, and at the Pugwash Village Commission CAP Site.

A Career Development Officer from the CRC will be available to assist job seekers in a number of areas including résumé development, interview techniques, career directions, cover letters, networking and job searches. Group sessions are also available if enough interest is shown.

Schedules for this service are posted at the designated CAP sites. Drop-ins are welcome.

For information or to make an appointment call toll free at 1-866-667-2344 or 667-3638. Details are also available on-line at <u>**www.amherstcrc.net.**</u>

Located in the Cumberland Economic Resource Centre at 35 Church Street in Amherst, the Career Resource Centre is a self-directed facility with six internet capable computers available for career development.

The CRC also offers an Employment Opportunities Board updated daily with the latest job ads from local and regional newspapers. Various reference books, pamphlets and handouts are also available to assist people in their job search.

The Career Resource Centre is an initiative funded by Service Canada and sponsored by CREDA.

<u>CREDA STAFF</u>

-Rhonda Kelly, Executive Director

-Kathy Douglas, Administration Officer/ISO Coordinator

-Kelly Mitchell, Financial Officer

-Paul Hopper, Development Field Officer (Business)

-Charlene Tuttle, Development Field Officer (Community)

-Ron Robinson, Development Field Officer (Community)

-Aaron Embree, Development Field Officer (IT)

-Amy Smith, Development Officer (Springhill-Oxford - Parrsboro)

-Janet Smith, Jr. Development Officer (Business)

-Stephanie Ogilvie, Jr. Development Officer (Community)

-Heather Carter, Receptionist

NSF-ISR

CREDA is Quality System Registered to ISO 9001:2000

Cumberland Regional Economic Development Association

35 Church Street
PO Box 546, Amherst,
Cumberland County
Nova Scotia, Canada

Phone: 902-667-3638
Fax: 902-667-2270
Email: cerc@creda.net

We're on the Web!

www.creda.net

In addition to CREDA, the Cumberland Economic Resource Centre is also the location of the following agencies and organizations:

- **CBDC Cumberland (CDC Ltd.) 667-5700**
- **Atlantic Canada Opportunities Agency (ACOA)- part time 661-6434**
- **NS Office of Economic Development (NSOED) 667-3223**
- **Nova Scotia Advisory Council on the Status of Women 667-8948**
- **Amherst & Area Chamber of Commerce 667-8186**
- **Downtown Amherst Revitalization Society (DARS)**
- **Career Resource Centre Toll Free: 1-866-667-2344 or 667-3638**
- **Cumberland Community Access Project (CAP) Site**
- **Canada/Nova Scotia Business Service Centre Regional Office**

Joggins Fossil Cliffs -(continued from page 1)

Tide charts and brochures will be available for visitors to the fossil cliffs in June.

Meanwhile, the Municipality of the County of Cumberland has committed a significant amount of funding to Joggins in the form of a $460,800 grant. The funding, recently approved in the County's 2005/06 budget, will be spread over two years.

Woodland Owners gather in Springhill

Dr. Carson and Marion Murray Community Centre in Springhill.

(..continued from page 1)

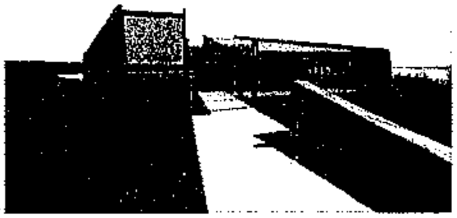
Many of the conference speakers were from Cumberland County including Murray Scott, Attorney General and Minister of Justice, MLA for Cumberland South who brought greetings on behalf of the province.

Amherst lawyer Cindy Bourgeois of Hicks Lemoine very effectively stressed the importance of being organized and documenting everything whether dealing with neighbors regarding property lines or contractors carrying out forest harvesting.

Since the conference was being held in the middle of blueberry country it was only fitting that a panel discussion be held on the use of land for blueberry production.

Amherst Chartered Accountant Susan McIsaac provided useful taxation information and tips, especially on intergenerational transfers of property. Participants also heard an informative presentation from Walter Rayworth of Rayworth & Roberts Surveys Ltd. on the various issues related to property boundary lines.

The annual conference is jointly organized through a cooperative planning effort by a number of organizations including Nova Scotia Forest Alliance, CREDA and its partner RDAs in Colchester, Pictou, Hants and Halifax Counties, the Federation of Nova Scotia Woodland Owners, and the Department of Natural Resources. Each year the conference is held in a different county throughout the region. This was the first time it was held in Cumberland.



CLIFF NOTES

A Newsletter of the Joggins Fossil Cliffs Advisory Board

January 2006

Site Development Planning Nears Completion

JOGGINS- A Halifax-based architectural and design firm, WHW Architects, have been leading the site development planning for the Joggins Fossil Cliffs. This fall a legal survey and archaeological investigation of the development site at the end of Main Street in Joggins was completed. Moreover, a backhoe was once again at the development site to complete further soil, water and subsidence testing.

Preliminary architectural plans have been completed that focus on the "Cliffs" and mining as key themes with a goal to have the interpretive centre use innovative "green building" technology. Further site development plans include opportunities for beach access via the "dug-way" behind the interpretive centre and also interpretive and visitor infrastructure near the old "Grindstone Quarry" in Lower Cove. The Centre will not only house interpretive materials but will also have a small cafe with internet access, an office for RCMP use, a multipurpose room for community use, and a gift shop.

A more detailed presentation of development plans for the Joggins Fossil Cliffs will be provided at the Community Meeting at the end of the month (Joggins Fire Hall, Monday January 30th from 7-9 pm).

Municipal Planning Underway for Joggins Area

Approximately forty Joggins and area residents attended an Open House at the Joggins Fire Hall on November 21, 2005. Sponsored by the Municipality of Cumberland and the Joggins Area Planning Advisory Committee, the Open House was held to consider potential changes to the County's Municipal Planning Strategy and Land Use Bylaw as they will affect the Joggins area. Specifically, the County is updating those planning documents to ensure that future land uses and forms of development in the vicinity of the Joggins Fossil Cliffs will be appropriate and compatible with potential UNESCO World Heritage Site designation and to ensure that all future growth and development in the area will reflect the goals and priorities of local community members.

The Open House provided an opportunity for residents to share with the Joggins Area Planning Advisory Committee and county staff their ideas about the future planning of their community. Jim Coughlin, Planner for the Municipality said that residents' feedback was generally supportive of what the Committee is doing. Comments and questions were generally for clarification as to this Committee's mandate in comparison to that of the Joggins Fossil Cliffs Advisory Board and action teams.

Many comments dealt with ideas for the design and impact of the Joggins Fossil Cliffs project and related facilities such as providing for parking and accommodations for tourists, good access to the beach for pedestrians and people with disabilities, and job opportunities for Joggins' youth.

With regards to planning for the broader community, residents were supportive of protecting views of the cliffs for the community through height and land use controls, but not strict architectural controls, and higher levels of maintenance of both public and private properties. Overall, the opinion was consistently expressed that local residents should continue to have free and open access to the beach and traditional use of their own properties.

Since the November open house, the Committee has been drafting a planning strategy to reflect the public comments and to support the development of the Fossil Cliffs as a World Heritage Site. The Committee hopes to have a draft of this strategy, as well as suggested Land Use By-Law amendments to implement the strategy, ready for review by community members in February. Afterwards, the strategy and By-Law amendments will be recommended to Municipal Council for formal adoption. Public consultation and involvement will continue throughout this process.

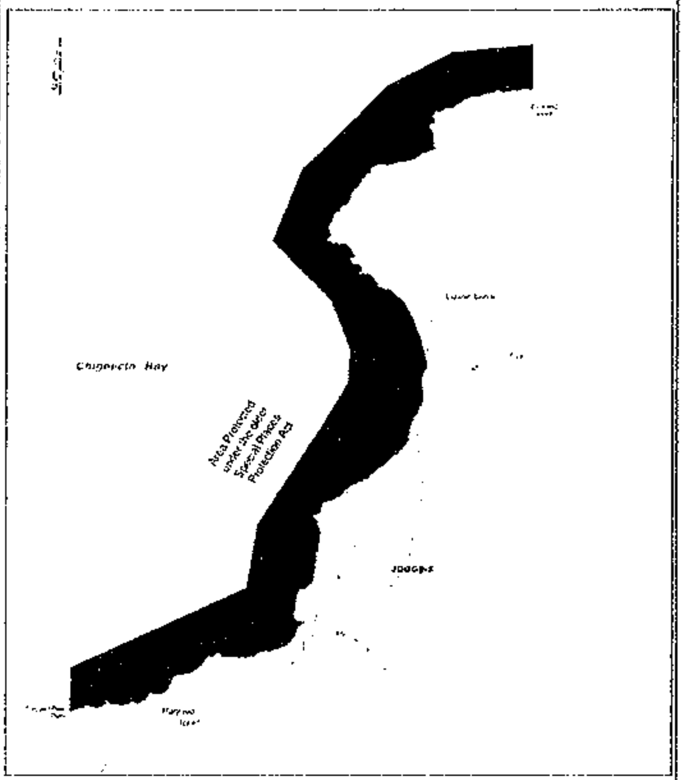
Members of the Joggins Area Planning Committee are: Edna Boon, Shelley G. Hoeg and Bill Fairbanks, (Community Representatives) Councillors John Reid, John Kellegrew and Gerald Read and County staff including Steve Ferguson and Jim Coughlin.

JOGGINS FOSSIL CLIFFS COMMUNITY MEETING

MONDAY, JANUARY 30
JOGGINS FIRE HALL
7:00– 9:00 P.M.

Residents will be provided with a detailed presentation of the development plans for the new Joggins Fossil Cliffs Interpretive Centre and on the overall Fossil Cliffs Development Plan

Refreshments will be served by the Joggins Fire Department Ladies Auxiliary



In support of the UNESCO World Heritage designation bid, the Nova Scotia government is considering expanding the extent of the Special Places Protection from the area shown in red to include the area extending from Ragged Reef to Downing Cove. For inquiries regarding the proposed extension of the Special Places Protection area call Robert Ogilvie, Nova Scotia Department of Tourism, Culture & Heritage at 902-424-6475.

The Joggins Fossil Cliffs Advisory Board has approved a new fossil collection policy for the Joggins Fossil Cliffs site. For more information visit our website @**www.fossilcliffs.net.**

Imagine the Fossil Cliffs Contest Winner

The Joggins Fossil Cliffs Advisory Board and CREDA have announced the winner of the "Imagine the Joggins Fossil Cliffs" contest. Darlene Strong of Amherst won the $500 cash prize after her submission was selected from a number of entries received during the three month contest that ran from July to October, 2005. Ms. Strong's entry, which included an essay titled "If the Cliffs Could Speak" and an original painting, was chosen by a panel of judges based on originality, creativity, concept and presentation.

The winning entry can be viewed at www.fossilcliffs.net.

Community Education and Skills Development Program– A portion of the funding has been secured for delivering a skills development program for community members. The program will focus on essential skills, entrepreneurship, customer service, basic paleontology, and tourism. We expect a start date early this spring.

Joggins Fossil Cliffs Project Team

The Joggins Fossil Cliffs project team includes numerous dedicated individuals from all levels of government including Parks Canada, the Atlantic Canada Opportunities Agency, the provincial departments of Natural Resources, Economic Development and Tourism Culture and Heritage, councillors and staff from the Municipality of the County of Cumberland, members of the scientific community, the Central Nova Scotia Tourism Association, Fundy Geological Museum, and representatives from the community. These individuals are working with the Cumberland Regional Economic Development Association (CREDA) to develop the Fossil Cliffs and submit application to UNESCO for World Heritage Designation.

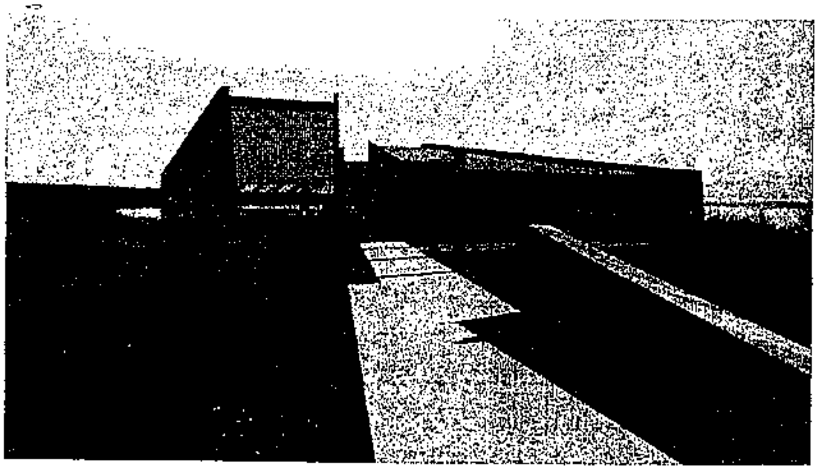
With the support of Service Canada, CREDA and the Joggins Fossil Cliffs Advisory Board have recently hired Mr. Donald Agnew as a Research Assistant to the Senior Project Manager for the Joggins Fossil Cliffs development. Mr. Agnew will be working in concert with CREDA and the Joggins Fossil Cliffs Advisory Board in preparation for the World Heritage Site nomination and as an aid to the Joggins Fossil Cliffs tourism sites currently in place.

Until recently, Mr. Agnew was a resident of the River Hebert/Joggins area and still has many family ties to the communities. He has been employed professionally as a graphic designer with several well known Cumberland County companies for the past ten years, as well as having been employed in the past with the tourism industry and Canada Post. Donald will be working two days a week in River Hebert at the Health Centre and the remainder of the week in Amherst at the CREDA office.

NOVA SCOTIA Canada

CREDA

CUMBERLAND REGIONAL
ECONOMIC DEVELOPMENT
ASSOCIATION



JOGGINS FOSSIL CLIFFS COMMUNITY MEETING

MONDAY, JANUARY 30
7:00-9:00 P.M.
JOGGINS FIRE HALL

The Cumberland Regional Economic Development Association, the Joggins Fossil Cliffs Advisory Board and the Municipality of Cumberland County will be on hand to provide residents with a detailed presentation of the development plans for the new Joggins Fossil Cliffs Interpretive Centre and to provide details on the overall Joggins Fossil Cliffs Development Site.

REFRESHMENTS WILL BE SERVED BY THE JOGGINS FIRE DEPARTMENT LADIES AUXILIARY

CREDA

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

CREDA NEWS

SPRING /SUMMER 2005

SENIOR PROJECT MANAGER CHOSEN FOR JOGGINS FOSSIL CLIFFS INITIATIVE

Joggins, NS– CREDA and the Joggins Fossil Cliffs Advisory Board recently announced the hiring of a senior project manager to oversee all components required to ready the Joggins Fossil Cliffs for nomination as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site.

The successful candidate, Jenna Boon, is a highly-qualified and skilled young professional, who is returning to the community where she spent her youth to manage this massive project. Her professional experience and educational background is related directly to natural resource management.

Ms. Boon will report to the advisory board, which is a subcommittee of CREDA, through executive director, Rhonda Kelly. "Ms. Boon will be responsible for overall planning, management and coordination of the UNESCO World Heritage Site nomination process," said Ms. Kelly. "She will also manage other aspects of the project, including the development of a $6-million Interpretive Centre, a site development plan, and beach access at the Dugway site."

Since 2002, Ms. Boon has been Manager of the Engineering, Trades and Technology Department at Holland College in Charlottetown, PEI during which time she has also served as Project Coordinator for developing a trades strategy for the province. Prior to returning to the Maritimes in 2002, Ms. Boon worked as Program Director of the Technology Division for the Saskatchewan Institute of Applied Science and Technology (SIAST).

(continued on page 3..)

Broadband Project Connects Communities

The Connecting Cumberland Broadband Project to bring high speed Internet to a number of previously unserved Cumberland County communities has wrapped up the installation phase of the project. Joggins and Malagash are the latest communities to be brought on line.

They join Pugwash, Wallace, Parrsboro, Advocate, Port Greville, River Hebert and Wentworth, the other communities that have been lit up as a result of this initiative.

CREDA, acting as community champion, was one of 33 applicants selected from across Canada to further advance the implementation of broadband to First Nations, northern and rural communities. An initiative of Industry Canada, this pilot program was also funded by Aliant, ACOA, the Municipality of the County of Cumberland, the town of Parrsboro, Nova Scotia Office of Economic Development and the Community Access Network.

A worker is shown (right) installing equipment to deliver high-speed Internet to Joggins.

CREDA Projects & Activities File

Oxford's Strategic Plan Being Drafted

Oxford- The Town of Oxford is in the process of drafting a new Five-Year Strategic Plan for the community. The Town, through its Community Enhancement Committee, has been working with residents, business owners/ operators, and other community stakeholders since January on a strategic planning process designed to lay the framework for a more prosperous future for the community and its residents. The community-based strategic planning initiative is being facilitated by CREDA.

The planning process has involved numerous meetings of the Community Enhancement Committee, at which a number of planning exercises were initiated. These included the creation of a Community Vision; a SWOTs Analysis to define the strengths, weaknesses, opportunities and threats in the community; identifying and ranking the Town's strategic issues; and developing and implementing action plans to address those issues.

The general public was invited to play an active role in the process by attending several community-based strategic planning sessions and going through a number of the same exercises to ensure that everyone was in agreement on what the Town's priorities should be.

It's anticipated that the Strategic Plan will be completed by early autumn.

Cape Chignecto Opens Early

Advocate Harbour- Cape Chignecto Provincial Park opened for the 2005 season on May 13. It was the earliest opening date yet for the park, which is now in its 10th season of operation. All park users, including local residents, are reminded that they must register at the Red Rocks Visitor Centre in West Advocate prior to entering Cape Chignecto. This is necessary for emergency protocols. It is absolutely essential that staff know at all times how many people are in the park as well as their general location. This information is critical in the slight chance that an emergency such as a forest fire requires the evacuation of the park, or if a serious injury should occur. While at the Visitor Centre check out the great selection of Cape Chignecto logo wear and other items in the well-stocked gift shop.

Meanwhile, work progresses on Phase 2 in the Eatonville-Three Sisters area. Scheduled for completion in time for the 2006 season, Phase 2 involves the construction of shorter, family oriented day-use coastal walking trails, scenic viewpoints, family picnic areas, and a renewable energy Visitor Information & Interpretation Centre.

CREDA hosts "Come To Life" Branding Workshop"

Amherst- Municipal governments, the private sector, individuals, community groups, and not-for-profit organizations and associations in Cumberland County are being encouraged to communicate Nova Scotia's great story and distinct attributes to the world.

The Office of Economic Development and Bristol Communications kicked off a province-wide tour to promote Nova Scotia's new brand "Come to Life" in Amherst on June 22. The three-hour Branding Workshop, held at Tantramar Theatre, was sponsored by CREDA and the Colchester Regional Development Agency (CoRDA) and brought together more than 50 participants from Cumberland and Colchester counties.

The purpose of the new brand is to help identify the province to people in Canada, the United States and around the world by promoting a clear and positive image for Nova Scotia through programs, policies and partnerships. Research has shown that people's perceptions about Nova Scotia are not always positive, and in many cases are untrue.

A group of branding and marketing experts from around the province helped develop the brand in partnership with the government. Through considerable focus testing and research, Nova Scotia's brand was developed around eight words that represent the province's key attributes – coastal, accessible, safe, genuine, dependable, resourceful, creative and innovative. The brand focuses on two things –variety and balance –that set Nova Scotia apart. The key reasons for developing a brand are to encourage economic growth, recruit or retain brain power, and to improve the quality of life for residents.

Ray Owen of the Office of Economic Development told the Amherst workshop that the brand "gives us all an opportunity to tell Nova Scotia's fantastic story to the world." She said the workshops and materials provided to participants were the "tools to do it in a focused way."

Public and private sector organizations can formalize their involvement in the initiative by signing the Brand Charter. As a signatory, each party agrees to foster the development of the brand through marketing and communications efforts and to embrace the meaning of the brand through the development of policies, programs and organizational governance.

CREDA Executive Director Rhonda Kelly, who also chairs the Nova Scotia RDA Association, said the regional development associations are very interested in working with the province to help build Nova Scotia's brand. "Certainly from our perspective, the more positive Nova Scotia is perceived by business investors, tourists, former residents, and potential immigrants the easier our jobs in community economic development become," she said.

Participants were presented with a toolkit designed to help them get the most out of the Nova Scotia brand.

Sr. Manager Named for Fossil Cliffs Project

(Continued from page 1...)

Ms. Boon also worked as an instructor in the Integrated Resource Management-Diploma Program at SIAST and as a Project Specialist for an Environmental Studies Program at Kenya Polytechnic in Africa. She established and managed her own environmental consulting business that focused on impact assessments in forestry and wildlife management. Ms. Boon graduated with honours with a Bachelor of Science degree in Physical Geography from the University of Regina.

Area county councilor John Reid, who also sits on the Fossil Cliffs Advisory Board, said he was very excited that a senior project manager has been chosen. "We are looking forward to moving this project forward and having a physical presence in the community," he added.

Economic Development Minister and Cumberland North MLA Ernie Fage said the province is very pleased to see such a talented young person returning to Nova Scotia to work in their community. "To have a Nova Scotian with all the right credentials, talent, and experience coming home and giving back to the province and their community is very important," the minister said. Cumberland South MLA and Speaker of the House Murray Scott also welcomed the announcement. "As a World Heritage Site candidate it is critical that the Joggins Fossil Cliffs has someone who has the knowledge, experience and passion for the area to take this project to the next level," he said.

The Nova Scotia departments of Tourism, Culture & Heritage; Natural Resources; and the Office of Economic Development contributed $180,000 over 3 years to assist with project management, administration, coordination and planning. The Atlantic Canada Opportunities Agency also contributed $291,257 towards the planning component of the project, which is also supported by the Municipality of the County of Cumberland.

Recently the provincial government announced a one time, $1.1-million dollar investment in the overall development of the Joggins Fossil Cliffs Interpretive Centre. The investment is being administered by CREDA and is being used to seek additional partners and leverage other public and private sector resources.

It is anticipated that the nomination will be presented to UNESCO in February 2007, followed by an 18-month evaluation process with a final decision on the prestigious designation by summer 2008.

CREDA welcomes new Executive/Board Members

Pugwash- The Cumberland Regional Economic Development Association (CREDA) elected a new executive and welcomed four new board members during the association's annual general meeting held June 15 in Pugwash.

Amherst business owner/operator Dan Burke was selected to serve another one-year term as chair, while Cumberland County municipal councilor Gerald Read of Nappan returns as vice chair. Both were selected by acclamation. Rounding out the executive are secretary Morgan Hunter of Oxford and Parrsboro town councilor Gleneida Canning, who was elected to the position of treasurer.

New board members include Larry Latta of RR 2, Amherst who was appointed by the Municipality of the County of Cumberland; Town of Parrsboro citizen appointee Ross Smith; and Irene Albertson and Raymond (Bud) Anderson, who were both appointed by the Town of Springhill.

Returning board members are: Don Smith-Cumberland County; Aubrey Chapman and Dale Fawthrop- Town of Amherst; Rose MacAloney-Parrsboro; Guy Brown-Springhill; and Paul Jones and Kent Thompson- Town of Oxford. Retiring board members Mary Lou Trenholm from Pugwash, Marjorie Sprague from Springhill, and Ron Levy, Parrsboro were honored during the meeting.

Executive Director Rhonda Kelly gave her Annual Review of CREDA's activities over the past year, touching on just some of the numerous projects the RDA is involved with, many in partnership with the municipal units. Attendees, who included board members, staff, and municipal, provincial and federal government representatives were also treated to a tour of Cyrus Eaton's Thinkers' Lodge.

Web Site/Handbook for Volunteer Organizations

Cumberland County has approximately 436 registered not-for-profit and volunteer organizations. These groups now have a valuable resource tool available to them thanks to the efforts of the Cumberland Rural Volunteer Coalition. The Cumberland Volunteer Handbook is a 77-page resource guide that is designed to answer the most common questions regarding volunteering and volunteer non-profit organizations. Copies of the Handbook are located at all branches of the Cumberland Regional Library, as well as at the five municipal offices. It can also be downloaded from the Coalition's website:

www.volunteercumberland.net. Other valuable information and resources can also be found on the website.

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

35 Church Street, P.O. Box 546
Amherst, NS B4H 4A1

Phone: 902-667-3638
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Email: cerc@creda.net
Website: www.creda.net

Our Mission:

"Creating an environment which facilitates sustainable economic growth in the Cumberland region in partnership with all municipal units."

Wallace & Area Museum Opens Expansion

Wallace– Eight years of planning , hard work and fundraising finally paid off for the Wallace and Area Museum Society on Saturday, June 11 with the grand opening of the museum expansion. More than 180 people gathered in the museum courtyard on a glorious sunny day to witness the ribbon cutting ceremony and hear from a number of dignitaries.

Guest speakers included Senator James Cowan, representing the Atlantic Canada Opportunities Agency (ACOA); the Honourable Rodney MacDonald, Minister of Tourism, Culture and Heritage; MP Bill Casey; area county councilor Gerry Langille; Architect George Rogers of McFawn & Rogers; Ron Robinson, representing CREDA; and Museum Society President Irma Reeves.

Other activities included a cake cutting ceremony, the dedication of the multi-purpose room to former treasurer Murray Reeves, the unveiling of a museum sandstone plaque recognizing the many sponsors, and the planting of an apple tree in the back garden. The $696,000 expansion, which more than doubles the size of the museum with the addition of two adjoining buildings, was made possible thanks to a multitude of funding partners. ACOA contributed more than $355,000 through its Strategic Community Investment Fund (SCIF), the province of Nova Scotia $40,000, the Wallace and Area Museum Trust Fund $182,000, and the Municipality of the County of Cumberland $20,000. In addition the Museum Society has to raise an additional $99,000 through local fundraising efforts. Human Resources and Skills Development Canada (HRSDC) also contributed to the project through its Job Creation Partnership Program.

Wallace & Area Museum Society President Irma Reeves and Senator James Cowan, representing ACOA, prepare to cut the ribbon to officially open the museum expansion, while past and present members of the Museum Society Board look on.

"Imagine the Joggins Fossil Cliffs" Contest Underway

The Joggins Fossil Cliffs Advisory Board, a sub-committee of CREDA, is inviting residents of Cumberland County to submit an original image and/or short written description that they feel represents what the world famous Joggins Fossil Cliffs mean to our county's history and future. A cash prize of $500 will be awarded to the winning entry. Visual images may be done manually or electronically (only tiff or jpg files will be accepted). Written descriptions should be typed and no longer than 250 words. The contest is open to all residents of Cumberland County regardless of their age.

Application forms are available at CAP sites around the county or online at: **www.creda.net.** The contest closes on October 1 and entries will be judged by a panel of judges based on originality, creativity, concept and presentation. Voting will close on October 15.

CLIFF NOTES

A Newsletter of the Joggins Fossil Cliffs Advisory Board

JUNE 2005

COMMUNITY UPDATED ON PROJECT STATUS AND TIMELINES

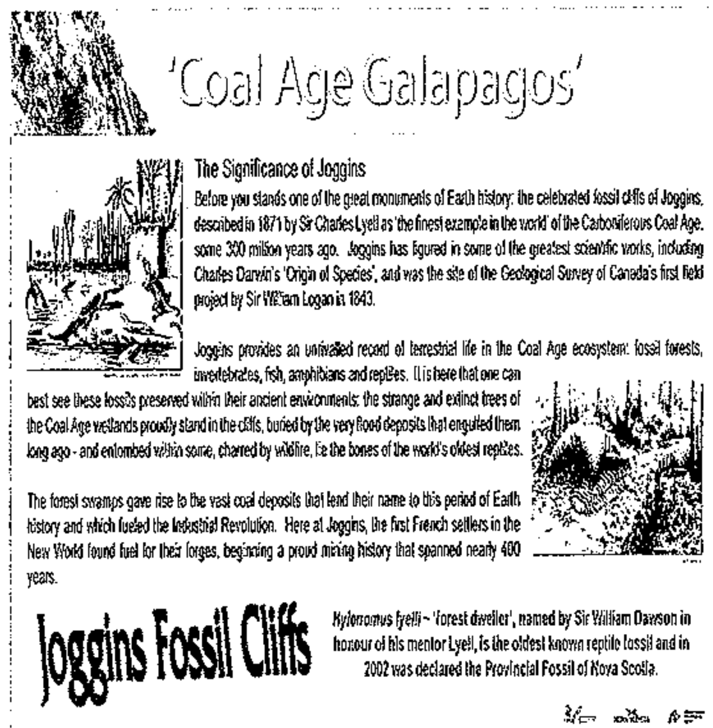
Joggins-Approximately 50 people turned out on a beautiful sunny evening on Monday, May 30 for a community meeting at the Joggins Fire Hall. The purpose of the meeting, which was put on by CREDA and the Fossil Cliffs Advisory Board, was to introduce Jenna Boon, the Senior Project Manager, to provide an update on the status of the project, and to answers any questions the public had. It was a very positive and productive meeting and the Project Manager, who spent her youth in the community was very well received.

Ms. Boon said she was extremely excited about the project. "Having lived on the fossil cliffs and having seen other UNESCO sites, I can tell you that Joggins is spectacular and is more than worthy of World Heritage Site status," she said.

CREDA Executive Director Rhonda Kelly gave an informative presentation on timelines and expectations. Now that the Advisory Board and Actions Teams and Manager are in place, she said residents can expect to see some visible activity this summer with the erection of interpretive and community signage and site clean up. In addition, a firm will be hired to prepare detailed architectural and interpretive plans for the Interpretive Centre, along with a site development plan and detailed engineering for beach access at the Dugway site. These planning activities will be completed in the fall to allow CREDA to start the process of securing the balance of funding for site development.

A training program for local residents who may be interested in working at the Interpretive Centre or pursuing entrepreneurial opportunities that may arise from the Fossil Cliffs development is hoped to be initiated in the winter or spring of 2006. The 18-month program would involve 15 to 20 participants. CREDA also hopes to secure the remaining funds required, approximately $4.5-million, by early 2006 to allow for a summer or fall ground breaking for the centre. The second half of 2006 will also see the finalization of the Nomination Dossier for submission to the Federal Government, which will in turn submit the Dossier to UNESCO early in 2007. At the same time the proposed training program would wrap up and the site development activities completed. This will allow for the opening of the Interpretive Centre in time for a community visit by UNESCO during the summer or fall of 2007.

Residents can expect regular updates on activities. The next community meeting is scheduled to take place in October or November.



New safety and interpretive signage will be appearing at the Fossil Cliffs and in the community this summer. Four new interpretive signs (including the one pictured above) and one safety sign are being erected in the Bell's Brook and Lower Cove areas. In addition a sign updating residents and visitors on the progress of the project will be placed at Don Reid's Fossil Centre and the Joggins Visitor Information Centre on Main Street.

CLIFF NOTES
JUNE 2005

NOVA SCOTIA Canada

Fossil Cliffs Project Timelines	
Today	• Senior Project Manager hired • Interpretive signage completed
Summer 2005	• Interpretive & safety signage erected • Hire firm for planning activities • Site clean-up
Fall 2005	• Completion of planning activities • Start process to secure balance of funding
Winter/Spring 2005-2006	• Initiate training program • Finalize funding
Summer/Fall 2006	• Break ground for Interpretive Centre • Submit Nomination Dossier to the federal government
Winter/Spring 2006-2007	• Submission of Nomination Dossier to UNESCO • Completion of site development • Completion of training program
Summer 2007	• Facility opening • Preparation for UNESCO community visit

Advisory Board Mandate

The mandate of the JFC Advisory Board is to facilitate and provide leadership, direction, and vision to the development of the Joggins Fossil Cliffs site towards World Heritage Status designation including, but not limited to, the following:

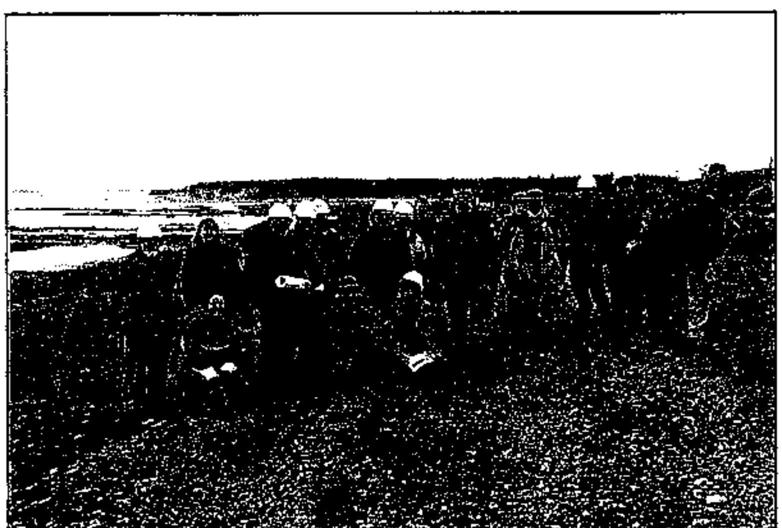
- Overseeing the design and development of a governance model (short and long term)
- Providing financial accountability
- Providing a forum for mandates/views to be shared with partners
- Monitoring and evaluation

Representatives on the Advisory Board include senior staff from provincial and federal government partners including; NS Natural Resources, NS Tourism, Culture & Heritage, NS Office of Economic Development, Parks Canada and the Atlantic Canada Opportunities Agency (ACOA). There is also representation from the Municipality of Cumberland County, the community, and CREDA.

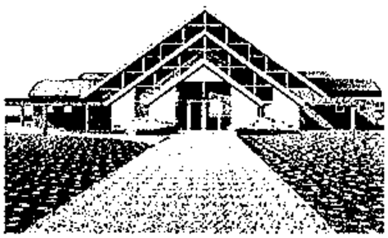
The Advisory Board has 5 action teams under the following headings: Nomination Dossier, Operational Governance & Management, Site Development, Marketing Strategy, and Land Use and Zoning.

To contact the Advisory Board phone Senior Project Manager Jenna Boon at 694-5516 or email jboon@creda.net.

Do you have an idea for an image for the Joggins Fossil Cliffs? Submit your design to the Advisory Board and you could win a $500 cash prize. Contest details and application forms will be available beginning July 4 at CAP sites throughout the county and on-line at www.creda.net.



A group of prominent geologists from Canada and the UK are shown during a field trip on May 19 to the Joggins Fossil Cliffs. The geologists were in Halifax for joint meetings and were anxious to visit the site of so many significant fossil discoveries. The field trip was led by Dr. John Calder from Nova Scotia Natural Resources, Martin Gibling of Dalhousie University, and Sarah Davies, University of Leicester, UK.



CLIFF NOTES

A Newsletter of the Joggins Fossil Cliffs Advisory Board

March 2005

Provincial/Federal funding approved for Joggins Fossil Cliffs

Joggins– In the words of Don Reid "to me this is a dream that is coming true." The man known as "the Keeper of the Cliffs" was referring to the announcement on February 18 that the provincial government is investing $1.1 million towards the development of the Joggins fossil cliffs into a unique tourism destination. Tourism, Culture & Heritage Minister Rodney MacDonald made the announcement at the Joggins Fossil Centre which houses the extensive collection of fossils Reid has gathered over more than 60 years of combing the beach.

Minister of Tourism, Culture & Heritage Rodney MacDonald presents a cheque for $1.1-million to CREDA Executive Director Rhonda Kelly while Speaker of the House Murray Scott and others look on.

"Developing the fossil cliffs into a world-class tourism product will bring tremendous economic benefits for Joggins and for Nova Scotia's tourism industry," said Mr. MacDonald. "It is also an important part of gaining the designation of a World Heritage Site."

The one-time investment will be administered by the Cumberland Regional Economic Development Association (CREDA), which is leading the project in consultation with the local community and various provincial and federal stakeholders.

Construction of a world-class interpretive centre and development of access to the beach for pedestrians and emergency vehicles are among the next steps in the project. Much of the work is expected to be completed in time for a visit from an evaluation team from the United Nations in 2006. A final decision on World Heritage status is expected in 2007.

CREDA will use this latest investment to seek additional partners and leverage other public and private sector resources. The total cost of the project is about $6 million.

The departments of Natural Resources and Economic Development are also active supporters of the fossil cliffs. Along with Tourism, Culture and Heritage they have contributed $180,000 over 3 years to assist with project management, administration, coordination and planning.

Meanwhile, the Atlantic Canada Opportunities Agency (ACOA) has announced a contribution of $300,000 under its Strategic Community Investment Fund (SCIF) Program.

The funding will allow the Joggins Fossil Cliffs Advisory Board, which is a subcommittee of CREDA, to retain a Senior Project Manager along with dedicated administrative support to facilitate, coordinate and lead the completion of the overall nomination dossier process for application to UNESCO.

The money will also pay for essential preliminary design activity including architectural and interpretive program design for the interpretive centre, a site development plan, and detailed engineering for beach access at what is known as the Dugway Site.

Other funding partners include the Municipality of Cumberland County and the local community.

International Magazine profiles Fundy Shore/Fossil Cliffs

The fossil cliffs are among the sites and attractions featured in the November/December 2004 issue of National Geographic Traveler Magazine. The article calls Cumberland County's Fundy shore from Parrsboro to Joggins one of Canada's 10 new places to love. It features several paragraphs and a 1/2 page colour photo of the fossil cliffs.

The feature quotes New Brunswick professor Bob Rosebrugh who says "the cliffs are protected, but you can easily collect fossils on the beach-just break open a rock and there might be one inside. Where else could you find beachcombing like that?"

CLIFF NOTES

March 2005

Did you know...
Interpretation of the cliffs at Joggins and their fossils was used by some of history's most important scientists, including Sir Charles Lyell, founder of the principles of geology and Charles Darwin, who wrote of Joggins in "The Origin of Species" the book that defined the theory of evolution.

New management structure to oversee development of Fossil Cliffs site

The Joggins Fossil Cliffs Transition Team has approved a new governance model. The mandate of the JFC Advisory Board is to facilitate and provide leadership, direction, and vision to the development of the Joggins Fossil Cliffs site towards World Heritage Status designation including, but not limited to, the following:

- Overseeing the design and development of a governance model (short and long term)
- Providing financial accountability
- Providing a forum for mandates/views to be shared with partners
- Monitoring and evaluation

Representatives on the Advisory Board include senior staff from provincial and federal government partners including; NS Natural Resources, NS Tourism, Culture & Heritage, NS Office of Economic Development, Parks Canada and the Atlantic Canada Opportunities Agency (ACOA). There is also representation from the Municipality of Cumberland County, the community and CREDA.

The Advisory Board has 5 action teams under the following headings:

- Nomination Dossier
- Operational Governance & Management
- Site Development
- Marketing Strategy
- Land Use and Zoning

A key priority for the Advisory Board is to retain a Senior Project Manager along with dedicated administrative support.

Community Meeting

A community meeting is being planned for late April or early May in Joggins to update residents on what's happening with the Fossil Cliffs. Watch the mail and local media for date, time and location.

CREDA

Canada

NOVA SCOTIA

Opportunity for Employment

Senior Project Manager- Joggins Fossil Cliffs Nomination Project

Reporting through the Executive Director of the Cumberland Regional Economic Development Association (CREDA) to the Joggins Fossil Cliffs Advisory Board, the Senior Project Manager will oversee all components required to ready the Joggins cliffs for nomination as a UNESCO World Heritage Site, as stipulated in the UNESCO Nomination Format.

Responsibilities and Duties
The Project Manager is responsible for overall planning, management, and coordination of the nomination process, and is accountable to the JFC Advisory Board for the accomplishment of all goals and objectives within specified time frames and budgets.

Employment Requirements

- Post secondary education in a relevant field
- Minimum of 5-7 years experience and a proven track record in project facilitation and management
- Computer literacy with spreadsheets and business systems an asset
- Demonstrated understanding of the business and community concept governing partner relationships
- Experience and/or knowledge in community economic development, tourism development, municipal government and relevant provincial and federal departments
- Technical expertise in natural history, particularly as it relates to the scientific case for Joggins, would be an asset
- Exceptional and proven communication skills with all levels of stakeholders as relevant to this initiative

Start Date: May 2, 2005. This is a 2-year full time position with potential option for renewal.

Salary Range: Commensurate with experience.

How to Apply: Send résumé with references to:
Selection Committee
Cumberland Regional Economic Development Association
P.O. Box 546, Amherst, Nova Scotia B4H 4A1

Deadline: Applications must be received by 4 p.m. March 25, 2005.

No phone calls please.

We thank all applicants for their submission; however, only those being considered for an interview will be contacted.

CREDA NEWS

Cumberland Regional Economic Development Association

FALL/WINTER 2004

Connecting Cumberland Broadband Project Up To Speed

Amherst -At a recent Connecting Cumberland Broadband Committee meeting it was revealed that the project to bring high speed internet services to several county communities is ahead of schedule. When presenting the progress report Ron MacNutt, CREDA's Broadband Administrator, indicated that the service will be available to all of the selected communities by the end of March 2005. Although there has been some delay in getting the first communities connected, work has been progressing steadily and these sites will begin activating in December and January.

Members of the Connecting Cumberland Broadband Committee are left to right: (back row) Aaron Embree, Paul Hopper, Ron MacNutt, Morgan Hunter, Gerald Langille. (Front row) Anne Newman, Kathy Langille. Missing: Gleneida Canning, Ron Levy.

CREDA, acting as Community Champion for this project, was one of 33 applicants selected from across Canada to further advance the implementation of broadband to First Nations, northern and rural communities. An initiative of Industry Canada, this pilot program will play a significant role in addressing the lack of high speed internet services in our region. The success of this project, and lessons learned, will be used to determine the best way to provide this infrastructure to the rest of the country.

Additional funding for this project is being provided by Atlantic Canada Opportunities Agency, Aliant, the Municipality of Cumberland County, Town of Parrsboro, Nova Scotia Economic Development and the C@P Community Access Network.

CREDA's Broadband Committee is planning a major public announcement and information event in Parrsboro for January 28, 2005.

Check the website at **www.creda.net/brand** for regular updates or contact Broadband Administrator Ron MacNutt at 667-3638.

CONNECTING CUMBERLAND

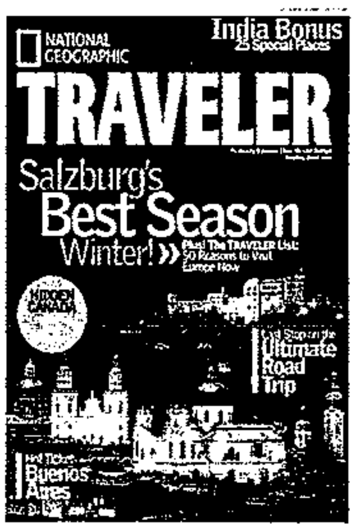
broadband for rural & northern development

National Geographic Traveler Magazine profiles Cumberland's Fundy Shore

Parrsboro -The November/ December issue of National Geographic Traveler magazine calls Cumberland County's Fundy shore from Parrsboro to Joggins one of Canada's 10 new places to love.

In the article author Barbara Peck writes, "this sweet northwestern corner, around the coastal town of Parrsboro, is more than picturesque; it's full of unusual things to see and do."

The author goes on to describe attractions such as the Fundy Geological Museum, Ship's Company Theatre, the lighthouse and light keepers



kitchen at Cape d'Or, Advocate Harbour, Cape Chignecto Provincial Park, and the Joggins Fossil Cliffs. The article, which is complimented by five beautiful photographs of the area, also mentions singer Anne Murray's hometown of Springhill.

Cumberland County Warden Keith Hunter said the article "can do nothing but good for the area. When you have a magazine like National Geographic featuring us, you get advertising that we simply could never pay for," he added. Hunter is expecting a lot more people to visit the area as a result.

The magazine reaches 5.7 million readers world wide.

CREDA News is a publication of the Cumberland Regional Economic Development Association.

Comments/suggestions: Contact Ron Robinson
Phone: 667-3638
Email: ronr@creda.net

Cumberland Regional Economic Development Association

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Our Mission:
"Creating an environment which facilitates sustainable economic growth in the Cumberland region in partnership with all municipal units"

NEW PROJECTS/STAFF

Human Resources Skills Development Canada (HRSDC) is providing funding to support Information Technology mentoring and community based IT projects for Community Access Program (CAP) sites throughout Cumberland County. The 11-month project will allow CAP sites to offer consistent hours, on-line marketing assistance for small businesses, and additional tutoring sessions for seniors and other county residents. Anne Newman has assumed the positions of CAP Technical Assistants Project Manager and Cumberland CAP Coordinator. The project is also employing 5 Tech Assistants to support the Cumberland CAP network and one Technical Coordinator who is working out of the Cumberland Regional Library. Anne is located at the Cumberland Municipal Building and can be reached by phoning 667-3853.

HRSDC has also provided funding for the Career Resources Outreach Program, which is designed to deliver the services of the Amherst-based CRC to the unemployed and under employed in other Cumberland County communities through the CAP sites. The program offers services such as résume writing, career planning, job searches, workshops, and employment counseling.

Meanwhile, Dawn Smith has joined the Career Resource Centre in the 6-month position of Older Worker Client Navigator. The project, funded through the Acadia Centre for Small Business and Entrepreneurship, is designed to provide Older Workers (aged 55-64) with the support, guidance and resources to pursue income-earning activities with the assistance of the Career Resource Centre. Dawn can be reached at 667-3638 or toll free at 888-667-2344.

Cape Chignecto Provincial Park Update

Advocate Harbour- December was a productive month for Cape Chignecto Provincial Park in Advocate Harbour with the presentation of two sizeable contributions totaling $70,000 from the Province of Nova Scotia for Phase 2 developments. Richard Hurlburt, Minister of Natural Resources and Economic Development Minister and Cumberland North MLA Ernie Fage each dropped into the CREDA office to present cheques for $35,000. Other partners making substantial contributions to Cape Chignecto include ACOA, Nova Scotia Tourism, Culture and Heritage and the Municipality of Cumberland County.

Don Fletcher, chair of the Cape Chignecto Provincial Park Management Board said he was really pleased with the funding, adding that "this kind of provincial support for the park, along with the recent publicity we received in National Geographic Traveler Magazine, will go a long ways to securing the future of the Fundy Shore as a viable international tourism destination."

Phase Two, now underway, involves the construction of shorter, family oriented day-use coastal walking trails, scenic viewpoints, shoreline access, a family picnic area, parking and access roads in the Eatonville area of the Park. Phase 2 will also see the construction of a renewable energy Visitor Information & Interpretation Centre and stairs to access the beach at the Three Sisters sea stacks, which are featured on the park logo and on clothing and other items sold at the park gift shop. Work on Phase 2 is expected to be completed by late summer of 2005.

Meanwhile, Cape Chignecto has just concluding another exciting and successful season. While tourism numbers were reported to be down in the area, Cape Chignecto continues to see growth both in the number of visitors who come to the park and in the length of time people are staying.

In its on-going efforts towards creating a world-class attraction, CREDA is working towards ISO 9001-2000 registration, which will also benefit Cape Chignecto as a key CREDA initiative. Further to this goal, the park administrator traveled to the Gros Morne Institute for Sustainable Tourism in Newfoundland to take specialized training in operating a green business. The majority of the costs for the trip were picked up by the Gros Morne Institute and Nova Scotia Tourism, Culture and Heritage.

And Cape Chignecto will be opening earlier in 2005. Due to popular demand the park will open for the season on May 13.

Best wishes for the future are extended to Apple River resident Wallace Rector who has become the first Cape Chignecto staff member to retire from the park.

CLIFF NOTES

A Newsletter of the Joggins Fossil Cliffs World Heritage Committee

June 2004

Joggins Makes Tentative List! What's Next?

The initiative to have the Joggins Fossils Cliffs declared a United Nations World Heritage Site has cleared a major hurdle. Joggins is one of 11 locations named to Canada's tentative list of potential world heritage sites. Only sites on the list can be nominated by the federal government for the prestigious UNESCO designation over a 10-year period beginning in 2005.

The sites were recommended by a Minister's Advisory Committee composed of Canadians recognized as leaders in their respective fields. The tentative list announced by Federal Environment Minister David Anderson cites Joggins as the world's richest, most representative and most significant Coal Age fossil site. The Joggins Fossil Cliffs World Heritage Committee is a sub-committee of the Cumberland Regional Economic Development Association (CREDA).

The April 30 announcement was greeted with excitement in the community. Mark Boon, a Joggins resident who helped launched the efforts to get Joggins recognized, said "it means our hard work is paying off." He added that the listing means that the scientific importance of Joggins has been vindicated and that there is the potential for some good economic news for the area.

District councillor John Reid said he hoped all three levels of government will now give more priority to plans to develop a multi-million dollar interpretive centre which is slated for construction on the old Dugway site in Joggins.

CREDA Executive Director Rhonda Kelly agrees. "Given this announcement, I'm optimistic we'll move even faster than anticipated," she said.

First up will be the site development plan and architecturals, which will be carried out this summer. Bush cutting will also be carried out as part of the preliminary work at the site. Other issues such as signage and safety are also being addressed.

Nova Scotia Natural Resources has committed to work with the committee on the development of a long-term management structure for the site. And the Municipality of the County of Cumberland will be reviewing land use and zoning issues in 2004 as part of its ongoing commitment to planning.

The Community Development team is working on a number of community pride and beautification initiatives including the erection of banners along main street and the planting of flowers. And tide charts are being made available once again this year.

Meanwhile, a host of dignitaries joined several hundred students at River Hebert District High School on Tuesday, May 25 to celebrate the inclusion of Joggins on the Tentative List. Tourism, Heritage and Culture Minister Rodney MacDonald told the audience that the opportunity the area has to move onto the world stage is very significant as there are currently only 13 World Heritage Sites in Canada, and only one in Nova Scotia. "The tourism potential for this place to become a destination area is absolutely tremendous, and that can truly make a difference to the area," the minister stated.

District councillor and Deputy Warden John Reid pointed out that at the height of the coal mining era Joggins had a population of more than 5,000 people, while River Hebert had about the same. Today there are 500 residents in Joggins. "I look at this as an opportunity to stop the bleeding and build our communities back up. Imagine Joggins and River Hebert as big as Amherst," he said.

Local fossil collector and Joggins Fossil Centre operator Don Reid told the gathering that seeing Joggins designated a World Heritage Site would be like a dream come true for him. He pointed out that Joggins now attracts 15,000 to 20,000 visitors annually and those numbers could swell to the hundreds of thousands. "We all have to work together to make this happen and it will happen," he said. Cumberland South MLA Murray Scott, Warden Keith Hunter and Dr. John Calder also addressed the students.

CLIFF NOTES
JUNE 2004

Did you know... Joggins is one of 8 Cumberland County communities scheduled to receive broadband or high-speed Internet service as part of the Connecting Cumberland initiative. Its anticipated that the required infrastructure will be in place to connect Joggins to the high-speed information highway by September of 2005.

What the Parks Canada Tentative List says about Joggins

Joggins, Nova Scotia

Joggins is the world's richest, most representative and most significant Coal Age fossil site.

The Joggins fossil site encompasses a 10 km strip of sea cliffs up to 30 m high along the coast of the upper Bay of Fundy. Preserved in the cliff face is a succession of Pennsylvanian Period (Coal Age) fossil swamp forests, including standing tree trunks up to 6 m high, a vast array of invertebrates, fish, amphibians and remains of the world's first reptiles. The largest fossil creature at Joggins is an arthropod nearly 2 m long. Twice-daily tides, among the world's highest, continually erode the cliff face and expose new fossil beds. Since the mid-1800s, the fossil forests of Joggins have been extensively studied and have been so instrumental in the development of geological and evolutionary principles that the site is often referred to as a "Coal Age Galapagos."

Criterion suggested:

(viii) Joggins is an outstanding example of the evolution of life on earth in the Pennsylvanian Period.

Upcoming Events

Community Meeting:
Tuesday, June 15 - 7 p.m.
Joggins Fire Hall
Learn more about plans for the site
View new community signage

Community Beach Walk:
Wednesday, June 16 - 6 p.m.
Join Nova Scotia Natural Resources geologist Dr. John Calder on the beach at Joggins for an interpretive walk along the fossil cliffs

Interested in receiving more information on this project?

Please feel free to contact the Cumberland Regional Economic Development Association
35 Church Street, P.O. Box 546, Amherst, NS B4H 4A1
Phone: (902) 667-3638 E-mail: **jfcliffs@creda.net**

Media Spokesperson: Rhonda Kelly, Executive Director, CREDA
Phone: (902) 667-3638 E-mail: **rhondak@creda.net**

CREDA NOVA SCOTIA Canada

Joggins Fossil Cliffs
WORLD HERITAGE COMMITTEE

CLIFF NOTES

Project Newsletter
February 2004

ENGINEERING ASSESSMENT CLEARS DUGWAY SITE FOR DEVELOPMENT

An assessment carried out by MGI Engineering has found no compelling reasons why the Dugway site cannot be the main area of development for infrastructure associated with the Joggins Fossils Cliffs. The final MGI report indicates that subsidence at the site is not a significant issue, and that any concern regarding site contamination should be able to be addressed. Several options for beach access were also identified in the report, which was reviewed by the newly-amalgamated Infrastructure and Site Logistics Action Committees in the fall. The next steps in the process will focus upon a site plan for the Dugway site that includes a phased plan for development. In the meantime, the committee continues to address collection policy as well as the process of site protection.

Action Committee Updates:

World Heritage Nomination:

- The Minister's Advisory Council met in Ottawa in November to decide which sites Canada will support as future World Heritage Sites. The official announcement may not take place until spring 2004, however, CREDA and the JFC sub-committee are optimistic about Joggins' status.

Business Plan Development & Management Regime:

- Nova Scotia Natural Resource's commitment to assist in securing funds for site development as well as long-term management structure development was reaffirmed when CREDA met with the Deputy Minister and senior staff in November.

Infrastructure:

- Land use and zoning is a municipal issue which should be addressed in the long term. The Municipality of the County of Cumberland will review this issue in 2004 as part of its ongoing commitment to planning.
- This committee is now combined with site logistics.

Community Development:

- A second small business workshop was held on October 20th. Follow up activity will focus on individual clients as opposed to another group session.
- Another "beach walk" is being scheduled for June with Dr. John Calder.
- Tide charts will be available by mid-May.
- Community Banners are being designed and should be in place by summer.
- The Committee is seeking suggestions and input from the public on various Community Pride initiatives including partnering with school children to grow flowers to plant in the community.

Natural Resources Minister Visits Joggins

Nova Scotia Natural Resources Minister, the Hon. Richard Hurlburt visited the cliffs in November. The Minister expressed his commitment to the project and was truly impressed by what has been accomplished to date by the community as well as the Sub-Committee's long-term plans. It is our hope that Minister Hurlburt will be back in the spring for an extended visit which will include a full site tour.

COMMUNITY NOTICE

Information Session on Coal-Based Methane Gas and Coal Mining

**Wednesday, February 18th
7:30 p.m.
River Hebert Legion**

**Sponsored by:
NS Office of Economic Development &
NS Department of Natural Resources**

**In attendance:
Richard Hurlburt, Minister of Natural Resources &
Murray Scott, MLA, Cumberland South**

Open to the Public

Fossil Cliffs Sub-Committee to hold Community Information Session

A Community Information Session is being planned for late February or early March at the Joggins Fire Hall. At that time representatives from the Joggins Fossil Cliffs Sub-Committee and its Action Committees will be on hand to provide an update on the status of the project and ongoing efforts to have the Fossil Cliffs declared a UNESCO World Heritage Site. Topics will include the MGI Engineering Study, Expansion of the Protected Site Boundary (Cliff Face) under the Special Places Protection Act and a question and answer session. Public notices will be distributed throughout the Joggins/River Hebert area once the date is finalized.

Joggins Fossil Cliffs

Frequently asked questions:

Q. Will the general public have access to the beaches of Joggins?
A. YES. There will be no restriction to the usage of public beaches in Joggins.

Q. Will access (facilities) to the beach be improved?
A. YES.

Q. Will fishers be able to set up weirs along the coast?
A. YES. There will be no change in that regard.

Q. Will there be an increase in tourists and traffic coming into the community?
A. YES. An increase in tourist traffic is anticipated, thus developing an economic spin-off with potential business activity.

Q. Will there be jobs as a result?
A. YES. This project will require dedicated staff at the site, and increases the opportunities for local employment and entrepreneurial initiatives.

Q. Will there be improvements to community streets, sidewalks, etc.?
A. YES. The World Heritage Site Committee looks favorably upon community capacity building i.e. community improvements; however that will require community input and involvement.

Q. Will the proposed expanded Protected Site have any impact on use of my sea-side property ?
A. NO. The designation will help protect your property and will not impact on your current use.

Q. Will I have to paint my house a certain color, or do other improvements because of the WHS?
A. NO. Some of this is happening in Lunenburg, but that's Because it's the historic town that was designated as a WHS. At Joggins, it's the cliffs that will be considered for UNESCO World Heritage status.

Q. We are concerned that traffic may get out of hand. What are you going to do about it?
A. Nothing has been decided. We want your input!

Did you know... The dramatic cliffs on the Bay of Fundy coast at Joggins offer the most splendid exposure in the world to the rocks of the Carboniferous 'Coal Age'. *(Sir Charles Lyell)*

Special Place Protection Act

Bob Ogilvie, Curator, Special Places
NS Tourism, Culture & Heritage
Chair - Site Logistics Action Committee

With regards to a permit, the Special Places Program does not presently require one for casual collecting of fossils from loose slabs and rocks along the shore. If you find something particularly good or interesting, the Special Places Program asks only that you bring it to their attention. This can be done at the Fundy Geological Museum in Parrsboro, or the Museum of Natural History in Halifax. If deemed to be significant, those fossils would be added to the provincial collection with your name listed as collector. Our legislation states that all fossils belong to the people of Nova Scotia, but we're only concerned about those with significant research, interpretation or educational value. The others remain our property, but we don't have any problem with people 'possessing' them. We retain ownership to discourage commercial collecting and all of the problems that come from that.

Collecting from bedrock is more restricted, and a permit is required to do so. Permits are only given to qualified scientists with a research focus. Even those fossils, after being taken away for study, find their way back to us once research is completed.

Interested in receiving more information on this project?

Please feel free to contact the Cumberland Regional Economic Development Association
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Phone: (902) 667-3638 E-mail: **jfcliffs@creda.net**

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CREDA NOVA SCOTIA Canada

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

CREDA NEWS

SUMMER 2003

Energy Still To Be Found In Springhill's Abandoned Mines

Springhill—A new study will determine how Springhill's coal mines can produce a different kind of energy and bring new businesses to the local area. The Nova Scotia Department of Energy is funding a market study for existing businesses to identify the unique opportunities for Geothermal energy in Springhill.

"It's amazing that a place that once produced coal, now has the potential to produce a clean, environmentally safe energy source," said Energy Minister and Cumberland North MLA Ernie Fage. "As we study alternative energy sources in our efforts to reduce greenhouse gas emissions, we have the opportunity to find innovative renewable energy resources that could also improve our economy."

Geothermal energy relies on the use of heat pumps to extract heat from warm floodwaters of abandoned coal mines for use in space and water heating. The process can also be reversed in the summer months to provide cooling as well. Currently, 11 businesses in Springhill use Geothermal energy and have benefited from the energy savings associated with this low-cost alternative.

The Department of Energy is providing $15,000 towards a market study that will identify new potential uses for Geothermal energy and ways in which the Town of Springhill can promote its unique energy resource.

Inside this issue:

CREDA's Mission

"Creating an environment which facilitates sustainable economic growth in the Cumberland Region in partnership with all municipal units."

Skills Inventory Project Now Underway

Over the next few months, the Regional Development Authorities (RDAs) in northern Nova Scotia will be conducting an important research and analysis project to develop a skills inventory database of employment age adults in their counties.

Funding for the approximately $835,000 project is being provided by the Government of Canada through a Local Labour Market Partnership of $499,598 from Human Resources Development Canada, a non-repayable contribution of $169,000 through the Atlantic Canada Opportunities Agency's Business Development Program, and $31,000 from Enterprise Cape Breton Corporation. In addition, Nova Scotia Economic Development is contributing $75,000 and the RDAs in Cumberland, Colchester, Pictou, Antigonish, Guysborough, Richmond and Inverness Counties are *(see Skills– page 2)*

Skills Inventory Project

(Continued from page 1)

providing a total of $60,000 through in-kind contributions.

Working-age adults in the seven counties will be contacted by phone and asked to complete a short survey. Information to be collected includes: education, current occupation, past occupations within the last five years, job-related training, professional licenses or credentials, and level of computer skills. A comprehensive skills database is key to developing a better understanding of the skills available in the local labour force that are of interest to potential employers and for attracting new businesses to Nova Scotia.

"Access to up-to-date, relevant labour data is essential for any region to enhance its efforts in sustainable economic development," said Rhonda Kelly, Executive Director of CREDA. " Accurate labour data will also be useful in recognizing shifts in the local labour force and helping to identify any training gaps that will need to be addressed."

Corporate site selectors have shown considerable interest in obtaining current and accurate employment and education data for Nova Scotia. Site selectors are a new breed of professionals specializing in selecting optimal sites for new business locations.

The skills inventory database will give site selectors, and businesses looking to relocate, an accurate snapshot of the education and work experience, past and present, of our working age population. Regular updates will be conducted to ensure the data remains accurate.

The project partners will have access to a comprehensive skills inventory database of the northern region for use in their economic development efforts. Key labour force data will also be made available to the public via a link on the Target Nova Scotia website **www.targetnovascotia.com.**

If you have any questions or want further information phone Kelly Millar at CREDA at 667-3638 or visit our website @ **www.creda.net**.

Broadband Business Plan submitted to Industry Canada

The Connecting Cumberland Broadband Business Plan was submitted to Industry Canada on June 6, 2003. Industry Canada will announce the recipients of Round 1, Phase 11 funding for the Implementation Phase this fall. CREDA has been awarded funding under Industry Canada's Broadband for Rural and Northern Development (BRAND) Pilot Program to assist with the development of a rural broadband business plan.

The objective of the development phase was to prepare and submit a business plan to compete for funding for the deployment of broadband (high speed Internet) services in rural Cumberland County.

CREDA and the Cumberland BRAND Committee would like to thank everyone for their continued support of the rural broadband project. Thanks also go out to our funding partners and the businesses and organizations who provided letters of support. The Broadband Initiative is supported by the Town of Parrsboro and the Municipality of Cumberland County.

Meet the CREDA Board of Directors

The CREDA Board of Directors has named it's new slate of officers for the 2003-2004 fiscal year. Howard Spence of Springhill was named to his third one year term as Chair during the well attended AGM held June 26 at Duncan's Pub in Amherst. Daniel Burke of Amherst is Vice-Chair; Gerald Read, representing Cumberland County was named Secretary, while Morgan Hunter from Oxford will serve as Treasurer. Ron Levy, Parrsboro is Past-Chair. The Board welcomed it's new member from Oxford Kent Thompson. The other members of the CREDA Board of Directors and the municipality they represent are:

Cumberland:

- Mary Lou Trenholm, Pugwash
- Don Smith, West Amherst

Amherst:

- Aubrey Chapman
- Roy Maltby

Parrsboro:

- *Rose MacAloney*
- *Gleneida Canning*

Springhill:

- Allen Dill
- Marjorie Sprague

Oxford:

- Opal Black
- Kent Thompson

CREDA NEWS

WINTER 2003

Cumberland Regional Economic Development Association

Inside this issue:

"Creating an environment which facilitates sustainable economic growth in the Cumberland Region in partnership with all municipal units."

Joggins Fossil Cliffs Tourist Concept Plan / Building Design Made Public

Details of a comprehensive Tourism Concept Plan for the Joggins Fossil Cliffs and a preliminary set of drawings for a potential Interpretive Centre were made public at a well attended Public Information Session in late January. Members of the Joggins Fossil Cliffs World Heritage Committee presented the final draft of the Tourism Concept Plan, which was prepared by Environmental Design and Management (EDM) Ltd. of Halifax.

The plan focuses on four main objectives according to CREDA Executive Director Rhonda Kelly. "It identifies the necessary improvements required to position Joggins as a world class attraction, provides an action plan to implement the identified improvements, identifies the main viewing audience and infrastructure needs for the Fossil Cliffs, and includes local input from the community," she said.

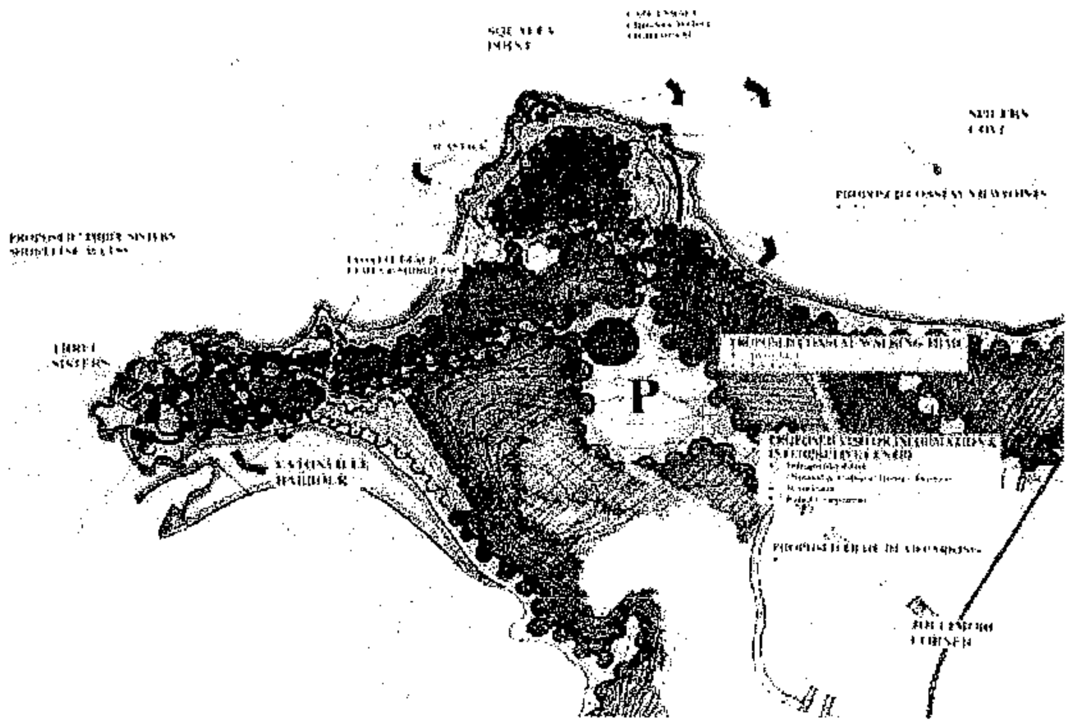
Members of the public also got their first look at the future infrastructure that may be developed when plans for a potential Fossil Cliffs Interpretive Centre were unveiled. Architects from the firm of Anywll Fogo Architects and Interiors Ltd. Of Halifax used the historical features found in the construction of the old Chignecto Mines in their preliminary design. (pictured is the front of the proposed Interpretive Centre)

The goal of the Joggins Fossils Cliffs World Heritage Committee is to seek nomination and designation of the Fossil Cliffs as a Natural World Heritage Site under the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Broadband Business Plan Funding Approved

An application submitted by CREDA on behalf of the Cumberland Brand Committee was accepted to receive business plan development funding as the next step towards making high-speed Internet access available to unserved rural communities in Cumberland County. CREDA was selected by the Municipality of Cumberland, the Town of Parrsboro, the Village of Pugwash and several community development associations throughout the county as the "Community Champion" to apply for a regional application for a "Broadband Business Plan". The funds were allocated as part of the $105-million Broadband for Rural and Northern Development Pilot Program announced by Minister Rock and Secretary of State Mitchell last summer. (see page 2)

Cape Chignecto Concept Plan Approved



Advocate— The above Concept Plan, approved at a Public Consultation Session, details the developments planned for the Eatonville/Three Sisters area of Cape Chignecto Park. Depending on funding, several new family oriented coastal trails and scenic look-offs, access roads and a parking lot will be constructed this year. Future plans also call for the construction of a Renewable Resource Visitor Information and Interpretative Centre.

Business Plan to Look at Rural Internet Access

(Continued from page 1)

In all 89 applicants representing approximately 1149 communities will develop business plans outlining how each community would use high-speed or broadband, Internet service. Each applicant receives up to $30,000 toward the cost of developing those plans.

Proposals selected for business plan development were chosen from 222 submissions, based on recommendations by an arm's-length National Selection Committee.Successful applicants will now use their funds to develop business plans to be submitted by May 22, 2003 to compete for implementation funding. The plans selected for implementation are expected to be announced this fall.

The Cumberland application was one of five proposals selected for Nova Scotia. The submission "Connecting Cumberland: Gateway to Nova Scotia" covers the communities of Advocate, Joggins, Malagash, Parrsboro, Pugwash, River Hebert, Wallace and Wentworth. Based on the provision that the recommended technology offers affordable access and a cost effective option for the Connecting Cumberland Business Plan, considerations could be allowed to include any of the following additional communities: Port Greville, Southampton, Maccan, Nappan, Oxford Junction, Pugwash Junction, Northport and Tidnish.

Career Resource Centre Celebrates Re-Opening

Representatives from a number of organizations including Human Resources Development Canada (HRDC), CREDA and the municipalities were in attendance December 12 to celebrate the re-opening of the Career Resource Centre in its new location in the Cumberland Economic Resource Centre.

"By moving to the front of the building, we were able to make the centre more accessible," said career navigator Michelle Landry. "This setup is much better because people don't have to go through office areas to get to the resource centre like before." The centre has also taken on an expanded role and now houses the CAP site and the business service centre.

First opened in 2000 as a joint project of CREDA and HRDC with assistance from the Department of Community Services, the centre continues to grow in popularity.

Bernie Murphy of HRDC said they are very pleased with how things have worked out. "The resource centre has been a big success and every has benefited from this partnership, "he said. "The statistics show how successful it has been."

The fully staffed centre offers a number of services including Internet access for employment and career research, job postings resume and cover letter writing, student loan information, on-line Employment Insurance applications, interview techniques and Canadian Armed Forces information sessions. The centre now offers extended hours and is open from 8:30 a.m. to 6:30 p.m. on Wednesday and Thursdays .

Funds Sought To Repair Heritage Building

The Amos Seaman School Museum in Minudie (pictured above) is in desperate need of repairs to enable it to reopen in July 2003. A fundraising campaign is currently underway with a goal of raising several thousand dollars for repairs to the bell tower, back walls and sills. Of immediate concern is the bell tower which has tipped backwards on to the roof. Temporary repairs have already been carried out to prevent further damage to the bell tower and roof of the museum.

The museum, built by Amos "King" Seaman in the mid 1800s, is one of the oldest remaining one-room school houses in Nova Scotia. It was designated as a Provincial Heritage property in 1997 and is part of the Nova Scotia Museum.

Donations can be mailed to the Minudie Heritage Association or the Minudie Tourist Association c/o General Delivery, River Hebert, NS B0L 1G0.

Acadians Target Cumberland County for Family Reunions

A number of Acadian families have chosen Cumberland County as the location for their family reunions in 2004. Thousands of people of Acadian descent will be in Nova Scotia from July 31 to August 15, 2004 for Congres Mondial Acadien, an international gathering of Acadians. Family reunions will form the base of the Congres, Other events such as music festivals, religious ceremonies, conferences, art fairs, tours and protocol ceremonies are also being planned. To date the Babineau, Granger, Bourgeois and Hebert families are scheduled to stage their reunions in the Amherst (Beaubassin) area. The River Hebert/Minudie area will also host some events.

The Babineau and Granger families have scheduled activities for August 8 and 15. The Bourgeois and Hebert family reunions are both scheduled for August 13–14 in Amherst (Beaubassin). A local steering committee has been formed to plan and coordinate events locally, to ensure that Cumberland County's Acadian heritage and history is recognized, and that the county is a full participant in the Congres celebrations.

Cumberland Regional Economic Development Association

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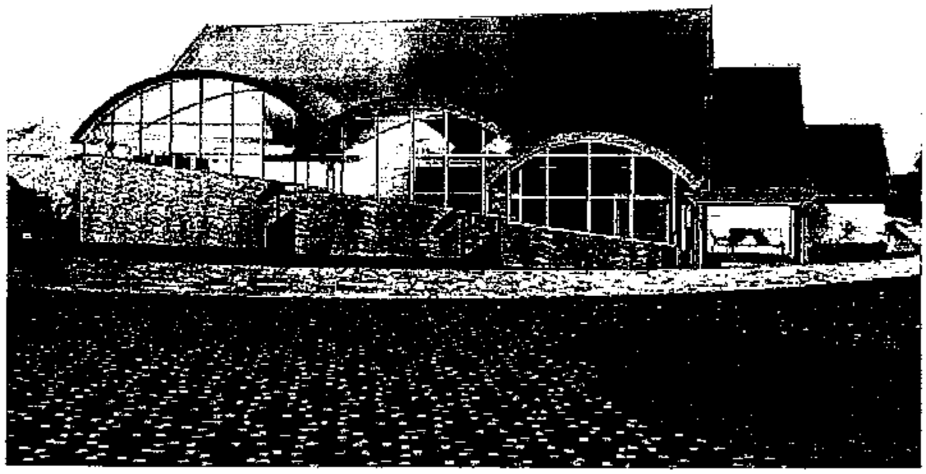

Joggins and area residents were impressed with the architect drawings for a proposed Fossil Cliffs Interpretive Centre. The Joggins Fossil Cliffs World Heritage Committee unveiled the preliminary drawings for the public to view at a community information session in late January. Several sites are being studied to determine the best location for any future infrastructure. Shown above is a side view of the proposed Interpretive Centre.

NEWS BRIEFS

Oxford - Congratulations to the Cumberland County Food Project on its nomination for a Nova Scotia Federation of Agriculture Awareness Award. The Cumberland County Federation of Agriculture nominated the Food Project for the award.

The Agricultural Awareness Awards were handed out during the Nova Scotia Federation of Agriculture's Annual General Meeting and Awards Banquet in Truro in December. The Cumberland County Food Project was one of five nominees Province-wide and received a plaque in recognition of its accomplishments.

Sponsored by CREDA, the Cumberland County School Food Project is designed to promote healthy eating habits among students while encouraging the distribution of locally produced/ processed foods to school cafeterias.

Parrsboro — Cumberland County has a new Community Access Program coordinator. Jennifer Winters of Parrsboro assumed the position in December. Jennifer can be reached at Parrsboro Town Hall at 254-2036 or by email at cumbcap@creda.net.

Amherst -The CREDA Board now has a full compliment of members with the additions of Marjorie Sprague representing the Town of Springhill and Rose MacAloney representing the Town of Parrsboro. Sprague operates Marcat Flowers & Gifts in Springhill while MacAloney is the Administrative Assistant at the Fundy Geological Museum. Welcome to our newest members!

Truro- Cumberland County was well represented among the award winners at the Central Nova Tourist Association's 2002 Annual General Meeting and Banquet. The Food and Beverage Award was presented to Darcy and Jenna Snell of the Lighthouse at Cape D'Or. Margolians of Amherst and Truro won in the Gift Shop category, while Debbie Boudreau, Manager of the Heritage Models Centre in River Hebert was honored with a Super Host award. Outgoing CNTA President Rob Laceby of the Amherst Shore Country Inn was presented with a plaque in recognition of his contributions to tourism in the region.

Joggins Entrepreneur Session Well Attended

Joggins—Entrepreneurship is alive and well in the Joggins/River Hebert area. An estimated 50 people attended an Entrepreneur Opportunity Information Session on Monday, June 23 at the Joggins Fire Hall. Purpose of the session, which was co-hosted by CREDA and the River Hebert/Joggins & Area Development Association, was to explore potential future business opportunities related to ongoing developments at the Joggins Fossil Cliffs.

The recent Tourism Concept Plan for the Fossil Cliffs prepared by EDM Environmental Design and Management Limited identifies a number of potential business opportunities associated with the Fossil Cliffs and efforts to have the Cliffs declared a UNESCO World Heritage Site.

Chris Pelham of the Acadia University Centre for Small Business and Entrepreneurship touched on the nature of the opportunities such as small retail, artisans and giftware, accommodations, and other tourism related products and activities. Darlene MacDonald from the Nova Scotia Department of Tourism & Culture provided an overview of tourism activities at similar sites. She also provided information on marketing, opportunities for existing businesses, tourist needs and considerations, and the types of resources, support and programs available for small tourism related businesses.

Of those in attendance 58% completed evaluation forms which yielded the following information:
-62% do not currently own their own business, but 59 % are interested in starting their own business.
-83% said they would be interested in attending a future workshop or seminar relating to small business. Topics they would like to see covered at a future session include: financing/ funding sources, accommodations, marketing, business plan development/micro-enterprise, entrepreneur training, the super host program, bike rentals, beach tours and networking.

A second session is tentatively scheduled for the fall.

Partners Aim to Brand Amherst a "Shopping Destination"

Amherst— CREDA will be working with the Town of Amherst, the Amherst & Area Chamber of Commerce (AACC) and the Downtown Amherst Revitalization Society (DARS) to explore partnership options for increasing the retail market area of Amherst through increased marketing promotion in neighboring southeastern New Brunswick. The unique partnership will also explore the need to clearly brand the region from a marketing perspective as a destination area for shopping and service needs, again focusing on the potential growth within southeastern New Brunswick.

DARS and AACC have enthusiastically agreed to partner to investigate opportunities to increase the overall retail market share. It was also agreed that to increase the town's profile as a potential "shopping destination" it is essential to develop a "brand" for the community to offer a consistent image for a marketing campaign.

A Request for Proposals will be issued this summer to perform the market assessment and branding initiative. It is hoped that the project will be completed by September in time to offer innovative marketing options for the fall and Christmas shopping season.

Avid Hiker writes book on Cape Chignecto

David Hamilton is so taken with Cape Chignecto Provincial Park that he decided to write a book about it. The result of his love affair with the Park is " Wilderness Trails and Day Hikes of Cape Chignecto", a complete guide that is a must for novice and avid hikers alike. In his book which is filled with maps, pictures and sometimes humorous illustrations Hamilton guides the hiker throughout the Park's extensive trail system taking them from one campsite to the next. He also details the many day-hike options that Cape Chignecto has to offer. In the book Hamilton writes " The Cape Chignecto Trail is as scenic as the famous West Coast Trail and as challenging as the historic Chilkoot Pass hike. This rugged trek offers the additional challenge of dealing with the Fundy coast and its maritime weather. It demands respect from both novice and experienced hikers." Copies of the book went on sale in June and can be purchased at a number of locations including the Park Visitor Centre. Hamilton, who grew up in Amherst, is a retired engineer who now resides in Cambridge-Narrows, New Brunswick.

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

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CREDA

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www.creda.net

Cumberland County School Food Project Update-

By Michele Reid, Coordinator

Oxford -The Cumberland County School Food Project (CCSFP) is pleased to acknowledge the end of another successful school year. Project initiatives throughout the year included a field trip for grade 8 students at Oxford Regional High School to Donkin's and Ripley's Sugar Woods in Fenwick where students witnessed both modern and old methods of producing maple syrup and enjoyed sampling a variety of different maple products. A second field trip was held for grade 7 students; this time to a local supermarket where a nutritionist conducted an interactive tour which focused on nutrition labeling in foods. Students at Oxford Regional Elementary were also involved in nutrition learning. A nutritionist visited the school and conducted assemblies for each grade level discussing the Canada's Food Guide and the importance of eating well-balanced meals. Taste-testing sessions were held throughout the year for students at Oxford Regional High and Elementary Schools. Students were given the opportunity to sample a variety of healthy locally produced/processed foods and offer their input as to whether or not they would like to see them available at their school cafeteria. Products sampled included apples, fruit, salad, vegetables, dried blueberries, milk flavors, and frozen yogurt. Currently we are working on a summer newsletter and are busy planning events/activities for the upcoming 2003/2003 school year.

CREDA/HRDC Partner to deliver Career Resource Centre services to all Cumberland County

CREDA has partnered with Human Resources Development Canada (HRDC) to deliver the services of the Career Resource Centre to all Cumberland County residents through their local Community Access (CAP) sites. The Career Resource Centre, based out of CREDA in Amherst has seen an influx of unemployed people. However this resource is more difficult for people in the surrounding areas to access as transportation can be a problem for the unemployed.

Career Resource Centre

The Career Development Outreach Project has hired five interns to be shared between neighboring CAP sites. These interns will offer consistent CAP hours, basic computer assistance, online and local and regional job searching, resume writing and assistance with faxing/photocopying.

The interns are Brian Smith, Amherst/Northport CAP sites; Sandra Tulk, Springhill/River Hebert; John Estabrooks, Oxford/Wentworth; Emily Skidmore, Parrsboro/Advocate CAP sites; and Gail MacFarlane, Pugwash/ Wallace sites.

In addition to the interns a Project Manager and Web Developer have also been employed to fill additional Information Technology needs of the communities. They will assist in the development of a Recreation web site for Cumberland County, increase assistance to small businesses, and offer one-on-one computer training. Don Hannah is the Outreach Web Developer. He is located at the County Municipal Building in Upper Nappan.

For more information on the Career Development Outreach Project contact Project Manager Ron MacNutt at CREDA.

The Career Resource Centre is a partnership initiative of CREDA and HRDC.

Joggins Fossil Cliffs
WORLD HERITAGE COMMITTEE

CLIFF NOTES

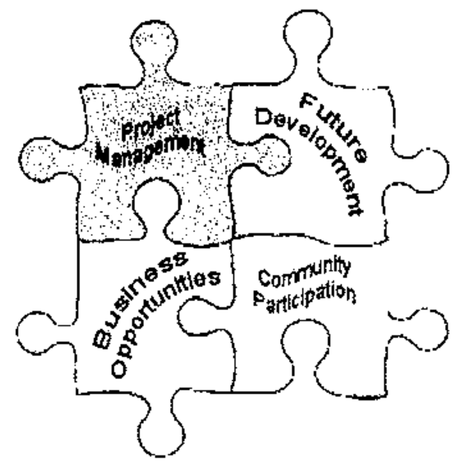
Project Newsletter
June 2003

YOU ARE INVITED TO ATTEND COMMUNITY INFORMATION SESSION

Mark your calendar and plan on attending the Entrepreneur Opportunity Information Session to be held in Joggins on Monday, June 23rd at 7 pm at the Fire Hall.

During the session, area residents will be informed on the potential business opportunities that may arise from the development and promotion of the Fossil Cliffs. This session will provide a general overview of future opportunities for the area.

Representatives from CREDA (Cumberland Regional Economic Development Association), River Hebert/Joggins Development Association, Nova Scotia Department of Tourism & Culture, Acadia University Centre for Small Business and EDM Environmental Design will be on hand to present the on-going project developments and to answer questions that area residents may have.



By working together, we can make sense of the challenges that a project of this size presents.

Also on that evening, a brief update will be provided on the progress made to date by the project partners of the designation of the Joggins Fossil Cliffs as a UNESCO (United Nations Educational, Scientific and Cultural Organization) World Heritage site.

The goal of this session is to provide a general overview of the potential future opportunities for the area and seek feedback from residents to help to develop specific programs related to this important project.

This is a very exciting time! Should the Fossil Cliffs be recognized as a World Heritage Site, visitors from around the globe will travel to Joggins/ River Hebert to experience all of the natural beauty, spectacular views and rugged coastline.

Plan on attending and participating in this session.

A VERY WARM WELCOME TO OUR NEW AREA BUSINESSES

If you haven't already had to chance to do so, take the chance to check out these two new businesses that have recently opened in the area. Best wishes and much success!

Once Upon A Time
Antiques & Collectibles
Buy, sell or trade

676 Lower Cove Road
Joggins, NS
B0M 1L0
(902) 667-2619

Laurell & Jim Hamilton

Back Room Boutique
Quality Used Clothing
Crafts and What-nots

1814 Main Street
River Hebert, NS
B0M 1L0
(902) 251-2023

Bernice Vance

COMMUNITY NOTICE

EVENT:
Entrepreneur Opportunity Information Session

PLACE:
Joggins Fire Hall

DATE:
Monday, June 23rd, 2003

TIME:
7:00 pm

This is a chance for all people who may be interested in finding out more information on the business opportunities that are related to the development of the Fossil Cliffs.

No advance registration is required.

No fee.

Refreshments will be served.

Co-sponsored by CREDA & River Hebert/Joggins Area Development Association

Joggins Fossil Cliffs

WORLD HERITAGE COMMITTEE

Did you know ...

That the meaning of the word "Joggins" translates from the Mikmaq language as the "meeting place".

NEW COMMITTEE STRUCTURE

As every project grows successfully, so too must the organization that manages its direction and charts its path into the future change and grow with it.

CREDA has adopted a new organizational structure for the Joggins Fossil Cliffs World Heritage Committee and has taken valuable work of the Steering Committee to the next level. This structure created a new CREDA Sub Committee named the Joggins Fossil Cliffs World Heritage Project Committee as well as seven new Action Committees. This change was effective in May.

All action committees are responsible to the Joggins Fossil Cliffs Sub-Committee of CREDA. All appointments to these new groups were made with a prospective representative's overall skill level and expertise in mind. Local and area representation remains strong on all newly developed Committees. They are as follows: Dara Legere, John Reid, Mark Boon, Bernice Vance, Don Reid, Ken Adams, Eric Leighton, Bill Fairbanks and Beth Boon.

These people are active participants in the Action Committees which play a key role in moving the project forward. All community volunteers are working in partnership with CREDA and its many government partners.

CREDA would like to take this chance to THANK the original steering committee members for their valuable contribution to the project. It has been through the efforts of a great number of people, both on and off committees, that the project has come to this point—one that the entire community can be proud of.

JOGGINS BRIEFS

In this newsletter, a sample of some of the work of the new Action Committees will be highlighted. At future times, further information will be featured making sure that area residents understand the items that each Committee are working on. Listed below is a sample of work in progress or considered :

- **Community Pride Program**— activities will be organized to assist area Residents with ideas and incentives to better promote their community to the world
- **Youth Involvement**– Opportunities to engage the youth in the area to become involved in supporting Community Pride efforts and educated on the value of the cliffs.
- **Fundy Tour**– a tour is planned to areas along the NB Fundy Shore that have experienced an increase of visitors to their communities. This will assist the committee to plan for the anticipated increase in tourist traffic to the area.
- **Tide Charts**—A Tide Time Table has gone for publication. It was sponsored by Albion Auto in Amherst. Charts will post the low water tide times for the Joggins beach and will include warnings of the dangers that visitors may encounter. Charts will be available free of charge at the following locations: Joggins VIC, Reid's Store and at the CREDA office in Amherst
- **Engineering Update**– the site assessment for the Dugway location is nearing completion. At this point all findings are positive, which means this may indeed be the optimum site for the Interpretive Centre. Expect the final report to be completed in July.
- **Signage**— both safety and interpretive signs are in the process of being designed for Joggins, River Hebert and outlying connected areas

Interested in receiving more information on this project?
Please feel free to contact the Cumberland Regional Economic Development Association
35 Church Street, P.O. Box 546, Amherst, Nova Scotia B4H 4A1
Phone: (902) 667-3638 Email: jfcliffs@creda.net www.fossilcliffs.net
Or
Media Spokesperson: Rhonda Kelly, Executive Director CREDA
Phone: (902) 667-3638 Email: rhondak@creda.net www.creda.net

CREDA NOVA SCOTIA Canada

Media Releases

JOGGINS FOSSIL CLIFFS

CREDA

MEDIA RELEASE

June 27, 2007 **For immediate release**

Students set to graduate from Joggins training program

A group of 13 students have successfully completed the Joggins Fossil Cliffs Essential Skills Development and Training Program and will receive their graduation certificates during a ceremony this Friday, June 29th at 11 a.m. at the Nova Scotia Community College Cumberland Campus in Springhill. The training program was delivered at the River Hebert District High School through a unique partnership between the Chignecto Central Regional School Board, the high school, and the NSCC Cumberland Campus.

The program was initiated by the Cumberland Regional Economic Development Association (CREDA) and the Joggins Fossil Institute to help address a growing labour shortage in the tourism sector, as well as to provide a potential labour pool to draw from when the new $9-million Joggins Fossil Cliffs Interpretive Centre opens this fall. Funding was provided by the Nova Scotia Department of Community Services, Service Canada and the Atlantic Canada Opportunities Agency (ACOA).

The 26-week program, which began in early January was designed to help individuals gain successful employment in the tourism sector within Cumberland County. Topics covered included general knowledge of the industry, local knowledge of the community, customer service, communications, and a wide range of professional skills. Specific training related to the Geology of Joggins and the surrounding area also made up a portion of the curriculum. The students also gained practical experience with a six-week work placement within the tourism industry.

Several of the students have already gained employment while others will have the opportunity to apply for jobs at the Joggins Fossil Cliffs Interpretive Centre in the near future.

For further information contact:

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JOGGINS FOSSIL CLIFFS

CREDA

MEDIA RELEASE

May 29, 2007 **For immediate release**

Original Joggins Fossil Centre to Open for one more Season

Joggins, NS – The Cumberland Regional Economic Development Association (CREDA) and the Joggins Fossil Institute are pleased to announce that the original Joggins Fossil Centre, formerly under the proprietorship of Mr. Don Reid of Joggins, will re-open to the general public effective Friday, June 1st. The Centre will include a small fossil display and a temporary satellite office of the Joggins Fossil Institute. A gift shop will be open during July and August offering a small number of items for sale.

Weekend tours of the Joggins Fossil Cliffs will be available on Saturdays and Sundays by appointment. To book a tour, please contact the Joggins Fossil Centre at (902) 251-2727. The Centre will be open from 10:30 a.m. to 6:30 p.m. daily between June 1st and 30th, and after Labour Day to the end of the season. Between July 1 and September 4, the Centre's hours will be from 9:30 a.m. to 7:00 p.m.

The re-opening of the original Joggins Fossil Centre will ensure that visitors to the Fossil Cliffs will have the information they require while construction continues on a new interpretive and research centre to showcase what is considered the world's richest and most significant Coal Age fossil site. Construction of the 13,000 square foot fossil centre is anticipated to be completed by early fall 2007. The new centre will house a gift shop, a laboratory and exhibition space devoted to the significance of the cliffs. It will also boast the best collection in the world of carboniferous fossils, thanks to local collector Don Reid who has donated his entire collection to the Joggins Fossil Institute.

More than $9-million has been committed to plan and build the new Joggins Fossil Cliffs Centre and improve beach access and safety at the cliffs. Key funding partners include the federal government, through ACOA; the provincial government, through the department of Tourism, Culture and Heritage; and the Municipality of the County of Cumberland. The project also has the generous support of Parks Canada and the Nova Scotia Departments of Natural Resources and Economic Development.

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MEDIA RELEASE

April 10, 2007 ***FOR IMMEDIATE RELEASE***

Joggins, N.S. - The Province of Nova Scotia has fulfilled its financial commitment to develop the Joggins Fossil Cliffs as a world-class tourism and heritage site.

Attorney General and Cumberland South MLA Murray Scott, acting on behalf of the province, presented a significant cheque to Rhonda Kelly, Executive Director of the Cumberland Regional Economic Development Association (CREDA) during a brief ceremony at the construction site in Joggins on Tuesday, April 10. This funding represents the remainder of the total provincial financial contribution of $2.9-million for the capital build and start-up costs of an interpretive and research centre to showcase what is considered the world's richest and most significant Coal Age fossil site.

More than $9-million has been committed to plan and build the new Joggins Fossil Cliffs Centre and improve beach access and safety at the cliffs. Key funding partners include the federal government, through ACOA, which has committed more than $4.8-million, and the provincial government, nearly $3-million through the department of Tourism, Culture and Heritage. The Municipality of the County of Cumberland has also committed more than $900,000.

Construction of the 13,000 square foot new fossil centre is on schedule for an early October opening. The centre will house a gift shop, a laboratory and exhibition space devoted to the significance of the cliffs.

Area Municipal Councilor and Joggins Fossil Institute Board member John Reid said he was excited to see the new centre being constructed at the end of Main Street in Joggins. "This is something the community has been waiting for and dreaming about for a long time," he said.

Joggins Fossil Institute Board Chair and CREDA Vice Chair Gerald Read added that " the opening of a world-class interpretive and research centre along with the possible designation of the Joggins Fossil Cliffs as a World Heritage Site will help revitalize Joggins and spur economic growth throughout the area."

Meanwhile, the Joggins Fossil Institute has received confirmation that the UNESCO World Heritage Centre has examined the Nomination Dossier for Joggins and has determined that it is complete.

The Dossier, which is the application for inscription on the list of World Natural Heritage Sites, will now be evaluated by the appropriate advisory bodies of UNESCO.

The evaluation process, which will include a site visit, could take up to 18 months to complete. Once a site has been nominated and evaluated, it is up to the intergovernmental World Heritage Committee to make the final decision on its inscription. The committee meets annually to decide which sites will be inscribed on the World Heritage List.

It is anticipated that Joggins will be designated a World Heritage Site by the fall of 2008.

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Media Contact:

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Rhonda Kelly, Executive Director
Cumberland Regional Economic Development Association
902-667-3638
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JOGGINS FOSSIL CLIFFS

CREDA

MEDIA ADVISORY

April 5, 2007

The Joggins Fossil Institute and the Cumberland Regional Economic Development Association (CREDA) invite you to attend a cheque presentation ceremony representing a significant financial contribution to the Joggins Fossil Cliffs Project from the province of Nova Scotia.

When: Tuesday, April 10, 2007
Time: 8:30 a.m.
Where: Joggins Fossil Cliffs Interpretive Centre building site (located at the end of Main Street in Joggins)

Attorney General and Cumberland South MLA Murray Scott, on behalf of the province, will make the presentation to CREDA's Executive Director Rhonda Kelly. The contribution represents the balance of the provincial commitment for the capital build and start up operating costs for the Joggins Fossil Institute. Media representatives will also be provided with an opportunity to view the construction site.

For further information and/or to confirm your attendance please contact:

Ron Robinson
Development Field Officer, Communications, CREDA
667-3638
Email: **ronr@creda.net**

MEDIA RELEASE

March 16, 2007 **For immediate release**

Open House will focus on Joggins Fossil Cliffs Project

Joggins, NS- People interested in learning more about the latest developments associated with the world famous Joggins Fossil Cliffs are invited to attend an Open House on Thursday, March 22 at the Royal Canadian Legion in Joggins.

The informal drop-in will run from 2:00 p.m. to 7:00 p.m. and will feature information on the UNESCO World Heritage Site nomination, construction of the new Joggins Fossil Cliffs Interpretive Centre, as well as on the Essential Skills Development and Training Program now underway at River Hebert District High School. Representatives from the Community Business Development Corporation (CBDC Cumberland) will be available to discuss small business development opportunities with potential entrepreneurs.

The Open House is being hosted by the Joggins Fossil Institute and the Cumberland Regional Economic Development Association (CREDA).

More than $9-million is being invested to build an interpretive centre to showcase what is considered the world's richest and most significant Coal Age fossil site. Access to the beach and site safety will also be greatly enhanced. Construction of the 13,000 square foot interpretive centre is well underway. The centre is scheduled to open this summer and will house a gift shop, a lab and 6,000 square feet of exhibition space devoted to the significance of the cliffs. Meanwhile, the Nomination Dossier, which is the application for inscription on the list of World Natural Heritage Sites, was formally submitted to the World Heritage Centre in Paris in January.

Funding is being provided by Canada's New Government, through the Atlantic Canada Opportunities Agency (ACOA), which is investing more than $4.8-million in the new centre. The Nova Scotia Department of Tourism, Culture and Heritage will invest $1.8-million. The provincial investment is in addition to $1.1-million provided in December 2005 to help leverage other funding, bringing the total provincial contribution up to $2.9-million. CREDA is leading the project and, with the support of the municipality of the County of Cumberland, has contributed $921,600.

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JOGGINS FOSSIL CLIFFS

CREDA

MEDIA RELEASE

February , 2007 **For immediate release**

Students being trained to welcome visitors to Cumberland County

A group of 15 students are learning skills they hope to use one day to welcome visitors from around the world to Cumberland County. The students are enrolled in the Joggins Fossil Cliffs Essential Skills Development and Training Program, which is being taught at River Hebert District High School through a unique partnership between the Chignecto Central Regional School Board, the high school, and the Nova Scotia Community College Cumberland Campus.

The program was initiated by the Cumberland Regional Economic Development Association (CREDA) to help address a growing labour shortage in the tourism sector as well as to provide a potential labour pool to draw from when the new $9-million Joggins Fossil Cliffs Interpretive Centre opens late this summer. Funding for the program is being provided by the Nova Scotia Department of Community Services, Service Canada and the Atlantic Canada Opportunities Agency (ACOA).

The 26-week program began in early January and is designed to help individuals gain successful employment in the tourism sector within Cumberland County. Topics being covered include general knowledge of the industry, local knowledge of the community, customer service, communications, and a wide range of professional skills. Specific training related to the Geology of Joggins and the surrounding area will also make up a portion of the curriculum. The students will gain practical experience with a six-week work placement within the tourism industry.

In addition to utilizing un-used space at River Hebert District High School, the unique partnership will also result in the development of a Student Wellness Centre. Students will help design the centre which will provide them with a relaxing, non-threatening environment where they can get assistance with courses, career planning, health information, and information to assist with other issues. All of the equipment purchased for the training program will be donated to the high school at the end of the program.

Construction got underway earlier this winter on the 13,000 square foot Joggins Fossil Cliffs Interpretive Centre. The centre will house a gift shop, a lab and 6,000 feet of exhibition space devoted to the significance of the cliffs. It is expected to employ approximately 10 people on a full or part time basis and attract an estimated 40,000 visitors annually.

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JOGGINS
FOSSIL CLIFFS

CREDA

MEDIA RELEASE

January 31, 2007 **For immediate release**

The Joggins Fossil Cliffs Project has reached another significant milestone with the formal submission to the World Heritage Centre in Paris of the application for inscription on the list of World Natural Heritage Sites. The Nomination Dossier was delivered last Friday, meeting the February 1st deadline set by the United Nations Educational, Scientific and Cultural Organization (UNESCO) for receiving 2007 nominations.

The Nomination Dossier is a 136-page document that is comparable to a scientific textbook. With 22 binders of appendix materials, the nomination fills a 31.5 by 13.5 by 12 inch oak case that weights, when full, approximately 50 pounds. As UNESCO requires 3 copies of everything, three wooden cases were hand delivered to the World Heritage Centre in Paris by Senior Project Manager Jenna Boon. It was more cost effective to personally deliver the Nomination Dossier rather than to send it by other means. This also ensured that the deadline was met.

Once Canada placed the site on its tentative list in April 2004, the formal work on the dossier began almost immediately. Its preparation involved many hours of research, data collection, and writing. It was co-authored by Dr. John Calder, Senior Geologist with the Nova Scotia Department of Natural Resources and Jenna Boon, Senior Project Manager. They received outstanding support from Parks Canada and a team of project and CREDA staff, along with members of the Joggins Fossil Cliffs Advisory Board and its Action Teams.

The Joggins Fossil Cliffs project is a collaborative effort being lead by a project team that includes numerous dedicated individuals from all levels of government, members of the scientific community, tourism organizations, and representatives from the community. These individuals are working with the Cumberland Regional Economic Development Association (CREDA) to develop the Fossil Cliffs.

"Joggins is a world-class site, with international significance," said Rhonda Kelly, Executive Director of CREDA. "Now that we have formally brought our case to UNESCO, we are hopeful that the Fossil Cliffs will be designated a World Heritage Site."

The World Heritage Centre will send the Joggins Nomination Dossier to the appropriate advisory bodies for evaluation. The evaluation process, which will include a site visit, could take up to 18 months to complete. Once a site has been nominated and evaluated, it is up to the intergovernmental World Heritage Committee to make the final decision on its inscription. The committee meets annually to decide which sites will be inscribed on the World Heritage List. It's hoped that Joggins will be designated a World Heritage Site by fall of 2008.

Meeting the UNESCO deadline is just the latest milestone for the project. In December, nearly $7-million in new federal and provincial capital was announced to help create a world-class tourism and heritage site at the Joggins Fossil Cliffs. This brought total funding for the project to more than $9-million.

"This very worthwhile project couldn't happen without the outstanding support of our funding partners," said Kelly. "Our thanks go out to ACOA, the Province of Nova Scotia, and the Municipality of the County of Cumberland."

The investment is being used to build an interpretive centre to showcase what is considered the world's richest and most significant Coal Age fossil site. Crews from Pomerleau Construction of Dartmouth began construction on the facility earlier this winter. Once completed the 13,000 square foot interpretive centre, which will open this summer, will house a gift shop, a lab and 6,000 feet of exhibition space devoted to the significance of the cliffs. Access to the beach and site safety will also be greatly enhanced.

WHW Architects of Halifax is the lead architectural and design firm for the project, while Design and Communications Inc. (D+C) of Montreal is the major sub-contractor responsible for interpretive planning and design. MT&L Public Relations Limited was retained to develop a new logo for the Fossil Cliffs site as well as a Marketing and Communications Plan.

The green design interpretive centre will feature a vegetation roof and will utilize a wind tower and solar panels to provide alternative energy sources. Once completed, the centre is expected to employ approximately 10 people on a full or part time basis. Based on existing visitor statistics, estimated initial visitation is 40,000 annually.

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For more information contact:
Rhonda Kelly, Executive Director
CREDA
667-3638
Email: **rhondak@creda.net**

MEDIA BRIEFING

January 30, 2007

The Joggins Fossil Institute and the Cumberland Regional Economic Development Association invites you to attend a Media Briefing to mark another significant milestone in the Joggins Fossil Cliffs Project. The Nomination Dossier for Inscription of the Joggins Fossil Cliffs on the list of World Natural Heritage Sites has been submitted to the World Heritage Centre in Paris, meeting the UNESCO deadline of February 1, 2007.

When: Wednesday, January 31 at 3:30 p.m.
Where: The CREDA Boardroom, 35 Church Street, Amherst

CREDA Executive Director Rhonda Kelly will be available to answers questions related to the Joggins Nomination Dossier, as well as the overall development of the Fossil Cliffs into a world-class tourism and heritage site. A brief promotional video (less than 5 minutes) on the Joggins Fossil Cliffs that was included as part of the nomination dossier will be shown for the first time.

For further information and/or to confirm your attendance please contact:

Ron Robinson
Development Field Officer, CREDA
667-3638
Email: **ronr@creda.net**

CUMBERLAND REGIONAL ECONOMIC DEVELOPMENT ASSOCIATION

MEDIA RELEASE

January 3, 2007

Premier visits with Fossil Cliffs training program participants

River Hebert- Nova Scotia Premier Rodney MacDonald met with participants in a tourism training program when he visited Cumberland County on Wednesday, January 3.

Premier MacDonald was at River Hebert District High School to visit with participants in the Joggins Fossil Cliffs Essential Skills Development and Training Program. He was accompanied by Justice Minister and Cumberland South MLA Murray Scott.

Fifteen participants are involved in the 26-week program which is designed to help individuals gain successful employment in the tourism sector within Cumberland County. Topics being covered include general knowledge of the industry, local knowledge of the community, customer service, communications, and a wide range of professional skills. Specific geological training pertinent to the Joggins Fossil Cliffs will also make up a portion of the curriculum. Students will also gain practical experience with a six-week work placement within the tourism industry.

Funding partners include the Nova Scotia Department of Community Services, Service Canada and ACOA. Delivering partners include Nova Scotia Community College-Cumberland Campus and the River Hebert District High School.

The unique partnership with the high school will see money donated for a Student Wellness Centre. Students will help design the centre which will provide them with a relaxing, non-threatening environment where they can get assistance with courses, career planning, health information, and information to assist with other issues. All of the equipment bought for the tourism training program will be donated to the school at the end of the program.

Earlier in the day, Premier MacDonald was at Northport Elementary School to update Northumberland Shore residents on the implementation of high speed Internet service for the Tidnish to Port Howe area. The communities have been selected for a pilot project that will look at ways to bring high-speed Internet service to rural and remote areas of the province.

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NEWS RELEASE / COMMUNIQUÉ

FOR IMMEDIATE RELEASE

Millions to Develop Joggins Cliffs

December 18, 2006, Joggins N.S.--Nearly $7 million in new federal and provincial capital investments will help create a world-class tourism and heritage site at the Joggins Fossil Cliffs in Cumberland County.

The investments will help build an interpretive centre to showcase one of the world's richest and most significant Coal Age fossil sites that dates back 310 million years.

Canada's New Government, through the Atlantic Canada Opportunities Agency (ACOA) is investing more than $4.8 million in the new centre. The Department of Tourism, Culture and Heritage will invest $1.8 million.

"Canada's New Government is getting things done for the people of Nova Scotia. Our investment of over $4.8 million will boost Atlantic Canada's eco-tourism potential" said Bill Casey, MP for Cumberland-Colchester-Musquodoboit Valley on behalf of the Honourable Peter MacKay, Minister of Foreign Affairs and Minister of ACOA. "This Government understands that strong tourism is key to strengthening the economy and to job creation opportunities for Atlantic Canadians"

The provincial investment is in addition to $1.1 million provided in December 2005 to help leverage other funding, bringing the total provincial contribution up $2.9 million.

"The Joggins Fossil Cliffs are a tremendous resource for Nova Scotia in terms of preserving our heritage and sharing it with the world," said Len Goucher, Minister of Tourism, Culture and Heritage. "Our investment will help develop a unique tourism experience and contribute to the efforts to get UNESCO World Heritage Site designation."

The Cumberland Regional Economic Development Association is leading the project and, with the support of the municipality of the county of Cumberland, has contributed $921,600.

Canada

NOVA SCOTIA

CUMBERLAND REGIONAL
ECONOMIC DEVELOPMENT
ASSOCIATION

MEDIA ADVISORY

December 15, 2006

There will be a significant funding announcement to mark the beginning of construction on the multi-million dollar Joggins Fossil Cliffs Interpretive Centre.

This special announcement will take place on Monday, December 18th at 11 a.m. at the St. Thomas Aquinas Parish Hall, 107 Main Street, Joggins.

A light luncheon and refreshments will be served.

For further information and to confirm attendance please contact:

Ron Robinson
Development Field Officer, CREDA
667-3638
Email: **ronr@creda.net**

MEDIA RELEASE

Construction Drawings/Interpretive Designs Completed for Joggins Fossil Cliffs Project

August 9, 2006 **(For Immediate Release)**

Joggins, NS- After approximately 10 years of development work and planning, construction of a world-class interpretive centre for the Joggins Fossil Cliffs is close to becoming a reality.

Construction drawings and interpretive designs for the 13,000 square foot centre have been completed. The project is on schedule for a tender date of August 15th with anticipated ground breaking before year end. The centre, which will open in 2007, will house a gift shop, a lab and 6,000 feet of exhibition space devoted to the significance of the cliffs. The centre is the key component of a $7.5-million project that will also see much improved access to the beach and nomination in 2007 of the Fossil Cliffs and beach area as a UNESCO Natural World Heritage Site.

A Halifax-based architectural and design firm, WHW Architects, was chosen last September to provide consulting services for the development of a Comprehensive Site Development Plan for designing, constructing and operating the Fossil Cliffs Centre and associated infrastructure. As the prime consultant, WHW Architects was responsible for the project as a whole, with a particular focus on architectural and engineering services for the Interpretive Centre and site, along with detailed engineering for beach access at what is known as the Dugway site. Design and Communications Inc. (D+C) of Montreal was the major sub-contractor responsible for providing services for exhibit and visitor experience design including interpretive planning.

Jenna Boon, Senior Project Manager for the Joggins Fossil Cliffs said the result of this collaboration between WHW Architects and D+C is spectacular. "The building design incorporates local materials including Wallace sandstone and will blend in perfectly with the location overlooking Chignecto Bay and the Fossil Cliffs. The design also captures the scope and magnitude of the cliffs while evoking memories of the community's coal mining history," she said. Boon went on to state that the interpretive designs for the centre and site are world-class and like nothing found anywhere else in the region.

The green design interpretive centre will feature a vegetation roof and a wind tower to provide electricity. Once completed, the centre is expected to employ approximately 10 people on a full or part time basis. Based on existing visitor statistics, estimated initial visitation is 40,000 annually.

Meanwhile, a wind test tower has been placed near the building site of the Joggins Fossil Cliff Interpretive Centre. The purpose of the tower is to collect data on the wind speed, temperature and wind direction and to determine the amount of wind energy that could be generated for the Interpretive Centre. The test is being conducted in partnership with the Nova Scotia Wind Energy Project, (NSWEP) whose goal is to raise awareness of climate change in Nova Scotia and to demonstrate how wind energy could be used to mitigate climate change through the use of wind turbine technology.

The Joggins Fossil Cliffs project is a collaborative effort being lead by a project team that includes numerous dedicated individuals from all levels of government, members of the scientific community, tourism organizations, and representatives from the community. These individuals are working with the Cumberland Regional Economic Development Association (CREDA) to develop the Fossil Cliffs and submit application to UNESCO for World Heritage Designation.

It is anticipated that the nomination dossier for World Heritage Site status will be presented to UNESCO in February 2007, followed by an 18-month evaluation process with a final decision on the prestigious designation by summer 2008.

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For more information contact:

Jenna Boon, Senior Project Manager

Rhonda Kelly, Executive Director, CREDA

Telephone: (902) 667-3638

Fax: (902) 667-2270

MEDIA RELEASE

July 11, 2005 **For Immediate Release**

Residents of Cumberland County are being invited to express, in visual or written form, what the Joggins Fossil Cliffs mean to them. The Joggins Fossil Cliffs Advisory Board, in conjunction with the Cumberland Regional Economic Development Association (CREDA), has launched an "Imagine the Joggins Fossil Cliffs" contest.

"What better way is there to get the residents of Cumberland County involved and excited about the new attention being brought to the world renowned site than to hold a contest?" asked Jenna Boon, Senior Project Manager for the Joggins Fossil Cliffs World Heritage Site designation project. "So go ahead let your imagination soar and you could win a $500 cash prize," she said.

Residents of all ages can submit an original image and/ or short written description that they feel represents what the fossil cliffs mean to our county's history and future. Visual images may be done manually or electronically generated – only tiff or jpg files will be accepted. Written descriptions should be typed and no longer than 250 words.

Application forms are available at CAP sites around the county or online at **www.creda.net**. Participants are not limited to the amount of entries that they wish to submit, but are encouraged to consider quality rather than quantity. The contest closes October 1 and entries will be judged by a panel of judges based on originality, creativity, concept and presentation. Voting will close on October 15 and the winner of the $500 cash prize will be announced through local radio, newspapers and on the Internet.

The Joggins Fossil Cliffs have been included on Canada's Tentative List for World Heritage Sites as designated through the United Nations Educational, Scientific and Cultural Organization (UNESCO). It's anticipated that the Nomination Dossier will go forward to UNESCO in early 2007, with a decision 12 to 18 months later.

The Joggins Fossil Cliffs Advisory Board is a sub-committee of CREDA.

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CREDA

MEDIA RELEASE

November 8, 2005 **For Immediate Release**

Joggins Fossil Cliffs Image Contest Winner Announced

Joggins, NS- The Joggins Fossil Cliffs Advisory Board and the Cumberland Regional Economic Development Association (CREDA) have announced the winner of the "Imagine the Joggins Fossil Cliffs" contest.

Darlene Strong of Amherst won the $500 cash prize after her submission was selected from a number of entries received during the three month contest that ran from mid-July to mid-October. Strong's entry, which included a written essay titled "If the Cliffs Could Speak" and an original painting, was chosen by a panel of judges based on originality, creativity, concept and presentation.

Strong, who resumed painting in 1999 after an extended absence since childhood, said she felt privileged to have been chosen the winner. "Considering the demographic area, I would like to say thanks for making this opportunity available to residents of Cumberland County. I felt this would be a unique opportunity to share the gift of art, capture the cliffs on canvass, and reflect on the miraculous account of Gage," she added referring to Gage Gabriel the young boy who survived a Christmas eve night on the beach after his mother Toby Gabriel was killed when their vehicle went over the cliff at Lower Cove.

Although she has no formal training in painting, Strong credits Joan Cameron of Amherst for being a mentor with regard to presentation.

The contest was open to all residents of Cumberland County and was widely promoted throughout the county. Posters were placed in a number of outlets while schools were contacted and asked to encourage their students to participate. The contest was also promoted on the CREDA and Joggins Fossil Cliffs websites (**www.creda.net** and **www.fossilcliffs.net**).

The Joggins Fossil Cliffs have been included on Canada's Tentative List for World Heritage Sites as designated through the United Nations Educational, Scientific and Cultural Organization (UNESCO). It's anticipated that the Nomination Dossier will go forward to UNESCO in early 2007, with a decision 12 to 18 months later. The Joggins Fossil Cliffs Advisory Board is a sub-committee of CREDA.

For more information contact:
Jenna Boon, Senior Project Manager
(902) 667-3638

CUMBERLAND REGIONAL
ECONOMIC DEVELOPMENT
ASSOCIATION

MEDIA RELEASE

FOR IMMEDIATE RELEASE **Date: May 12, 2005**

Joggins, NS- The Cumberland Regional Economic Development Association and the Joggins Fossil Cliffs Advisory Board have announced the hiring of a senior project manager to oversee all components required to ready the Joggins Fossil Cliffs for nomination as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site.

The successful candidate, Jenna Boon, is a highly-qualified and skilled young professional, who is returning to the community where she spent her youth to manage this massive project. Her professional experience and educational background is related directly to natural resource management.

Ms. Boon will report to the advisory board, which is a sub-committee of the Cumberland Regional Economic Development Association (CREDA), through CREDA executive director, Rhonda Kelly. "Ms. Boon will be responsible for overall planning, management and coordination of the UNESCO World Heritage Site nomination process," said Ms. Kelly. "She will also manage other aspects of the project, including the development of a $6-million Interpretive Centre, a site development plan, and beach access at the Dugway site."

Since 2002, Ms. Boon has been Manager of the Engineering, Trades and Technology Department at Holland College in Charlottetown, PEI during which time she has also served as Project Coordinator for developing a trades strategy for the province. Prior to returning to the Maritimes in 2002, Ms. Boon worked as Program Director of the Technology Division for the Saskatchewan Institute of Applied Science and Technology (SIAST). She also worked as an instructor in the Integrated Resource Management-Diploma Program at SIAST and as a Project Specialist for an Environmental Studies Program at Kenya Polytechnic in Africa. Ms. Boon established and managed her own environmental consulting business that focused on impact assessments in forestry and wildlife management. Ms. Boon graduated with honours with a Bachelor of Science degree in Physical Geography from the University of Regina.

Area county councilor John Reid, who also sits on the Fossil Cliffs Advisory Board, said he was very excited that a senior project manager has been chosen. "We are looking forward to moving this project forward and having a physical presence in the community," he added.

Economic Development Minister and Cumberland North MLA Ernie Fage said the province is very pleased to see such a talented young person returning to Nova Scotia to work in their community. "To have a Nova Scotian with all the right credentials, talent, and experience coming home and giving back to the province and their community is very important," the minister said. Cumberland South MLA and Speaker of the House Murray Scott also welcomed today's announcement. "As a World Heritage Site candidate it is critical that the Joggins Fossil Cliffs has someone who has the knowledge, experience and passion for the area to take this project to the next level," he said.

The Nova Scotia departments of Tourism, Culture and Heritage; Natural Resources; and the Office of Economic Development contributed $180,000 over three years to assist with project management, administration, coordination and planning. The Atlantic Canada Opportunities Agency also contributed $291,257 towards the planning component of the project, which is also supported by the Municipality of the County of Cumberland.

Recently the provincial government announced a one time, $1.1-million dollar investment in the overall development of the Joggins Fossil Cliffs Interpretive Centre. The investment is being administered by CREDA and is being used to seek additional partners and leverage other public and private sector resources.

It is anticipated that the nomination will be presented to UNESCO in February 2007, followed by an 18-month evaluation process with a final decision on the prestigious designation by summer 2008.

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CONTACT: Rhonda Kelly
Cumberland Regional Economic Development Association
Phone: (902) 667-3638
Fax: (902) 667-2270
Email: *rhondak@creda.net*

MEDIA ADVISORY

February 15, 2005

The Hon. Rodney MacDonald, Minister of Tourism, Culture and Heritage will be making a significant announcement on behalf of the Province of Nova Scotia regarding the construction of the Joggins Fossil Cliffs Interpretive Centre.

This special announcement will now take place on Friday, February 18, 2005 at 11 a.m. at the Joggins Fossil Centre, 30 Main Street, Joggins.

A light luncheon and reception will follow at the Fossil Centre.

For further information and to confirm attendance please contact:

Ron Robinson
Development Field Officer, CREDA
667-3638
Email: **ronr@creda.net**

MEDIA RELEASE

FOR IMMEDIATE RELEASE

Date: December 13,2004

Province of Nova Scotia commits funds for Joggins Fossil Cliffs

Amherst- The Province of Nova Scotia, through the Office of Economic Development and the Department of Tourism, Culture and Heritage, will contribute $180,000 over three years towards efforts to promote the protection and enhancement of the Joggins Fossil Cliffs.

Ernie Fage, Minister of Economic Development and MLA for Cumberland North along with Speaker of the House and MLA for Cumberland South Murray Scott were on hand Monday, December 13 to present a cheque for $15,000 to CREDA Executive Director Rhonda Kelly, on behalf of the Joggins Fossil Cliffs Advisory Board. The cheque represents the first installment of the Office of Economic Development's three-year commitment to assist with Project management, administration, coordination and planning.

The funding will allow the Joggins Fossil Cliffs Advisory Board, which is a sub-committee of CREDA, to retain a Senior Project Manager along with dedicated administrative support to facilitate, coordinate and lead the completion of the overall nomination dossier process for application to the United Nations for World Heritage Site designation. It's anticipated that the Nomination Dossier for the Joggins Fossil Cliffs will be presented to the United Nations Educational, Scientific and Cultural Organization (UNESCO) in February 2006, followed by an 18 month evaluation process with a final decision on designation by summer 2007.

Additional funding is expected to be approved shortly for essential preliminary design activity for the Fossil Cliffs including architectural and interpretive program design for a proposed world-class Interpretive Facility, a Site Development Plan, and detailed engineering for beach access at what is known as the Dugway Site. Other funding partners for the estimated $560,000 project will include the Department of Tourism, Culture & Heritage, Atlantic Canada Opportunities Agency (ACOA), the Municipality of Cumberland County, and the local community.

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Canada

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We believe in you.

MEDIA RELEASE

October 14, 2003 **FOR IMMEDIATE RELEASE**

Joggins, N.S. –Interested entrepreneurs who may be considering starting or expanding a business in the Joggins area are invited to attend an ***Entrepreneur Information Session*** on Monday, October 20 from 7 p.m. to 9 p.m. at the Joggins Fire Hall.

The free information session is sponsored by the River Hebert/Joggins & Area Development Association and the Cumberland Regional Economic Development Association (CREDA), in partnership with the Nova Scotia Association of Community Business Development Corporations (CBDCs) and the Atlantic Canada Opportunities Agency (ACOA).

"This is a follow up to a very successful session we held in the community last June," said Bernice Vance, spokesperson for the River Hebert/Joggins & Area Development Association. "We had about 50 people in attendance who were interested in exploring business opportunities that could result from the ongoing developments at the Joggins Fossil Cliffs," she added.

A Tourism Concept Plan, prepared by EDM Environmental Design and Management Limited, identifies a number of potential business opportunities associated with the Fossil Cliffs and efforts to have the cliffs declared a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Chris Pelham of the Acadia University Centre for Small Business and Entrepreneurship, who was on hand for the June session, will return to present an overview on how to develop a Business Plan. Pelham has in excess of 25 years of community development and business advisory experience. The Acadia Centre for Small Business and Entrepreneurship has been designing and delivering training and counseling to existing and would-be entrepreneurs for 10 years to in excess of 5,000 clients.

No pre-registration is required for the session. Refreshments will be served.

For more information please contact:

River Hebert/Joggins & Area
Development Association
Bernice Vance – 251-2342
John Reid – 251-2194

Paul Hopper
CREDA
667- 3638

Joggins Fossil Cliffs
WORLD HERITAGE COMMITTEE

CREDA

MEDIA RELEASE

JUNE 16, 2003 **FOR IMMEDIATE RELEASE**

Joggins, N.S. – Local entrepreneurs wishing to explore potential future business opportunities related to ongoing developments at the Joggins Fossil Cliffs are invited to attend an Information Session scheduled for next week in Joggins. The River Hebert/Joggins & Area Development Association and the Cumberland Regional Economic Development Association (CREDA) are partnering to present an ***Entrepreneur Opportunity Information Session*** on Monday, June 23 from 7:00 to 9:00 p.m. at the Joggins Fire Hall.

Representatives from both organizations will be on hand to provide information regarding potential business opportunities as outlined in the recent Tourism Concept Plan for the Joggins Fossil Cliffs prepared by EDM Environmental Design and Management Limited. There will also be an update on the status of efforts to have to Fossil Cliffs declared a World Heritage Site by UNESCO, the United Nations Educational, Scientific and Cultural Organization.

Chris Pelham of the Acadia University Centre for Small Business and Entrepreneurship will offer an introduction to entrepreneurship and touch on the nature of the opportunities such as small retail, artisans and giftware, accommodations, and other tourism related activities and products. In addition a representative from the Nova Scotia Department of Tourism and Culture will give an overview of tourism activities at similar sites. Tourist needs and considerations, opportunities for existing businesses, marketing, resources and support information and programs will also be covered.

The goal of the Information Session is to provide a general overview of the future opportunities and to seek feedback to help develop specific programs suited to the interests of the community.

The session is open to everybody interested. No pre-registration is required and refreshments will be served.

For more information please contact:

River Hebert/Joggins & Area
Development Association
Bernice Vance – 251-2342
John Reid – 251-2194

Paul Hopper
CREDA
667- 3638

JOGGINS ENTREPRENEURSHIP SESSION WELL ATTENDED

Entrepreneurship is alive and well in the Joggins/River Hebert area. An estimated 50 people attended an Entrepreneur Opportunity Information Session on Monday, June 23 at the Joggins Fire Hall. Purpose of the session, which was co-hosted by CREDA and the River Hebert/Joggins & Area Development Association, was to explore potential future business opportunities related to ongoing developments at the Joggins Fossil Cliffs.

The recent Tourism Concept Plan for the Fossil Cliffs prepared by EDM Environmental Design and Management Limited identifies a number of potential business opportunities associated with the Fossil Cliffs and efforts to have the Cliffs declared a UNESCO World Heritage Site.

Chris Pelham of the Acadia University Centre for Small Business and Entrepreneurship touched on the nature of the opportunities such as small retail, artisans and giftware, accommodations, and other tourism related products and activities. Darlene MacDonald from the Nova Scotia Department of Tourism & Culture provided an overview of tourism activities at similar sites. She also provided information on marketing, opportunities for existing businesses, tourist needs and considerations, and the types of resources, support and programs available for small tourism related businesses.

Of those in attendance 58% completed evaluation forms which yielded the following information:
-62% do not currently own their own business, but 59 % are interested in starting their own business.
-83% said they would be interested in attending a future workshop or seminar relating to small business. Topics they would like to see covered at a future session include: financing/funding sources, accommodations, marketing, business plan development/micro-enterprise, entrepreneur training, the super host program, bike rentals, beach tours and networking.

A second session is tentatively scheduled for the fall.

Joggins Fossil Cliffs
WORLD HERITAGE COMMITTEE

MEDIA RELEASE

FOR IMMEDIATE RELEASE

DATE: January 30, 2003

Public Gets First Look at Fossil Cliffs Building Design

Joggins, N.S. – Joggins and area residents have had their first look at the future infrastructure that may be developed at the world famous Joggins Fossil Cliffs. The Joggins Fossil Cliffs World Heritage Committee unveiled the preliminary set of drawings for a potential Fossil Cliffs interpretative building for the public to view during a Community Information Session on Thursday, January 30.

Architects from the firm of Anwyll Fogo Architects & Interiors Ltd. of Halifax used the historical features found in the construction of the Chignecto Mines, a cluster of buildings that operated in the early 1900s, in their preliminary design of the potential Interpretive Centre. After reviewing literature and pictures gathered about the area and the site, the unique structural concept was developed. Inspiration for the building plans came from coal mines of the past, waves of the Bay of Fundy and land formations located near the site. The preliminary design features timbered overhead beams inspired by mine-shaft construction, high rolling ceilings representative of ocean waves, and angled stone walls suggestive of the stratified fossil cliff geology.

Rhonda Kelly, Executive Director of the Cumberland Regional Economic Development Association (CREDA) said members of the Steering Committee are pleased with the design. "They were impressed by the highly creative and interesting methods used by the architects to depict the various elements of the community's mining history and world famous fossil cliffs," she said.

"It should be stated that these plans represent only the first step in any potential future construction of a fossil cliffs related building," Kelly added. "Identification of possible funding partners and activities, development of site management plans and an area marketing strategy are just a few of the necessary steps required to assure the sustainable success of the Joggins Fossil Cliffs project."

Plans are now underway to determine the best location for any potential future Interpretive Centre buildings or structures at the Fossil Cliffs. A Request For Proposals has been prepared to obtain proposals from qualified parties interested in completing the necessary geo-technical work for the project.

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Joggins Fossil Cliffs
WORLD HERITAGE COMMITTEE

MEDIA RELEASE

FOR IMMEDIATE RELEASE

DATE: January 27, 2003

Fossil Cliffs Tourism Concept Plan and Building Design Ready for Public Viewing

Joggins – Details of a comprehensive Tourism Concept Plan for the Joggins Fossil Cliffs will be presented to the public at a community information session scheduled for Thursday, January 30 at 7 p.m. at the Joggins Fire Hall. Members of the Joggins Fossils Cliffs World Heritage Committee will be on hand to present the final draft of the Tourism Concept Plan, which was prepared by Environmental Design and Management (EDM) Ltd. of Halifax.

The Plan focuses on four main objectives according to Rhonda Kelly, Executive Director of the Cumberland Regional Economic Development Association (CREDA). "It identifies the necessary improvements required to position Joggins as a World Class attraction, provides an action plan to implement the identified improvements, identifies the main viewing audience and infrastructure needs for the Fossil Cliffs, and includes local input from the community" she said. "The Concept Plan provides a tourism market summary for the Joggins area, a vision for the proposed Interpretive Centre, and a design concept for the potential building as well as other related infrastructure", Kelly added.

The preliminary set of drawings for the proposed future Joggins Fossil Cliffs Interpretive Centre will also be on display for the public to view. Several guests will be on hand to provide their insight into the project including representatives from CREDA, the Municipality of Cumberland and other project partners.

The Joggins Fossil Cliffs World Heritage Committee falls under the umbrella of CREDA. The committee's goal is to seek nomination and designation of the Fossil Cliffs as a Natural World Heritage Site under the United Nations Educational, Scientific and Cultural Organization (UNESCO).

All residents of Joggins and area are encouraged to attend the community information session.

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CONTACT: Rhonda Kelly
Cumberland Regional Economic Development Association
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Fax: (902) 667-2270
Email: rhondak@creda.net

United Nations
Educational, Scientific and
Cultural Organization

Organisation
des Nations Unies
pour l'éducation,
la science et la culture

Organización
de las Naciones Unidas
para la Educación,
la Ciencia y la Cultura

Организация
Объединенных Наций по
вопросам образования,
науки и культуры

منظمة الأمم المتحدة
للتربية والعلم والثقافة

联合国教育、
科学及文化组织

Culture Sector

Mr Larry Ostola
Directeur general des Lieux historiques nationaux/ Director General, National Historic Sites
Parcs Canada / Parks Canada
25, rue Eddy / 25 Eddy St
K1A 0M5 Gatineau
Canada

24 September 2008

Ref. : WHC/74/1098/CA/KM/

Subject: **Inscription of the property *Joggins Fossil Cliffs / Falaises fossilifères de Joggins* (N 1285) (Canada) on the World Heritage List**

Sir,

I have the pleasure to inform you that the World Heritage Committee, at its 32nd session (Quebec, Canada, 2 – 10 July 2008), examined the nomination of ***Joggins Fossil Cliffs*** and decided to **inscribe** the property on the World Heritage List. The decision of the Committee concerning the inscription is attached below (Decision **32 COM 8B.9**).

I am confident that your government will continue to take the necessary measures for the proper conservation of this extended World Heritage property. The World Heritage Committee and its Secretariat, the World Heritage Centre, will do everything possible to collaborate with you in these efforts.

The *Operational Guidelines for the Implementation of the World Heritage Convention* (paragraph 168), request the Secretariat to send to each State Party with a newly inscribed property a map of the area(s) inscribed. Please examine the attached map and table and inform us of any discrepancies in the information by **1 December 2008**.

The inscription of the property on the World Heritage List is an excellent opportunity to draw the attention of visitors to, and remind local residents of, the *World Heritage Convention* and the outstanding universal value of the property. To this effect, you may wish to place a plaque displaying the World Heritage and the UNESCO emblems at the property. You will find suggestions on this subject in the *Operational Guidelines for the Implementation of the World Heritage Convention.*

In many cases States Parties decide to hold a ceremony to commemorate the inscription of a property on the World Heritage List. Upon request to the World Heritage Centre by the State Party, a World Heritage Certificate can be prepared for such an occasion.

I would be grateful if you could provide me with the name, address, telephone and fax numbers and e-mail address of the person or institution responsible for

7, place de Fontenoy
75352 Paris 07 SP, France
Tél. : +33 (0)1 45 68 14 40
Fax : +33 (0)1 45 68 55 70

www.unesco.org

the management of the property so that we may send them World Heritage publications.

Please find attached the brief description of your site in English, prepared by ICOMOS and the World Heritage Centre. The French version will be provided in due course. As these brief descriptions will be used in later publications, as well as on the World Heritage website, we would like to have your full concurrence with their wording. Please examine these descriptions and inform us, by **1 December 2008** at the latest, if there are changes that should be made. If we do not hear from you by this date, we will assume that you are in agreement with the text as prepared.

Furthermore, as you may know, the World Heritage Centre maintains a website at http://whc.unesco.org, where standard information about each property on the World Heritage List can be found. Since we can only provide a limited amount of information about each property, we try to link our pages to those maintained by your World Heritage property or office, so as to provide the public with the most reliable and up-to-date information. If there is a website for the newly inscribed property, please send us its web address.

The full list of the Decisions adopted by the 32nd session of the World Heritage Committee will be sent to you in due course.

As you know, according to paragraph 172 of the *Operational Guidelines for the Implementation of the World Heritage Convention*, the World Heritage Committee invites the States Parties to the *Convention* to inform the Committee, through the World Heritage Centre, of their intention to undertake or to authorize in the area protected under the *Convention* major restorations or new constructions which may affect the outstanding universal value of the property.

May I take this opportunity to thank you for your co-operation and for your support in the implementation of the *World Heritage Convention.*

Yours sincerely,

F Bandarin

Francesco Bandarin
Director
World Heritage Centre

cc: Permanent Delegation of Canada to UNESCO
National Commission of Canada for UNESCO
IUCN

Annex 1

Decision: 32 COM 8B.9

The World Heritage Committee,

1. Having examined Documents *WHC-08/32.COM/8B* and *WHC-08/32.COM/INF.8B2,*

2. Inscribes **The Joggins Fossil Cliffs, Canada**, on the World Heritage List on the basis of **criterion (viii)**;

3. Adopts the following Statement of Outstanding Universal Value:

Values
The Joggins Fossil Cliffs have been termed the "coal age Galápagos" and are the world reference site for the "Coal Age". Their complete and accessible fossil-bearing rock exposures provide the best evidence known of the iconic features of the Pennsylvanian (or Carboniferous) period of Earth History.

Criterion (viii): Earth's history, geological and geomorphic features and processes: The "grand exposure" of rocks at Joggins Fossil Cliffs contains the best and most complete known fossil record of terrestrial life in the iconic "Coal Age": the Pennsylvanian (or Carboniferous) period in Earth's history. The site bears witness to the first reptiles in Earth history, which are the earliest representatives of the amniotes, a group of animals that includes reptiles, dinosaurs, birds, and mammals. Upright fossil trees are preserved at a series of levels in the cliffs together with animal, plant and trace fossils that provide environmental context and enable a complete reconstruction to be made of the extensive fossil forests that dominated land at this time, and are now the source of most of the world's coal deposits. The property has played a vital role in the development of seminal geological and evolutionary principles, including through the work of Sir Charles Lyell and Charles Darwin, for which the site has been referred to as the "coal age Galápagos".

Integrity
The boundaries of the property are clearly defined in relation to logical stratigraphic criteria and include all of the areas necessary to fully display the fossil record of Joggins including the cliff face and foreshore rock exposures, and include both the most fossiliferous strata and younger and older rocks that provide geological context. The inland extent of the property is defined based on the eroding top of the cliffs and this is a fully justifiable and logical basis to cope with the dynamic nature of this coastal property. A relatively narrow buffer zone is defined, which is not part of the inscribed property, but is sufficient to control coastal development which could otherwise threaten the values of the property.

Requirements for Protection and Management
The property has effective legal protection and has the strong support of all levels of government, including in relation to the provision of funding. Some aspects of the legislation, such as for the licensing of fossil collection are cumbersome and would benefit from review, although can be better

implemented if site managers are empowered to do so. The site is well resourced, including through the provision of a new visitor centre, and is managed in a way that can be considered to set international standards. The effective process of community involvement and partnerships between scientists, museums and economic interests are also noted, and the biggest challenge of the property will be to maintain the level of performance and resources required in the future.

4. Notes the very high quality of documentation of the nomination and the process of community engagement in its preparation, over a period of almost ten years, as models in the preparation of nominations and in effective management of World Heritage properties;

5. Recommends that the State Party widely publicise the results of its monitoring of fossil resources produced by natural erosion and the development of educational and research collecting policies, which could serve as a model for such management elsewhere.

Annex 2

Brief Description

The Joggins Fossil Cliffs, a 689 ha palaeontological site along the coast of Nova Scotia (eastern Canada), have been described as the “coal age Galápagos” due to their wealth of fossils from the Carboniferous period (354 to 290 million years ago). The rocks of this site are considered to be iconic for this period of the history of Earth and are the world’s thickest and most comprehensive record of the Pennsylvanian strata (dating back 318 to 303 million years) with the most complete known fossil record of terrestrial life from that time. These include the remains and tracks of very early animals and the rainforest in which they lived, left in situ, intact and undisturbed. With its 14.7 km of sea cliffs, low bluffs, rock platforms and beach, the site groups remains of three ecosystems: estuarine bay, floodplain rainforest and fire prone forested alluvial plain with freshwater pools. It offers the richest assemblage known of the fossil life in these three ecosystems with 96 genera and 148 species of fossils and 20 footprint groups. The site is listed as containing outstanding examples representing major stages in the history of Earth.

Outstanding Universal Value

Values

The Joggins Fossil Cliffs have been termed the “coal age Galápagos” and are the world reference site for the “Coal Age”. Their complete and accessible fossil-bearing rock exposures provide the best evidence known of the iconic features of the Pennsylvanian (or Carboniferous) period of Earth History.

Criterion (viii): Earth’s history, geological and geomorphic features and processes: The “grand exposure” of rocks at Joggins Fossil Cliffs contains the best and most complete known fossil record of terrestrial life in the iconic “Coal Age”: the Pennsylvanian (or Carboniferous) period in Earth’s history. The site bears witness to the first reptiles in Earth history, which are the earliest representatives of the amniotes, a group of animals that includes reptiles, dinosaurs, birds, and mammals. Upright fossil trees are preserved at a series of levels in the cliffs together with animal, plant and trace fossils that provide environmental context and enable a complete reconstruction to be made of the extensive fossil forests that dominated land at this time, and are now the source of most of the world’s coal deposits. The property has played a vital role in the development of seminal geological and evolutionary principles, including through the work of Sir Charles Lyell and Charles Darwin, for which the site has been referred to as the “coal age Galápagos”.

Integrity

The boundaries of the property are clearly defined in relation to logical stratigraphic criteria and include all of the areas necessary to fully display the fossil record of Joggins including the cliff face and foreshore rock exposures, and include both the most fossiliferous strata and younger and older rocks that provide geological context. The inland extent of the property is defined based on the eroding top of the cliffs and this is a fully justifiable and logical basis to cope with the dynamic nature of this coastal property. A relatively narrow buffer zone is defined, which is not part of the inscribed property, but is sufficient to control coastal development which could otherwise threaten the values of the property.

Requirements for Protection and Management

The property has effective legal protection and has the strong support of all levels of government, including in relation to the provision of funding. Some aspects of the legislation, such as for the licensing of fossil collection are cumbersome and would benefit from review, although can be better implemented if site managers are empowered to do so. The site is well resourced, including through the provision of a new visitor centre, and is managed in a way that can be considered to set international standards. The effective process of community involvement and partnerships between scientists, museums and economic interests are also noted, and the biggest challenge of the property will be to maintain the level of performance and resources required in the future.

Brève description

Les falaises fossilifères de Joggins forment un site paléontologique de 689 hectares, situé le long de la côte de la Nouvelle Ecosse (est du Canada). Le site est décrit comme « les Galapagos du Carbonifère » pour sa richesse en fossiles de cette période géologique (354 à 290 millions d'années). Les roches du site sont considérées comme des exemples types de cette période de l'histoire de la Terre; elles représentent le vestige le plus épais et le plus riche au monde de la strate pennsylvanienne (318 à 303 millions d'années) avec le registre fossilifère connu le plus complet des formes de vie terrestres de cette époque. S'y trouvent des restes et des traces des tout premiers animaux et des forêts pluviales dans lesquelles ils vivaient, révélés in situ, dans un contexte géologique non perturbé et intact. Avec ses 14,7 km de falaises maritimes, microfalaises, plates-formes et plages, le site regroupe les vestiges de trois écosystèmes : une baie estuarienne, une forêt pluviale de plaine d'inondation et une plaine alluviale boisée et sensible aux incendies avec des mares d'eau douce. Il offre l'ensemble le plus complet de fossiles de ces trois genres d'écosystèmes avec 96 genres et 148 espèces de fossiles ainsi que 20 groupes d'empreintes. Le lieu est inscrit sur la Liste pour ses échantillons spectaculaires d'étapes majeures de l'histoire de la Terre.

Valeur universelle exceptionnelle

Valeurs

Les falaises fossilifères de Joggins ont été qualifiées de « Galápagos du Carbonifère » et sont le site de référence mondial pour le Carbonifère. Leurs affleurements de roches fossilifères, complets et accessibles, fournissent la meilleure illustration connue des caractéristiques iconiques de la période pennsylvanienne (ou Carbonifère) de l'histoire de la Terre.

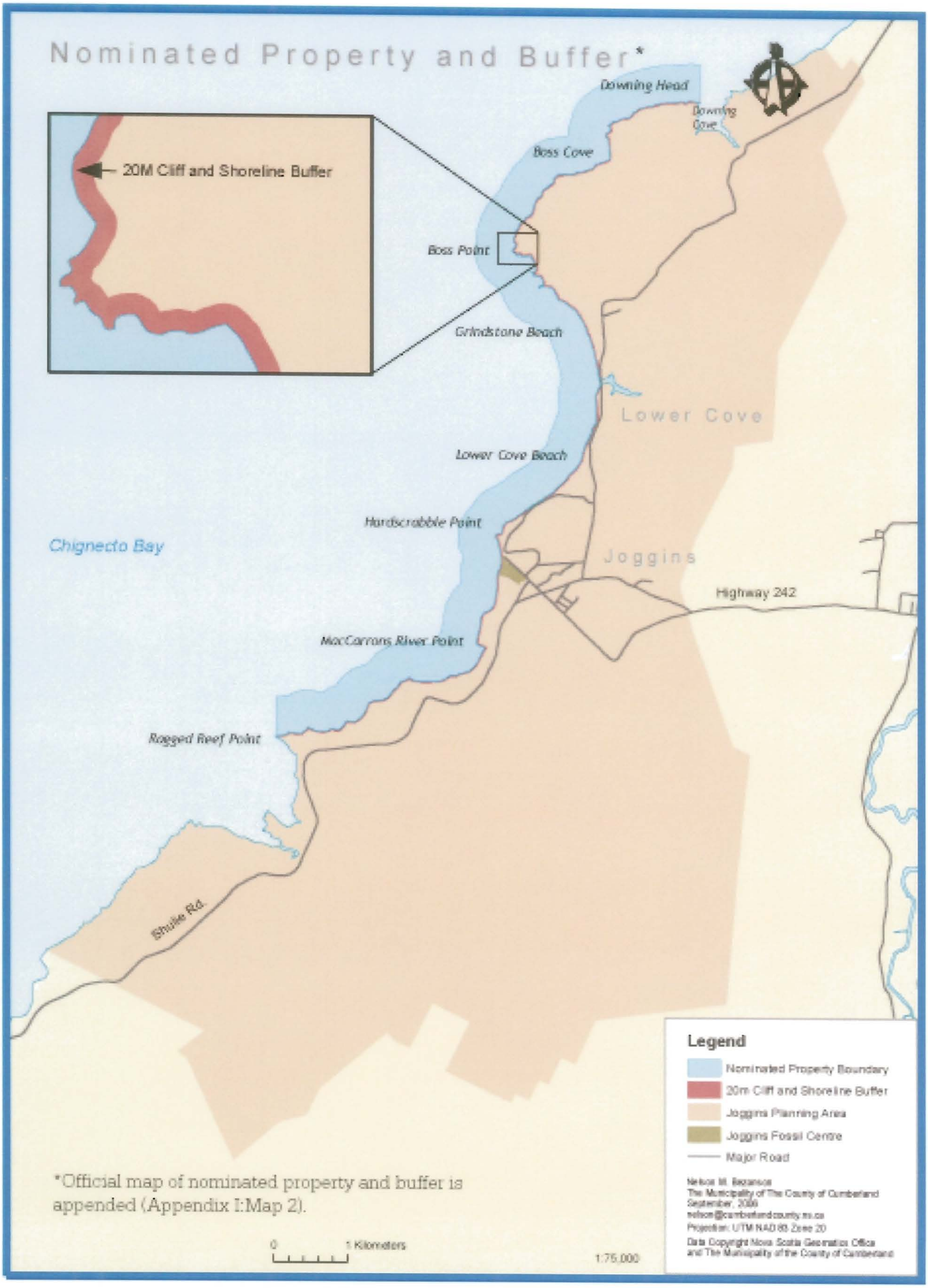
Critère (viii) : Histoire de la Terre, éléments et processus géologiques et géomorphiques : Le « grandiose affleurement » de roches des falaises fossilifères de Joggins contient le registre fossile connu le meilleur et le plus complet de la vie terrestre à l' « âge du charbon » iconique : la période pennsylvanienne (ou Carbonifère) de l'histoire de la Terre. Le site témoigne des premiers reptiles de l'histoire de la Terre qui sont les représentants les plus anciens des amniotes, un groupe d'animaux comprenant les reptiles, les dinosaures, les oiseaux et les mammifères. Des arbres fossilisés sont préservés sur pied dans une série de niveaux des falaises en compagnie de fossiles d'animaux, de plantes et de traces fournissant le contexte environnemental et permettant une reconstruction complète des vastes forêts qui dominaient ces terres à l'époque, et qui sont aujourd'hui la source de la majeure partie des gisements de charbon du monde. Le bien a joué un rôle vital dans le développement des principes fondamentaux de la géologie et de l'évolution, notamment à travers les travaux de Sir Charles Lyell et de Charles Darwin, ce qui explique que le site soit connu sous le nom de « Galápagos du Carbonifère ».

Intégrité

Les limites du bien sont clairement définies du point de vue des critères stratigraphiques logiques et englobent toutes les zones nécessaires pour présenter l'ensemble du registre fossilifère de Joggins, y compris le front des falaises et les affleurements rocheux de l'estran avec à la fois les strates les plus fossilifères et les roches les plus jeunes et les plus anciennes qui fournissent le contexte géologique. L'étendue vers l'intérieur du bien est définie par rapport au sommet en érosion des falaises, ce qui est pleinement justifié et qui est une base logique pour tenir compte de la nature dynamique de ce bien côtier. Une zone tampon relativement étroite est définie. Elle ne fait pas partie du bien inscrit mais suffit pour contrôler le développement côtier qui pourrait, sans cela, menacer les valeurs du bien.

Mesures de protection et de gestion

Le bien jouit d'une protection juridique efficace ainsi que de l'appui solide de tous les paliers de gouvernement, y compris en ce qui concerne son financement. Certains aspects de la législation, comme par exemple les licences de collecte de fossiles, sont lourds et mériteraient d'être révisés mais pourraient aussi être mieux appliqués si les gestionnaires du site en avaient le pouvoir. Le site est bien financé, notamment grâce au nouveau centre d'accueil du public, et géré de telle sorte qu'on peut le considérer comme un modèle au niveau international. Le processus efficace de participation communautaire et de partenariat entre les scientifiques, les musées et les intérêts économiques est également remarquable et la difficulté principale consistera à maintenir le niveau d'efficacité et les ressources requises à l'avenir.


Nominated Property and Buffer*
20M Cliff and Shoreline Buffer
Downing Head
Downing Cove
Boss Cove
Boss Point
Grindstone Beach
Lower Cove
Lower Cove Beach
Hardscrabble Point
Chignecto Bay
Joggins
Highway 242
MacCarrons River Point
Ragged Reef Point
Shulie Rd.
Legend
Nominated Property Boundary
20m Cliff and Shoreline Buffer
Joggins Planning Area
Joggins Fossil Centre
Major Road
The Municipality of The County of Cumberland
Data Copyright Nova Scotia Geomatics Office
and The Municipality of the County of Cumberland
0
1 Kilometers
1:75,000
*Official map of nominated property and buffer is
appended (Appendix I:Map 2).

Parcs Canada Parks Canada

25 Eddy Street, 5th Floor
Jules Léger Building (25-5-N)
Gatineau (Québec) K1A 0M5
CANADA

NOV - 3 2008

Mr. Francesco Bandarin
Director
World Heritage Centre
UNESCO
7, place de Fontenoy
75352 Paris 07 SP
France

Subject: **WHC/74/1098 – Inscription of the property Joggins Fossil Cliffs / *Falaises fossilifères de Joggins* (N 1285) (Canada) on the World Heritage List**

Dear Mr. Bandarin:

I am writing in response to your letter of 24 September 2008 on the above-noted subject. I am pleased to inform you that the map you sent as an attachment to your letter is appropriate. Further, we have no comments to make with respect to the Brief Description (English) that you sent to us. However, we request that the World Heritage Centre use the attached *brève description* of Joggins, which has a number of changes to the *brève description* that you submitted. An electronic version of this text will be sent separately.

For the purposes of sending World Heritage publications to the managers of the Joggins Fossil Cliffs, you should use the following contact information:

Joggins Fossil Institute Association
Joggins Fossil Centre
100 Main Street
Joggins, Nova Scotia CANADA
B0L 1A0
Email: director@jogginsfossilcliffs.net
Phone: 902.251.2727 ext 222
Fax: 902.251.2502

The official website to which the World Heritage Centre's website can provide a link is www.jogginsfossilcliffs.net.

...2/

I trust that this information is helpful.

Yours sincerely,

Larry Ostola
Director General
National Historic Sites
and
Head of Canadian Delegation to the World Heritage Convention

Attach.

cc Kathy Bunka, Deputy Permanent Delegate of Canada to UNESCO
David Walden, Canadian Commission for UNESCO
David Sheppard, IUCN
Jenna Boon, Joggins Fossil Institute

Les falaises fossilifères de Joggins

Brève description

Les falaises fossilifères de Joggins constituent un site paléontologique de 689 hectares, situé le long de la côte de la Nouvelle-Écosse (dans l'Est du Canada). On le surnomme le « Galápagos du carbonifère » en raison de la profusion de fossiles qu'on y trouve et qui remontent à cette période géologique (datant de 354 à 290 millions d'années). Les roches du site sont considérées comme des exemples types de cette période de l'histoire de la Terre; elles constituent le vestige de la strate pennsylvanienne (vieille de 318 à 303 millions d'années) le plus important en épaisseur et en richesse au monde, ainsi que le registre fossilifère le plus complet des formes de vie terrestres de cette époque. On y trouve des restes et des traces des premiers animaux et des forêts tropicales humides dans lesquelles ils vivaient, conservés in situ, intacts et non perturbés. Les 14,7 kilomètres de falaises maritimes, de microfalaises, de plates-formes rocheuses et de plages du site regroupent les vestiges de trois écosystèmes : une baie estuarienne, une forêt tropicale humide en plaine inondable et une plaine alluviale boisée sujette aux incendies et comportant des mares d'eau douce. Le site offre l'ensemble le plus complet de fossiles de ces trois types d'écosystème, soit 96 genres et 148 espèces de fossiles ainsi que 20 groupes d'empreintes. Il est répertorié en raison des échantillons spectaculaires qu'il renferme et qui représentent les principales étapes de l'histoire de la Terre.

Valeur universelle exceptionnelle

Valeurs
Les falaises fossilifères de Joggins ont été qualifiées de « Galápagos du carbonifère » et constituent le site de référence mondial pour l'« Âge du charbon ». Leurs affleurements de roches fossilifères, complets et accessibles, fournissent la meilleure illustration connue des caractéristiques particulières de la période pennsylvanienne (ou carbonifère) de l'histoire de la Terre.
Critère (viii) : Histoire de la Terre, éléments et processus géologiques et géomorphiques : L'« affleurement grandiose » de roches aux falaises fossilifères de Joggins constitue les archives fossilifères connues les plus remarquables et les plus complètes de la vie terrestre à cette époque marquante appelée « Âge du charbon » : la période pennsylvanienne (ou carbonifère). Le site témoigne des premiers reptiles de l'histoire de la Terre, qui sont les représentants les plus anciens des amniotes, un groupe d'animaux comprenant les reptiles, les dinosaures, les oiseaux et les mammifères. Des arbres fossilisés sur pied sont préservés dans plusieurs niveaux des falaises, de même que des fossiles d'animaux, de plantes et d'autres traces qui fournissent une contexte environnemental et permettent une reconstitution complète des vastes forêts qui dominaient les terres émergées à l'époque, et qui sont aujourd'hui la principale source de charbon du monde. Ce lieu a joué un rôle crucial dans l'élaboration des principes fondamentaux de la géologie et de l'évolution, notamment grâce aux travaux de sir Charles Lyell et de Charles Darwin, ce qui explique que qu'il soit connu sous le nom de « Galápagos du carbonifère ».

Intégrité

Les limites de la propriété sont clairement définies en fonction de critères stratigraphiques logiques, et englobent toutes les zones nécessaires à une représentation complète du registre fossilifère de Joggins, y compris le front des falaises et les affleurements rocheux de l'estran ainsi que les strates les plus fossilifères et les roches les plus jeunes et les plus anciennes qui fournissent le contexte géologique. La superficie de la propriété à l'intérieur des terres est définie par rapport au sommet en érosion des falaises, ce qui est pleinement justifié et constitue un fondement logique qui tient compte de la nature dynamique de ce site côtier. Une zone tampon relativement étroite est également délimitée. Elle ne fait pas partie de la propriété inscrite, mais suffit pour freiner le développement côtier qui pourrait menacer les valeurs du site.

Mesures de protection et de gestion
La propriété jouit d'une protection juridique efficace ainsi que de l'appui solide de tous les ordres de gouvernement, y compris en ce qui concerne son financement. Certains aspects de la législation, comme ceux qui ont trait à la délivrance de permis relatifs à la collecte de fossiles, sont lourds et mériteraient d'être révisés. Cependant, les lois pourraient être mieux appliquées si les gestionnaires du site avaient des pouvoirs suffisants à cet égard. Le site est bien financé, notamment grâce au nouveau centre d'accueil, et géré de telle sorte qu'on peut le considérer comme un modèle sur le plan international. Le processus consistant à faire participer la communauté et à favoriser les partenariats entre les scientifiques, les musées et les intervenants économiques est également remarquable, et la difficulté principale consistera à maintenir le niveau de rendement et les ressources nécessaires à l'avenir.