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Tales set in stone, p.2

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### Time travel

**If** beauty is in the eye of the beholder, so too is utility. As Iain Stewart from Plymouth University (UK) observed last February at the 40<sup>th</sup> anniversary of the International Geoscience Programme (IGCP) at UNESCO in Paris, show a piece of coal to an industrialist and they will see a source of fuel; show it to an ecologist and they will see a source of carbon emissions; show it to a geologist and they will see a climate which existed more than 300 million years ago (Ma).

Geoscientists help us to travel through time. The IGCP was founded in 1972 to confirm the existence of Gondwana, one of two megacontinents with Laurasia which formed about 145 Ma, by correlating the geology of modern continents. As time went by and supporting evidence for Gondwana became overwhelming, IGCP research teams turned to questions of special societal relevance. New disciplines emerged like archaeoseismology, which draws on both the geological and archaeological record to identify past earthquakes. One IGCP project in 2000 was even at the origin of a new field: medical geology, the science dealing with the impact of our natural environment on human and animal health. Arsenic, for example, is a natural chemical which poisons millions of people worldwide who absorb it unwittingly through groundwater.

Given the concern over climate change and the looming shortage of fossil fuels and uranium which overshadows our industrial future, geoscientists are focusing more on renewable energy these days. Kenyan geoscientists, for instance, are currently employed on a government project to develop geothermal energy in the Great Rift Valley.

As the third Earth Summit (Rio+20) in June has just demonstrated, civil society and the private sector have become central players in sustainable development. UN Secretary-General Ban ki-Moon announced in Rio that more than 50 governments had launched new energy strategies but also that private investors had pledged more than US\$50 billion towards the goal of doubling the share of global renewable energy and improvements in energy efficiency by 2030.

Understanding natural disasters is another critical area for sustainable development in which the IGCP can make a difference. A consensus rapidly emerged in February of the need for IGCP projects to monitor seismic activity in subduction zones like that responsible for the Japanese earthquake and tsunami last year.

One of the world's most active subduction zones is located in the Mediterranean Sea, south of the island of Crete. Overleaf, we follow the fortunes of *Homo sapiens sapiens* around the Black and Mediterranean Seas through 30 000 years of a tumultuous history marked by sporadic earthquakes, tsunamis and volcanic eruptions, as well as more insidious hazards tied to a changing climate, such as flooding from glacier melt, gradual sea-level rise or prolonged drought. Through these palaeostudies, the IGCP is helping us to understand how human societies and ecosystems coped with a changing environment in the past and why some civilizations failed. There are obvious lessons to be learned for contemporary societies.

Gretchen Kalonji  
Assistant Director-General for Natural Sciences

# Tales set in **stone**

Over the past 30 000 years, humans living around the Caspian, Black and Mediterranean Seas have had to adapt to climate change, with warmer periods chasing ice-age temperatures. Over time, progress in navigation and the development of sophisticated bronze and iron weapons enabled dominant powers to extend their empire across the Mediterranean region. Ultimately, however, even these civilizations would falter. In some cases, their fall would be precipitated by an environmental catastrophe, like the Minoan volcanic eruption 3 600 years ago; other civilizations would survive nature's wrath, like Pharaonic Egypt 4 200 years ago.

To what extent did climate change and environmental catastrophes influence the rise and fall of civilizations? Within the International Geoscience Programme (IGCP), geoarchaeologists, palaeontologists, archaeoseismologists and others have pooled their talents to piece together parts of the puzzle. One project studied the history of the corridor formed by the Caspian, Black and Mediterranean Seas as a single entity for the first time. It asked questions like: When the last Ice Age waned, was sea-level rise so abrupt that it dispersed early cultures, or did it leave them time to adapt? Could the Black Sea be the site of the Great Flood depicted in the *Bible*? At times, these IGCP projects crossed paths with historic sites safeguarded by UNESCO under the World Heritage Convention or the Convention on the Protection of Underwater Cultural Heritage. Let's take a stroll through history.

For 30 000 years, the corridor formed by the Caspian, Black and Mediterranean Seas has been shaped by sweeping changes in climate and sea level. In glacial times when global sea level was low, the Black and Marmara Seas were isolated from the Mediterranean, becoming inland lakes like the Caspian Sea today. When temperatures warmed, water was able to flow from the Mediterranean through the Bosphorus Strait into the Sea of Marmara then on through the Dardanelles Strait into the Black Sea, a journey of several thousand kilometres.

Our story begins towards the end of the last Ice Age. After 90 000 years, it is about to reach its coldest point, 21 000 years ago. Temperatures will subsequently start rising, causing ice sheets to melt and sea level to rise, until an

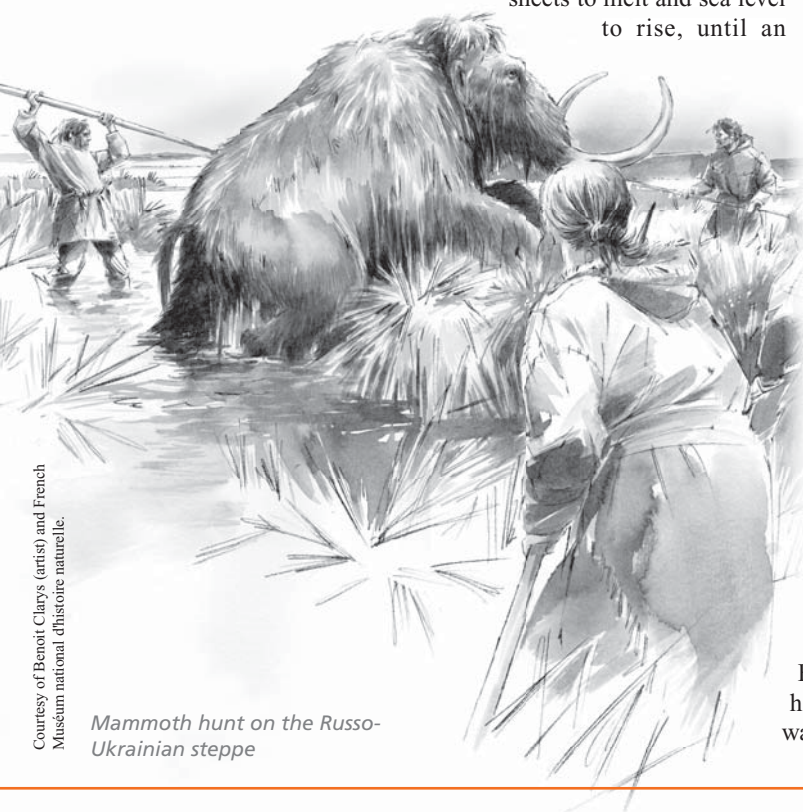
abrupt change in climate known as the Younger Dryas (or Big Freeze) sends temperatures plummeting again about 11 000 years ago.<sup>1</sup> The Younger Dryas was probably triggered by the melting North American ice sheets, which many attribute to overflow from glacial Lake Agassiz in Canada, once the largest lake in the world. The rapid influx of a huge volume of freshwater into the North Atlantic Ocean would have slowed or stopped the northward transport of heat currents via the Gulf Stream, sinking temperatures in the North Atlantic by about 5°C in less than a decade. Glaciers in Europe advance once more and a glacial climate returns to the continent for 1 000 years before temperatures begin warming again.

About 10 000 years ago, the Earth left behind the Pleistocene period for the Holocene period we still inhabit today. Then, 6 000 years ago, Europe experienced a particularly warm period normally associated with the Holocene Climatic Optimum in the Northern Hemisphere before cooling slightly again. The Holocene Climatic Optimum may be the result of the Earth tilting slightly on its axis thousands of years earlier. By orienting the Northern Hemisphere a little closer to the Sun, this change in the Earth's orbit had already brought the Ice Age to an end.

Our journey into the past will end about 2 000 years ago, at a time when the development of human societies around the Caspian, Black and Mediterranean Seas has become so complex that we could never hope to tell a fraction of the tale in just a few pages.

## ***Homo sapiens sapiens* takes up residence in the Black Sea**

Temperatures during the last Ice Age were not uniform. Prior to 28 000 years ago, the climate in the Eastern Mediterranean was generally mild for the time, with only shallow permafrost (frozen soil) at high latitudes and greater rain- and snowfall than today. Farther south, the level of the Mediterranean Sea was a few metres higher than today and the basin was populated by exotic warm-water animals of the type that you would find in Senegal nowadays,



Mammoth hunt on the Russo-Ukrainian steppe

Courtesy of Benoît Clarys (artist) and French Museum national d'histoire naturelle.

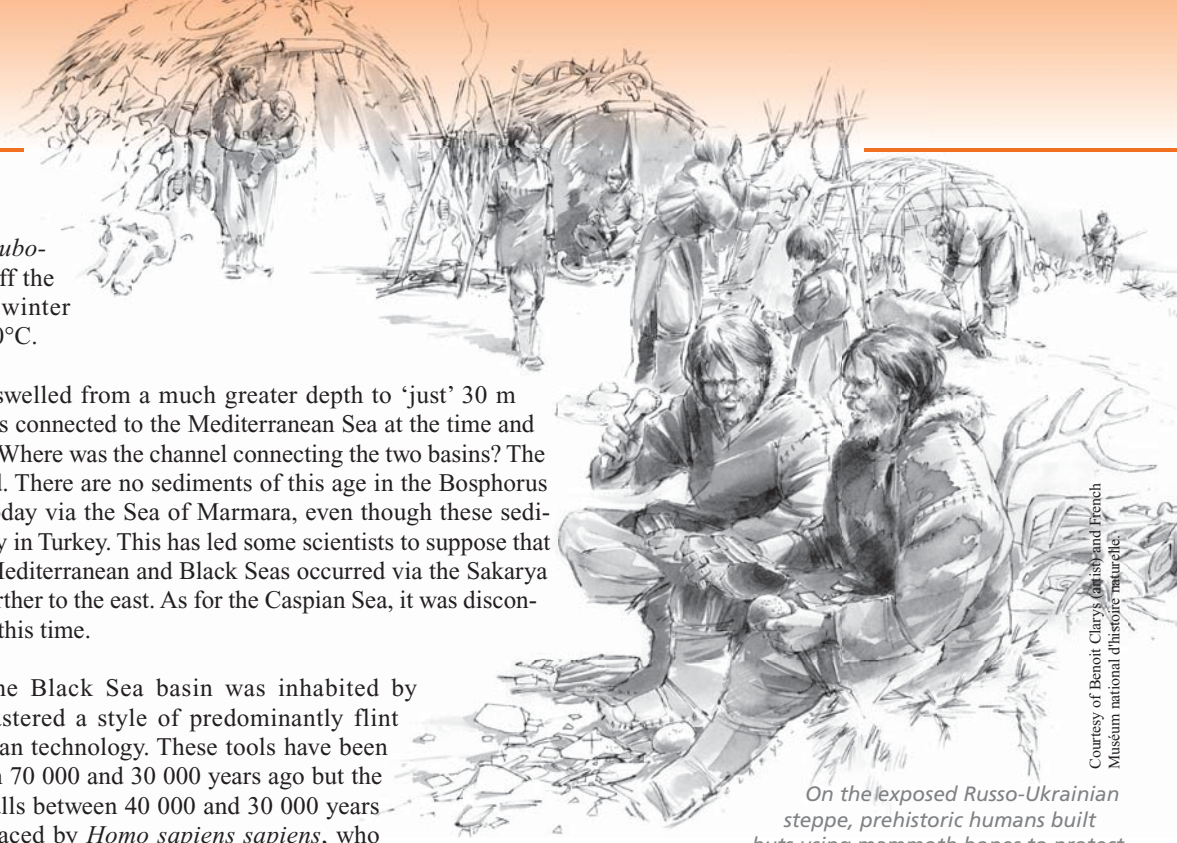
like the mollusc *Strombus bubonius*, which lives in waters off the West African coast where winter temperatures hover around 20°C.

The Black Sea itself had swelled from a much greater depth to 'just' 30 m below present sea level. It was connected to the Mediterranean Sea at the time and had salinity of around 11‰<sup>2</sup>. Where was the channel connecting the two basins? The question remains unanswered. There are no sediments of this age in the Bosphorus Strait linking the two seas today via the Sea of Marmara, even though these sediments are present in Izmit Bay in Turkey. This has led some scientists to suppose that the connection between the Mediterranean and Black Seas occurred via the Sakarya Bosphorus, a strait slightly farther to the east. As for the Caspian Sea, it was disconnected from the Black Sea at this time.

The northern coast of the Black Sea basin was inhabited by Neanderthals. They had mastered a style of predominantly flint tools known as the Mousterian technology. These tools have been radiocarbon dated to between 70 000 and 30 000 years ago but the main cluster of dated sites falls between 40 000 and 30 000 years ago. Neanderthals were replaced by *Homo sapiens sapiens*, who first appeared on the East European Plain and Caucasus between 41 000 and 32 000 years ago.

The appearance of anatomically modern humans in the northern Black Sea region could be the result of migration from Africa through the Levant<sup>3</sup> and southeastern Europe that would eventually extend to western Europe. Neandertals and *H. sapiens sapiens* probably cohabited in western Europe for several thousand years. The most recent remains of Neandertals have been found in Spain and date back less than 30 000 years.

IGCP project co-leader Pavel Dolukhanov observes that the northern Black Sea region, positioned as it was south of the continental glaciers, would have appealed to *H. sapiens sapiens* with its mild climate, regular water supply and abundant prey. Large Palaeolithic settlements like Anetovka 1 in Ukraine (see box overleaf) were concentrated along the Dniester, Dnieper



Courtesy of Benoit Clarys (British and French Muséum national d'histoire naturelle).

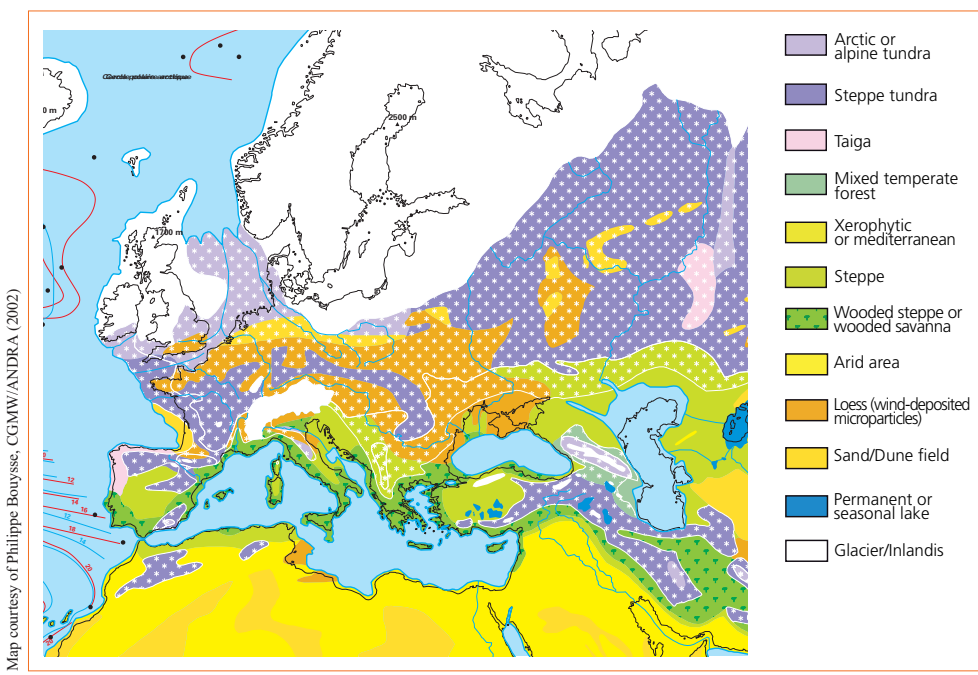
On the exposed Russo-Ukrainian steppe, prehistoric humans built huts using mammoth bones to protect themselves from the glacial wind.

and Don Rivers and also in the Carpathians and Crimea. The growth of these settlements coincides with the disappearance of the bones of mammoths and woolly rhinoceroses from the region. Around 20 000 years ago, the fossil remains of bison begin to appear more frequently in ancient settlements. We can deduce from this that mammoths and woolly rhinoceroses had been exterminated by this time and replaced by bison as the main prey for hunting groups.

### The Ice Age hits its coldest point

The Last Glacial Maximum occurred between about 27 000 and 17 000 years ago. Ice sheets spread over much of North America and Asia. Over Hudson Bay in Canada, the ice was 4 km thick.

In Europe, ice sheets extended over much of the UK and as far south as Germany and Poland (see map). The spread of ice profoundly impacted the Earth's climate, causing drought, desertification and a dramatic drop in sea levels in basins connected to the ocean. You would have been able to walk from England to France without getting your feet wet. 'About 21 000 years ago,' observes Paolo Pirazzoli from the French National Centre for Scientific Research, 'the world's oceans were 120 m lower than today. So too was the Mediterranean Sea, which was connected to the Atlantic Ocean through the Gibraltar Strait. The north of the Adriatic Sea was completely exposed and, in the Aegean Sea, it would have often been possible to walk from one island of the Cyclades to another.'



Map courtesy of Philippe Bouysse, CGMW/ANDRA (2002)

Ice cover in Europe 18 000 years ago when the world was 4.5°C colder on average than today

On the edges of glacial areas, the entire East European plain was covered with tundra-steppe vegetation. The climate was also dry and cold along the Black Sea coast, which was covered by pine and birch forest in Romania and by plants that had adapted the capacity to survive in a water-stressed environment (xerophytic plants) on the grassland steppes of southern Ukraine and Moldova. Given the cold climate, there would have been little river flow into the Black Sea. This would have caused the level to drop dramatically to 100 m below the present level, exposing a large portion of the sea shelf (or floor). Farther south, the Balkan Peninsula was covered in grassland steppe and forest.

The level of the Marmara and Aegean Seas was about 100 m and 115 m lower than today respectively. Both the Marmara and Black<sup>4</sup> Seas were land-locked lakes isolated from each other, populated by organisms that could survive in cold water with a salt content of 1–5‰. All the Mediterranean species had disappeared. The entire coastal plain was covered by a relatively fertile soil composed of a mixture of clay, sand, silt and organic matter. The mouths of the Pre-Danube, Pre-Dnieper, and Pre-Dniester Rivers would have been located 80–100 km farther seaward than today with poorly developed deltas.

The extremely harsh climate drove people to migrate from Central and Western Europe onto the more fertile steppes of the Black Sea. We know this from the great variety of cultural groups living in Eastern Europe at the time, in contrast to the virtual depopulation of southern Germany and the UK. The high population density around the Black Sea suggests that these groups thrived. Similarities in lifestyle and stone tools indicate that these groups circulated freely along the coast, with the Black Sea's northern coast representing a bridge between modern-day Varna in Bulgaria and Sarych Cape in Crimea in Ukraine. All the occupied sites belonged to groups of foragers who specialized in hunting big game. In their search for food, the bison hunters moved south

and southwest along the Dnieper, Southern Bug, Dniester and Prut River valleys to the shores of the Black Sea.

The lake water was undrinkable, with salinity of 0.5–5‰ (near-brackish). The coast was marshy and mosquito-infested and the rivers periodically flooded the region. This may have been good for hunting and fishing but would not have been conducive to settled farming. The soils would have been too salty, a problem that still plagues farmers today. People preferred to settle in the valleys of small rivers.

The settlements were so successful that population growth ended up forcing the hunter-gatherers to search for food farther afield. An Eastern European people known as the Anetovka Mikrogravette (28 000–23 000 years ago) established a large settlement which served as their base, together with a series of camps a day's walk from each other. While at their home base, these hunter-gatherers produced stone tools with small pointed blades which they used to hunt bison, horses, reindeer and mammoths. They spent most of the year scattered along the valleys of small rivers in search of prey, visiting their base only a few times a year for a short respite to celebrate a successful hunt and prepare for the next one.

**Two hypotheses for a Great Flood**

Between 17 000 and 10 000 years ago, the Black Sea remained a lake, even if it rose from 100 m to just 40 m below the present sea level. The greatest change occurred in the first 3 000 years. As Europe became warmer, the Scandinavian ice sheet and permafrost melted. This in turn swelled rivers, causing megafloods and resulting in a cascade of Eurasian basins extending from the Aral Sea all the way down to the Aegean Sea (see map). Contributing to this deluge was an outburst of flooding from ice-dammed lakes in the Altai Mountains. The cascade inundated about

**Taking climate archives from a lake**

Palaeontologists study fossils to reconstruct the past sea level and the salinity, depth, oxygen content and temperature of the Caspian, Black and Mediterranean Sea basins (or Corridors). Some organisms lived on the bottom (we call them benthic), while others swam in the water column (we call them planktonic). They fall into different groups, such as single-celled foraminifera, ostracoda (microcrustaceans like the fossil on the left) and molluscs. These organisms grow hard shells made of calcium carbonate which are well preserved in sediments after

they die. Foraminifera and ostracoda are usually as small as a grain of sand and can only be seen under a microscope.

The shells of planktonic foraminifera contain oxygen isotopes that enable scientists to determine the temperature of surface water, which is controlled by the state of the climate at the time. Molluscan shells contain radiocarbon (14C) isotopes that allow us to determine the age of the sediments in which they were buried. The presence of Mediterranean or Caspian fossils in Black Sea sediments indicates a connection with either basin.

Other microscopic planktonic fossils called dinoflagellates and diatoms are used to reconstruct the water's salinity and temperature due to the narrow range of tolerance many species demonstrate to these conditions. Remnants of plants, such as microscopic spores and pollen, provide direct evidence for Neolithic agriculture on shelves that were once exposed until sea level rose. Correlating the succession of pollen zones for the Late Pleistocene and Holocene with the pollen zones of surrounding upland areas helps us reconstruct the temperature and precipitation (rain- and snowfall) dynamics across these entire corridors.

Valentina Yanko-Hombach



© V. Yanko-Hombach

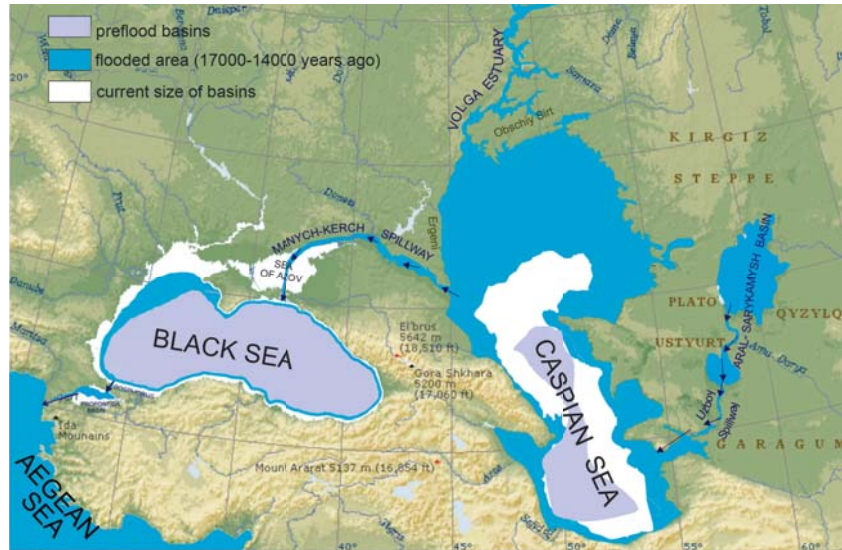


The Caspian-Black-Mediterranean Sea Corridor today, showing key archaeological sites. The dotted yellow line denotes the study area of the IGC project.

1.5 million km<sup>2</sup> of land and raised the level of the Caspian Sea<sup>5</sup> by 50 m. The Caspian basin could not retain all the inflowing water, so the excess was discharged through the Manych–Kerch Spillway into the Black Sea, raising the lake by at least 60 m and causing it to spill into the Marmara Sea.

The dramatic rise in sea level caused extensive coastal flooding (up to 10–20 km per year) of lands which would have been of great value to Stone Age populations. This has led A. L. Chepalyga to claim that a Great Flood took place at this time. In fact, there is not one theory but two about a Great Flood inundating the Black Sea. However, the second hypothesis, that of W. Ryan *et al.*, dates the Great Flood to a much later period, 8 400 years ago in the Early Holocene (*see box*).

©A.L. Chepalyga, modified by V. Yanko-Hombach



Pre- and post-flood size of the Black and Caspian Seas, according to A.L. Chepalyga

## Was there a Great Flood in the Black Sea?

The book of Genesis from the *Bible* tells the tale of how God sent a Great Flood lasting 40 days to punish human beings for their sins. Warned by God in advance, Noah built a giant boat (the Ark) for his family and a pair of each animal species on Earth, who were all saved.

Some think there really was a huge flood in the Black Sea a few thousand years ago which swept Noah's ark to the top of Mount Ararat and that vestiges of the boat remain there today. The scientific evidence, however, clearly shows that the flood waters were never higher than 20 m below present sea level and that the biggest flood took place just after the Ice Age, thousands of years before the first towns and farms were settled.

Two hypotheses situate a Great Flood in the Black Sea basin, both at a time when it was a lake. The first hypothesis is proposed by A.L. Chepalyga (2007), who situates the Great Flood just after the Ice Age between 17 000 and 14 000 years ago with no link to the biblical story. According to Chepalyga, the brackish Black Sea filled rapidly with the overflow from the Caspian Sea via the Manych Spillway shortly after the Last Glacial Maximum when ice cover was melting rapidly.

The second hypothesis, or 'Noah's Flood', is proposed by W. Ryan *et al.* (2003). They claim that the climate became drier immediately after the Younger Dryas and that the resulting evaporation caused the Black Sea to drop to 95 m below the present level. As the climate warmed and ice cover melted in Europe, sea level rose in the Mediterranean, causing a catastrophic flow of salt water into the Black Sea 8 400 years ago.

If a catastrophic flood did occur in the Black Sea, there should be a record of it. An IGCP project searched for traces in sea-bottom sediments, fossils, landforms, old coastlines and so on. Here is what it uncovered.

### How low did the Black Sea sink?

Ryan *et al.* claim that dry climatic conditions caused the water in the Black Sea to evaporate to 95 m below the present level. Yet, we know from pollen records that the exposed shelf and immediately adjoining coasts were covered by moisture-demanding forest trees such as deciduous oak, linden, beech and elm, together with shade ferns, aquatic and swamp plants. These plant species are indicative of warm winters and year-round rainfall of between 600 mm and 1000 mm.

The last time the level of the Black Sea basin dropped to 95 m lower than today was during the Last Glacial Maximum. At the beginning of the Holocene period about 10 000 years ago, the Black Sea, a lake at the time, gradually rose from 40 m to 20 m below the present level, owing to the inflow of Mediterranean water. Could such an insignificant rise in water level cause catastrophic flooding?

### Was the Black Sea a freshwater lake?

If the Black Sea contained freshwater suitable for drinking, as Ryan *et al.* claim, why do all the fossils discovered in the lake sediments belong to organisms that thrived in brackish water? And if the lake water was potable, why would people have chosen to settle instead in the valleys of small rivers, as supported by numerous archaeological sites?

### Were prehistoric settlements submerged by the Great Flood?

Ryan *et al.* claim that, before the Great Flood, people inhabited not only today's coast but also that part of the present sea bottom (called the shelf) which was dry land at the time. Despite decades of searching for submerged prehistoric habitations on the previously exposed shelves of the Black Sea, there have been no definite finds below a water depth of 10 m.

### Was there farming in the Black Sea region at the time?

The pollen records reveal no evidence of grain production around the Black Sea before 5 718 years ago. The sparse nature of traces in shelf cores of charcoal particles from burned grasslands and fungal spores grown on animal dung in crowded enclosures discredit the idea that animal husbandry was practiced on the exposed shelf. This absence contrasts with the archaeological evidence for animal husbandry as early as 8 000 years ago found at Ilipinar south of the Sea of Marmara.

### The evidence points to gradual sea-level rise in the Black Sea

The hypothesis of a Great Flood in the Black Sea 8 400 years ago captured the public's imagination but what most media failed to mention was that geologists and archaeologists from Ukraine, Russia, Canada and elsewhere had found no evidence of catastrophic flooding of the Black Sea. Rather, the evidence points to a gradual reconnection with the Mediterranean Sea from about 9 500 to 8 000 years ago.

For Chepalyga, the Great Flood of 17 000–14 000 years ago is not the one described in the Bible. He argues that catastrophic floods would have endured in the collective memory for thousands of years, until they were consigned in ancient Aryan scriptures such as the Rigveda (Hindu) and Avesta (Indo-Iranian). The story of a Great Flood was also told by the ancient inhabitants of Mesopotamia.

This research was part of a joint project involving the IGCP and International Union for Quaternary Research between 2005 and 2011 on sea-level change and human adaptive strategies in the Caspian–Black–Mediterranean Sea Corridor.

Valentina Yanko-Hombach



Bowl from the Tripolye-Cucuteni culture

Photo: Wikipedia Commons

## The rise of agriculture

Although they situate the Great Flood thousands of years apart, both Chepalyga and Ryan *et al.* posit that there would have been a mass exodus from the flooded areas and that this, in turn, might have allowed new communities to settle and an agricultural economy to develop. Chepalyga even suggests that horses may have been domesticated during this conversion to a productive economy. The available evidence contradicts this theory, as it places horse domestication sometime between 8 500 and 4 300 years ago, long after Chepalyga's Great Flood. Chepalyga also argues that the advent of agriculture could have favoured the rise of ancient civilizations and the construction of the first ships for the purposes of exploration. To support this hypothesis, he cites the oldest-known images of boats, dated to 8 000–9 000 years ago. These rock carvings were discovered in Gobustan on the Caspian coast, south of the Kura River Delta. The carvings show flat-bottomed boats and keel-built vessels suitable for marine navigation, some with as many as 37 oarsmen (*see photo*).

As yet, there is no archaeological evidence linking the Great Floods with the transition from hunting-gathering to stock-breeding. No large, long-term settlements have been found in the submerged parts of the Black Sea, nor any trace of an agricultural economy before 5 718 years ago. The only major ecological catastrophe on record for the late glacial period that prompted major changes in settlement or subsistence is the disappearance of bison from the steppes, which Ukrainian archaeologist Vladimir Stanko attributes to overkill by hunters.

The earliest evidence for animal husbandry was found at Ilipinar on the coastal plain south of the Sea of Marmara. It has been dated to 8 000 years ago. Plants were first domesticated prior to this, during the Younger Dryas. When the global temperature suddenly dropped by several degrees celcius, this corresponded to a drying in the Levant. It seems more and more likely that climate-induced stress caused annual yields of wild cereal strands to drop, creating the need for cultivation. Recent research indicates that some of the main steps happened within years rather than decades. Prior to the Younger Dryas, dense populations of hunter-gatherers lived in some year-round settlements. In addition to hunting, they gathered wild cereals, fruits and nuts. During the Younger Dryas, most of these sites were abandoned. Some groups, however, became sedentary in order to grow cereals. Alongside cultural and social changes, the Younger Dryas played an essential role in this dramatic change in lifestyle, laying the foundations for the early civilizations of Mesopotamia<sup>6</sup> (including the Assyrians and Babylonians) and Egypt (*see box*).

Thanks to the Tripolye-Cucuteni culture, which flourished 5 900–5 600 years ago, we know that there were fully developed farming economies in the forest steppe northwest of the Black Sea by this time. The Tripolye-Cucuteni culture stretched from the Carpathian Mountains to the Dniester and Dnieper regions in modern-day Romania, Moldova and Ukraine.

In addition to developing new techniques for agriculture and animal husbandry, the Tripolye-Cucuteni produced woven

## How a drought brought Egypt's pharaohs to their knees



Scene dating from 3 200 years ago

Some 11 300 years ago, the Sahara was dotted with lakes. Giraffes, hippopotamuses, lions, elephants, zebra, gazelles, cattle and horses roamed across grasslands that may have received ten times more rainfall than the same area today.

By 9 000 years ago, pastoralists had colonized much of the Sahara. They prospered for another 3 000 years, until a shift in the monsoon belt to lower latitudes steered potential rains away from the continent, causing catastrophic droughts. The pastoralists took refuge in the Sahel, Saharan highlands and Nile Valley, where they gave rise to numerous African cultures, including that of Pharaonic Egypt.

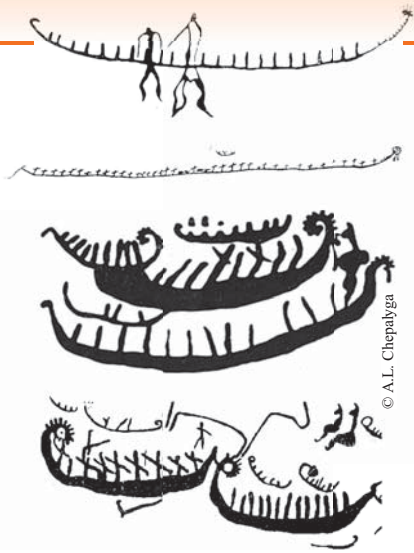
Those who settled in the Nile Valley were forced to abandon nomadic pastoralism for lack of summer rains. Instead, they adopted an agricultural way of life. Small sedentary communities gradually coalesced into large social groups. About 5 200 years ago, the first pharaoh managed to unify Upper and Lower Egypt into a single state with Memphis as its capital.

A long period of prosperity followed, characterized by bountiful Nile floods that produced abundant grain harvests. Successive pharaohs took advantage of this prosperity to launch ambitious pyramid-building programmes to give themselves a tomb worthy of their rank. The pharaohs asserted their authority over the population by claiming the power to intercede with the gods to ensure the Nile River flooded each year. This strategy worked perfectly – until about 4 200 years ago when the harvests failed for six long decades. Brought about by a drop in rainfall at the Ethiopian headwaters during a prolonged El Niño cycle, this drought was so long and so severe that the Nile could be crossed on foot. With the pharaoh powerless to prevent the resulting famine, regional governors seized control.

It took 100 years for Egypt to reunify and thereby bring to an end a century of political and social chaos known as the First Intermediary Period. The return to stability heralded the advent of the Middle Kingdom. This time, the pharaohs would not make the same mistake. To avoid suffering the fate of their improvident predecessors, they would invest massively in irrigation and grain storage.

This work was part of an IGCP project from 2003 to 2007 on The Role of Holocene Environmental Catastrophes in Human History.

Suzanne Leroy



These are the oldest-known images of boats. They were carved into rock on the Caspian coast 8 000–9 000 years ago.

© A.L. Chepalysga

clothing, finely decorated ceramics, tools and weapons. They also mass-produced salt, as evidenced by what may be the world's oldest saltworks uncovered in Lunca (Romania). One of the most notable aspects of this culture was that, every 60–80 years, the inhabitants would burn down their entire village then reconstruct it. Why remains a subject for debate among scholars.

The Tripolye-Cucuteni culture became vulnerable when the climate grew more arid between *circa* 4 700 and 4 200 years ago. Faced with water shortages and overpopulation, one of the Tripolye groups, Usatovo, turned to stock-breeding, especially horses, sheep and goats. The Tripolye gradually abandoned agriculture in favour of nomadic cattle-breeding. After the total collapse of the Late Tripolye agricultural societies, there followed the gradual rise of the Pit-Grave, Catacomb and Timber Grave cultures based on nomadic cattle-breeding. The Pit-Grave (or Yamna) culture reached its peak during the course of the 3<sup>rd</sup> millennium BCE<sup>7</sup>. By this time, it encompassed the entire East European steppe, from the Urals in the east to the lower reaches of the Danube River in the west.

### The Bronze Age

The Pit-Grave culture signals the transition from the Stone Age to the Bronze Age in the 4<sup>th</sup> millennium BCE. It was a contemporary of the Maykop culture, to which is attributed the most ancient bronze sword ever found. The sword was discovered in the northern Caucasus between the Black and Caspian Seas. Implements and weapons from the early Bronze Age have also been found in the Aegean, Anatolia (modern-day Turkey), Egypt and the Levant.

The birth of the European Bronze Age dates back about 5 200 years in the Aegean Sea. The Aegean Bronze Age civilization encompassed the Greek mainland and Greek populations on the Cyclades islands and the islands of Cyprus and Crete.

The technology for smelting copper and its alloy, bronze, spread across Asia and Europe, thanks in part to the development of maritime trade in the Mediterranean, which opened up new markets and favoured the emergence of a monetary economy.

Scholars still debate the reasons for the collapse of the Bronze Age civilizations in the course of the 1<sup>st</sup> millennium BCE. Some suggest that strong migration during this period may have been linked to power struggles or natural disasters, or both. Conflicts

in the Mediterranean may also have made it harder for merchants to obtain bronze goods, inciting them to turn to iron implements.

### Power struggles around the Mediterranean

Excellent navigators, the Phoenicians turned the Mediterranean into a thoroughfare for trade during the Bronze Age. Originally from the Levant, they established several city-states south of Ugarit (Syria) on the coast, including Byblos, Sidon and the major centre of Tyre in 2 750 BCE (*see box and map overleaf*). Phoenician merchants ventured far afield in search of new markets. From about 1 550 BCE onwards, they colonized much of the Mediterranean, including the islands of Sicily and Sardinia, founding cities which functioned as independent political entities, like Kition on the island of Cyprus or Carthage (814 BCE) on the Tunisian coast. From North Africa, they imported minerals like gold and copper, as well as ivory and other goods. After Rome was founded in the 8<sup>th</sup> century BCE, Carthage, Athens and Rome became rivals for the domination of the Mediterranean's shores.

The Phoenicians developed an alphabet to keep track of their trade with North Africa and Europe. The first two letters in Phoenician, *aleph* and *beth*, became *alpha* and *beta* in Greek, giving the alphabet its name. The Greeks added vowels and passed on the alphabet to the Etruscans in Italy. They, in turn, passed it on to the Romans.

Roman naturalist Pliny the Elder, who died in Stabiae during the eruption of Mount Vesuvius in 79 CE, was a great admirer of the Phoenicians, whom he credited with inventing glass.

The Eastern Mediterranean saw a succession of empires rise and fall during the course of the 1<sup>st</sup> millennium BCE. First, the Assyrians subdued a territory stretching from Egypt to southern Anatolia. The Babylonians then extended their empire as far west as the Levant. The Persians went on to defeat the Babylonians in 539 BCE before extending their own empire into Greece and around the Black and Caspian Seas, conquering the Phoenicians in the process.

*This Greek bronze statue was one of several discovered in a Roman shipwreck that sank off the Greek island of Antikythera in about 100 BCE. The wreck also contained a unique object: an analogue computer able to calculate with great precision the cycles of the Sun, Moon and planets. It is thought that the ship had set sail from Rhodes, a major centre for astronomy and mechanical engineering at the time. Today, the wreck is safeguarded under the Convention on the Protection of Underwater Cultural Heritage.*

©Ulrike Guérm/UNESCO



Two centuries later, Alexander the Great won back these same territories from the Persians in just a few years. He founded a city on the coast in 331 BCE which would remain Egypt's capital for 1000 years. Alexandria became famous for the Pharos lighthouse, one of the seven wonders of the ancient world. Today submerged, it is safeguarded under the Convention on the Protection of Underwater Cultural Heritage. Alexandria was also famous for its library, the largest in antiquity until it burned down in 48 BCE.

Following a popular uprising in Athens in 508 BCE, the Greeks granted this city-state and others a new form of government which they termed democracy (rule of the people). About this time, the Romans themselves devolved the supreme power to a representative of the people, thereby replacing their kingdom with a republic (the *res publica*, literally public affair). Other civilizations also employed democratic practices at the time, including Mesopotamia and Phoenicia.

As Greek influence waned, many Phoenician cities flourished under Roman occupation. Carthage counted a population of about 100 000 in the 3<sup>rd</sup> century BCE. This did not prevent it

from being completely destroyed by Rome at the height of the third Punic War in 146 BCE. By this time, the Romans controlled so much of the Mediterranean that they even referred to it as *mare nostrum* (our sea). However, their vast Mediterranean empire was also vulnerable to piracy, especially in light of the Romans' growing dependence on grain imports from Egypt. In 30 BCE, Rome secured its supply line – and a new source of taxes – by making Egypt a Roman province.

**Greek colonies on the Black Sea coast**

The Greeks did not limit their colonies to the Mediterranean basin. They also established a string of colonies along the northern Black Sea coast between the 7<sup>th</sup> and 5<sup>th</sup> centuries BCE at sites close to large estuaries and river mouths. The main colonies were Gorgippia on the Caucasian coast (the site of modern-day Anapa in Russia) and, in Ukraine: Tyras in the Dniester Estuary, Olbia Pontica in the Bug-Dnieper Estuary and Chersonesos, Theodosia and Panticapaeus in Crimea. In a stable environment, the Greeks introduced numerous customs related to agriculture, trade, worship and their own democratic political system,

**Tyre: the city that sank beneath the waves**

Six thousand years ago, the island on which Tyre would be founded in 2 750 BCE lay a few metres above sea level. Today a World Heritage site, Tyre was an ideal location for the Phoenician city-state, as the island was easy to defend and an ideal port of call for maritime trade between the Levant, Egypt and the Aegean Sea.

The decline of Crete's Minoan civilization in about 1 400 BCE, coupled with a drop in Egyptian influence, paved the way for Tyre to become a major commercial hub and port in the Eastern Mediterranean. During the Iron Age, the city prospered, thanks to locally made glassware and cedarwood products, as well as the invention of a purple dye from sea snails that made expensive Tyrian textiles a must for any nobleman's wardrobe. The Greek historian Theopompus (born circa 380 BCE) wrote that 'purple for dyes fetched its weight in silver at Colophon' (city in Asia Minor).

Tyrian merchants ventured far and wide in search of new markets. They founded many prosperous trading centres, including Carthage in modern-day Tunisia and Cadiz on the Atlantic side of the Gibraltar Strait. The growing maritime traffic obliged the city to build complex port equipment to enable sailing vessels to berth and unload and store their cargo.

Tyre was repeatedly attacked, including by the King of Assyria, Shalmaneser V, between 727 and 722 BCE, and by Egypt. The city withstood most of these onslaughts thanks to its imposing fortifications. Alexander the Great nevertheless managed to subdue Tyre on his way to conquer Egypt.

During his seven-month siege of the city in 332 BCE, he built a causeway linking the island to the mainland using cut stones from buildings he had demolished. Over time, sediments accumulated on this causeway, creating a spit (tombolo) and turning the island into a peninsula (see figure).

In 64 BCE, Tyre became a Roman province. By this time, enough sediment had accumulated on the spit for the Romans to build an impressive urban infrastructure, including a stadium and necropole.

However, a serious problem of subsidence affected Tyre towards the end of Roman occupation in the 4<sup>th</sup> century CE. Seventeen hundred years later, divers discovered a submerged urban quarter 2 m beneath the water level, together with a quarry and remnants of the original city walls.

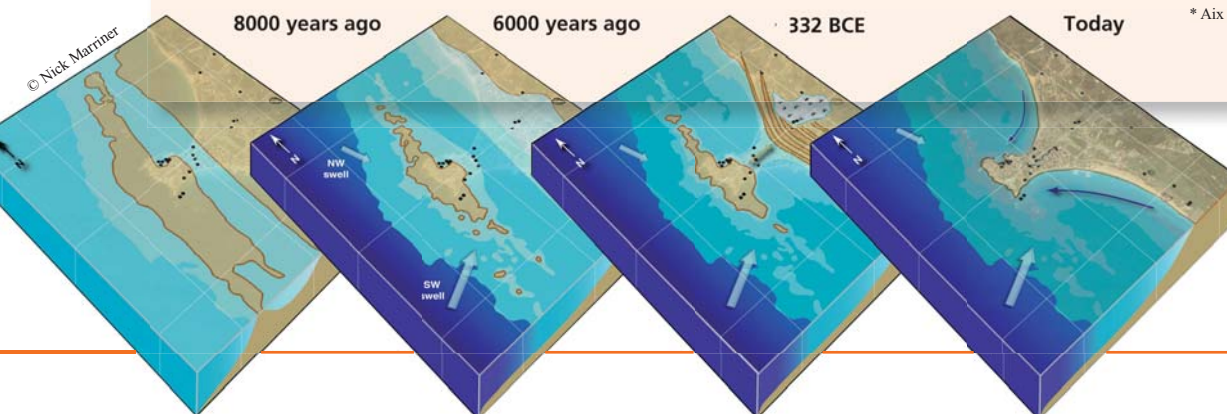
This dive was one of about 100 carried out in 2002 within a project funded primarily by UNESCO's World Heritage Centre and the Association internationale pour la sauvegarde de Tyr. A multidisciplinary team travelled to Tyre to study the ancient port with the support of CEDRE, a Franco-Lebanese agreement for scientific cooperation. The first objective was to locate the port, no easy task when much of it lies buried beneath the current city centre.

The second objective was to date the ancient ports. Due to the dense urban fabric, the team relied on drilling samples to probe past environmental changes. These samples can be radiocarbon dated, thereby giving a rapid and accurate chronology of events. If we combine radiocarbon dating with information from ancient texts and archaeological publications, it appears that the ancient port of Tyre was partially abandoned in the 6<sup>th</sup> century CE for both environmental and cultural reasons: the Levant suffered earthquakes and numerous tsunami between the 4<sup>th</sup> and 11<sup>th</sup> centuries CE which caused the ancient city to sink farther; and, by 650 CE, the south of the Levant, Persia and Egypt were all controlled by Islamic forces.

In light of these discoveries and given the speed with which Tyre is urbanizing, the research team recommended to the municipality and the Department of Antiquities that they protect all the vestiges of the port lying 5 m or less underwater.

*Christophe Morhange\* and Nick Marriner\**

\* Aix Marseille University, CNRS, France



*Tyre's changing seashore over the past 8000 years*



gradually improving the welfare of the local populations. First, they imported the concept of city-state (*polis*) then, in the 4<sup>th</sup> and 3<sup>rd</sup> centuries BCE, they integrated each *polis* with the surrounding countryside (*chora* in Greek) to form a single territory.

Olbia Pontica was one of the first Greek settlements. Dating back to the 7<sup>th</sup> century BCE, it was established on the island of Berezan, about 2 km from Bug Estuary. At the time of Greek colonization, the island was part of the mainland and remained so until the 1<sup>st</sup> century CE. Between the 6<sup>th</sup> and 3<sup>rd</sup> centuries BCE, Olbia Pontica became one of the largest of all Greek settlements with an estimated population of 30 000–40 000, including the hinterland where intensive agriculture was practiced.

A combination of factors triggered the general decline of settlements in the North Pontic area in the 2<sup>nd</sup> and 1<sup>st</sup> centuries BCE. Growing aridity caused harvests to fail at a time when the settlements were overpopulated. This led to a spate of popular uprisings opposing rich and poor. In parallel, Scythians, Sarmatians and other nomadic populations who had been cohabiting peacefully with the Greeks invaded the settlements. Archaeological sites in most northwestern Pontic colonies attest to the numerous armed conflicts which erupted among these cohabiting cultures during this fraught time.

The environmental crisis deepened towards the end of the 1<sup>st</sup> century CE when sea level rose by 1–3 m, causing large-scale soil erosion and landslides, as well as salinization and water-logging of soils. Known as the Nymphaean transgression, this rise in sea level was the result of shifting wind patterns over the Atlantic Ocean. These winds dumped additional rainfall on the region over a very short period, swelling the rivers which emptied into the Black Sea. The shift in wind patterns also channelled greater volumes of water first into the Mediterranean Sea then, through the Marmara Sea and Bosphorus Strait, into the Black Sea.

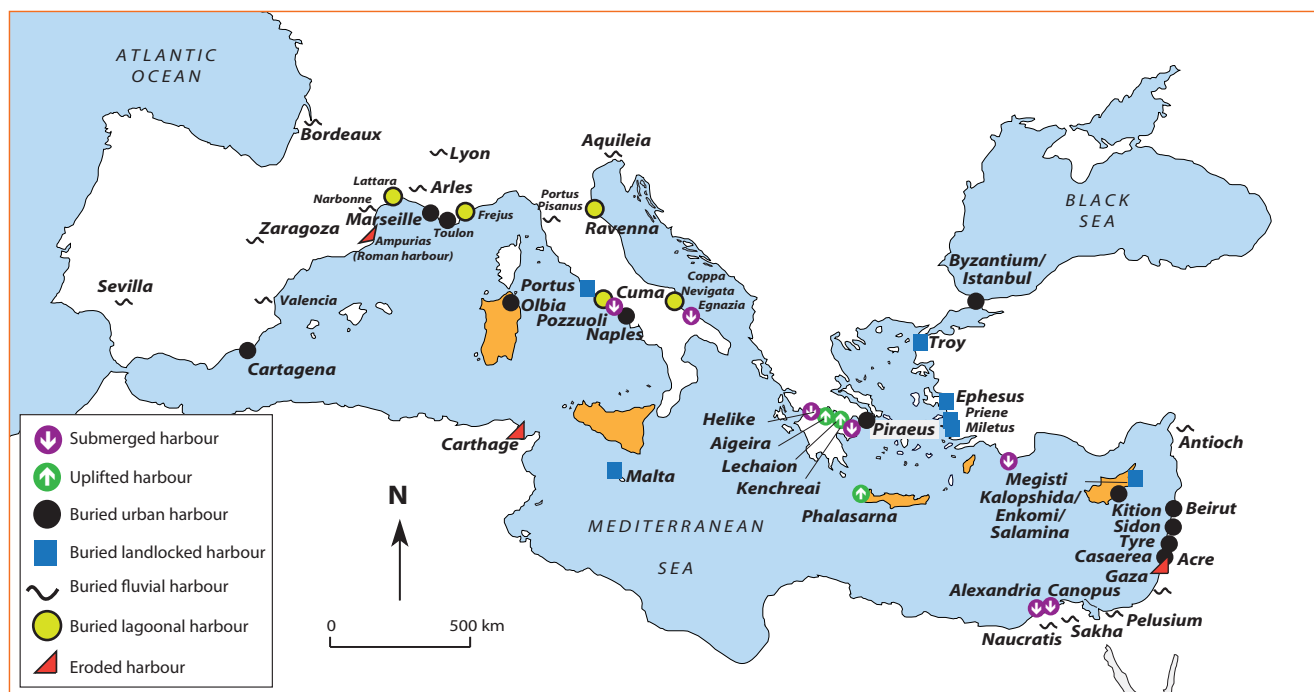
### Mediterranean civilizations in a changing environment

Mediterranean civilizations also had to cope with a changing environment. ‘By about 6 000 years ago, towards the end of the Holocene Optimum, all the freshwater from the melted ice sheets had found its way back into the oceans,’ observes Paolo Pirazzoli, ‘raising sea level in the Mediterranean by 120 m. This influx of water exerted pressure on the seafloor, causing it to



© V. Yanko-Hombach

Ruins of Ephesus, on the west coast of Turkey. First Greek then Roman, Ephesus had a population of more than 250 000 by 100 BCE, making it a megacity by the standards of antiquity. Today, Ephesus lies 8 km inland from the sea but, from excavated sedimentary deposits, we know it was once a port.



Some of the Mediterranean’s ancient sunken harbours. The islands highlighted in yellow are, from left to right, Sardinia, Sicily, Crete, Rhodes and Cyprus.

Reproduced with permission. © Map Mairiner, N. (2007) Geoaerchaeology of Phoenicia’s buried harbours.

subside in shallow waters in particular. As a result, sea level rose less along the coast than in deep waters. This explains why humans were able to access Cosquer Cave, for example, which today lies 37 m below sea level (*see box*).’ For the past 6 000 years, the level of the Mediterranean Sea has remained more or less stable.

‘Over time,’ Pirazzoli explains, ‘sediments deposited near river estuaries caused the coastline to expand into the sea, leaving ports high and dry, as in the case of Ephesus in the Aegean Sea (*see photo*). The coastline was also modified by tectonics, above all in the Eastern Mediterranean. An earthquake in the Gulf of Corinth in 373 BCE caused the land to subside, submerging the Greek town of Helike. In 365 CE, another earthquake had the opposite effect, raising the western part of Crete by 8 m.’

The earthquake of 365 CE generated a tsunami which swept across the Eastern Mediterranean. The wave reportedly penetrated far inland in Alexandria, drowning more than

5 000 people, and also caused great suffering on the island of Sicily. Records suggest that most large earthquakes and tsunamis in the Mediterranean are generated south of Crete. This is logical, as this is the only segment where you still have an old oceanic plate moving under (subducting) the Eurasian continent.

The Minoan civilization originated on the island of Crete, where it built extravagant palaces during the Bronze Age, including Knossos. Most probably once a century, these palaces suffered serious damage in an earthquake but were rebuilt each time. A maritime power, the Minoan civilization came to dominate the islands of the Aegean Sea, including that of Santorini.

When the Thera volcano on Santorini erupted about 3 600 years ago, the population of Akrotiri managed to evacuate. We know this because not a single skeleton has been found under the layers of ash which buried the town and have preserved many of its frescoes. The Santorini eruption, the largest volcanic eruption witnessed by humanity since the end of the

## Cosquer Cave: the sunken world

Today, Cosquer Cave near the French city of Marseille lies below sea level. A sanctuary used for religious ceremonies, it was abandoned between 27 000 and 19 000 years ago for an unknown reason. Numerous stactites have fallen from the ceiling, suggesting that an earthquake may have made the cave unsafe for a time.

The walls of the sanctuary were decorated by hunter-gatherers with stenciled hand prints and engravings or coloured paintings of animals: horses (35.6%), ibex, chamois, bison and auroch (18.6%) and deer (9.6%). Some rarer subjects for prehistoric rock art are represented, such as saïga (Eurasian antelope), megaceros (extinct Eurasian giant deer) and elk, as well as marine animals that include penguins and seals. One engraving could even be interpreted as being half-human, half-seal.

We know from an ancient accumulation of pebbles and mussel shells cored near the Planier lighthouse 10 km to the southwest that, by 14 000 years ago, the Mediterranean had risen to 100 m below the present level. At the base of the Ile of Riou, algal rims encrusted in the limestone cliff face testify to a sea level 55 m lower than today about 10 000 years ago. Another 1 000 years and the entry to Cosquer Cave would disappear beneath the waves.

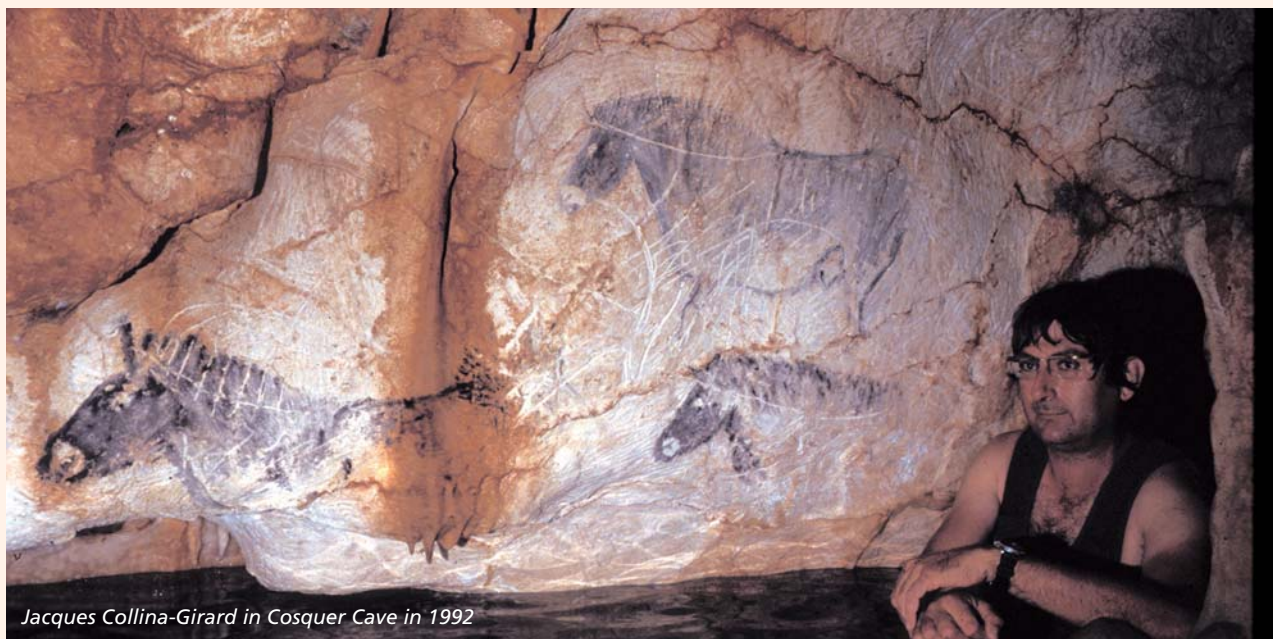
The cave is closed to the public but if you are lucky enough to be authorized to visit, you will find a dry environment after the initial perilous dive. From the entrance 37 m below sea level, a narrow tunnel sloping gently upwards for 116 m takes you to one of two spacious semi-submerged caves. Most of the wall paintings have been engulfed by the sea in the caves explored by the speleologists; at the back of one cave, a panel showing horses and ibex, drawn with charcoal or engraved, is slowly disappearing beneath the current sea level (*pictured*).

A geomorphological study in 2001 revealed that sea level only stabilized in the ancient port of Marseille 1 500 years ago. Marseille was founded by the Greeks about 2 600 years ago before coming a Roman city.

Cosquer Cave falls under the Convention on the Protection of Underwater Cultural Heritage managed by UNESCO.

Jacques Collina-Girard\*

\* University of the Mediterranean, Marseille, France



Jacques Collina-Girard in Cosquer Cave in 1992

© J.Collina-Girard and French Ministry of Culture (DRASM)

Ice Age, set in motion a series of environmental changes that would eventually lead to the demise of the Minoan civilization. The ash from the Minoan eruption blanketed fields on Crete, poisoning crops and wrecking the harvest for years. By the time the Greek Myceneans took over Crete about 3 450 years ago, Minoan society had collapsed, leaving a power vacuum.

British archaeologist Arthur Evans (1928) was the first to suggest that successive earthquakes were responsible for the destruction of the palace at Knossos. In 1936, Carl Blegen also ascribed structural damage to the sixth layer of ruins<sup>8</sup> in the city of Troy (Asia Minor, *see map*) to a massive earthquake about 3 300 years ago. Likewise, Claude Schaeffer associated structural damage to Ugarit (Syria) with successive earthquakes. In fact, Schaeffer drew a parallel between structural damage to ruins at all Late Bronze Age sites throughout the Middle East and the Eastern Mediterranean in his *Stratigraphie Comparée* (1948). This idea gave rise to the myth of an earthquake storm, or 'Late Bronze Age paroxysm', occurring in a 50-year time period between 1 225 and 1 175 BCE, which caused the demise of the Late Bronze Age civilizations throughout the region.

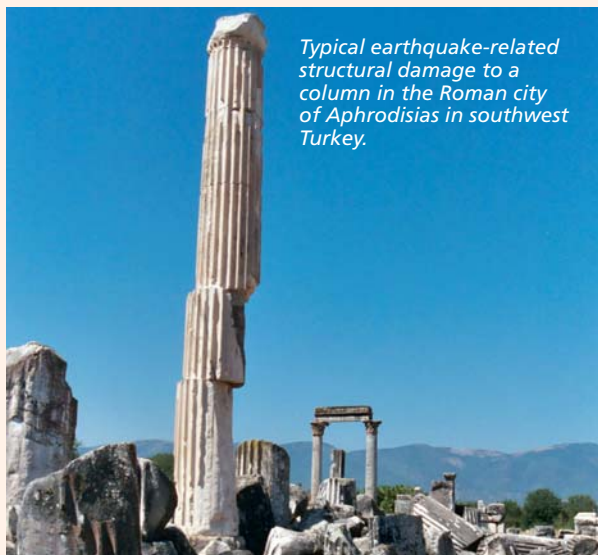
## Signs of trouble in all that rubble

Archaeoseismology is a young discipline that sets out to fill gaps in the historical and geological record of earthquakes. After all, the instruments that can record earthquakes have only been around for about 100 years.

Archaeoseismology studies cultural indicators of catastrophic earthquakes, such as structural damage to buildings (*see photo*) and myths and legends. The biblical story of the walls crumbling in the city of Jericho definitely refers to an earthquake. Jericho is built on top of one of the major earthquake faults in the region, the Dead Sea Transform Fault.

Archaeoseismology calls upon the expertise of historians, anthropologists, archaeologists, geologists, seismologists, geophysicists, architects and structural engineers. The challenge for one IGCP project running from 2008 to 2012 was to bring all these disciplines to the table to develop a rigorous methodology for this burgeoning field.

Manuel Sintubin



Typical earthquake-related structural damage to a column in the Roman city of Aphrodisias in southwest Turkey.

It is true that the archaeological evidence of earthquakes from Bronze Age sites in the Eastern Mediterranean confirms that earthquakes did affect these ancient settlements. The Eastern Mediterranean and Middle East is indeed seismically a very active region. A debate within an IGCP project on archaeoseismology (*see box*) concluded that these earthquakes may have influenced the local power balance but that they in no way led to a catastrophic collapse of the Late Bronze Age civilizations.

## We can learn from the past

Studying the past can teach us a lot about how natural phenomena and changing environments affect civilizations and how they manage to adapt. These natural phenomena may be a 'flash in the pan' like an earthquake, volcanic eruption or tsunami, or more insidious threats like sea-level rise as a corollary of climate change. How effective are the adaptive strategies that contemporary human societies have put in place to cope with extreme natural hazards and the environmental change expected this century? To what extent are we still able to adapt? These questions are of critical socio-economic and political importance for every country.

We have come to realize that the interrelation between human societies and their natural environment is one of such complexity that no single science can alone complete the puzzle. That is why, increasingly, palaeostudies are not purely the purview of geoscientists but also involve the collaboration of biologists, archaeologists, historians, meteorologists and other specialists.

Valentina Yanko-Hombach<sup>9</sup>, Suzanne Leroy<sup>10</sup>,  
Manuel Sintubin<sup>11</sup> and Susan Schneckens<sup>12</sup>

Read about these and other IGCP projects in *Tales set in Stone*, *see page 24*

- 1 Dates in the present article are based on non-calibrated radiocarbon dating using the Carbon 14 method. For details of this method, *see A World of Science*, October 2007 (page 4).
- 2 Brackish water has a salt content of about 5–12‰. Today, the salinity of the Black Sea varies from 1–3‰ in the Danube Delta to 26‰ near the Bosphorus, compared to 39‰ in the Eastern Mediterranean.
- 3 The Levant comprised modern-day Israel, Lebanon and Palestine, western Jordan and Syria.
- 4 Scientists refer to it as the Early Neoeuxinian Lake.
- 5 Scientists refer to it as the Early Khvalynian Lake.
- 6 Mesopotamia comes from a Greek word meaning 'land between rivers', used to designate the Tigris–Euphrates river system, a territory largely corresponding today to Iraq and parts of Iran, Syria and Turkey.
- 7 BCE (Before the Common Era) and CE (Common Era) mark the period prior to and following the start of the Gregorian calendar that has become the common standard today.
- 8 Troy was rebuilt six times, according to evidence left behind in six destruction layers. The Archaeological Site of Troy is a World Heritage site.
- 9 IGCP project co-leader, I.I.Mechnikov National University, Odessa, Ukraine, and Avalon Institute of Applied Science, Canada
- 10 IGCP project co-leader, Institute of Environment, Brunel University, UK
- 11 IGCP project co-leader, Katholieke Universiteit, Leuven, Belgium
- 12 Editor, *A World of Science*

## UNESCO to host **scientific advisory board** to UN

**UN Secretary-General Ban ki-Moon has tasked UNESCO with implementing the science-related recommendations of a major report presented on 21 June during the third UN Conference on Sustainable Development (Rio+20) in Rio de Janeiro (Brazil).**

Entitled *Resilient People, Resilient Planet: a Future Worth Choosing*, the report was prepared by members of the UN Secretary-General's High-level Panel on Global Sustainability.

One recommendation invites governments and the scientific community to take practical steps to strengthen the interface between policy and science, including through the launch of a major global scientific initiative. 'This should include the preparation of regular assessments and digests,' the report states, 'of the science around such concepts as "planetary boundaries", "tipping points" and "environmental thresholds" in the context of sustainable development.' The report goes on to say that, 'in addition, the Secretary-General should consider naming a chief scientific adviser, or establishing a scientific advisory board with diverse knowledge and experience to advise him or her and other organs of the United Nations.'

The Secretary-General has invited UNESCO to take the lead in setting up this board and to provide the secretariat. The board will be composed of eminent specialists from diverse backgrounds and regions.

As a first step, UNESCO Director-General Irina Bokova has assembled an *ad hoc* group of UN agencies with substantive science portfolios and leaders of major international scientific bodies. 'It is important that advice to the Secretary-General on science recommendations of the report span a broad spectrum,' she said in Rio, 'from the basic sciences, through engineering and technology, incorporating also health sciences, agricultural sciences, human and social sciences, in addition to environmental sciences.' The board will also suggest avenues for promoting cooperation among UN agencies and with the international scientific community.

In the outcome document of Rio+20, *The Future we Want*, 193 governments 'recognize the important contribution of the scientific and technological community to sustainable development,' and state that 'we are committed to working with, and fostering collaboration among, the academic, scientific and technological community, in particular in developing countries, to close the technological gap between developing and developed countries, strengthen the science-policy interface as well as to foster international research collaboration on sustainable development.'

Although the outcome document contains few fresh commitments, the UN chief praised it for renew[ing] and strengthen[ing] political commitment to sustainable development [and] 'recogniz[ing] poverty as the greatest challenge to economic, social and environmental well-being.'

*The Future We Want* recognizes the right to food security for all. In Rio, Ban ki-Moon launched the Zero Hunger Challenge to end childhood malnutrition, promote sustainable food systems, increase smallholder productivity and halt food wastage.

The outcome document places water at the core of key global challenges for sustainability, including food security, basic sanitation, clean energy, natural hazard mitigation and health. Governments reaffirm earlier commitments to halve by 2015 the proportion of people without access to safe drinking water and basic sanitation, as well as to develop water efficiency plans and adopt an integrated approach to water management that considers food, water and energy as a whole rather than separately as at present.

The document launches a process to establish universal sustainable development goals for the post-2015 period and acknowledges the need to go beyond GDP as a measure of progress. Governments have also adopted a ten-year Framework of Programmes on Sustainable Consumption and Production.

Governments 'commit to take action, by 2025, to achieve significant reductions in marine debris', especially plastics, and to reduce other forms of marine pollution, such as persistent organic pollutants, heavy metals and nitrogen-based compounds (from agriculture). They vow to tackle ocean acidification and eliminate subsidies that contribute to overfishing. These commitments echo the *Rio+20 Declaration on Oceans* issued by a side event in Rio co-organized by UNESCO's Intergovernmental Oceanographic Commission. Governments also acknowledge the urgency of protecting marine biodiversity in the high seas.

For the UN chief, 'civil society and the private sector played an unprecedented role' in Rio. In all, 700 commitments were made. Eight multilateral banks committed to promoting sustainable transport, while 250 universities in about 50 countries committed to the Higher Education Sustainability Initiative. The UN chief praised the numerous pledges made by both governments and private investors in Rio totalling US\$513 billion, for 'governments alone cannot get the job done.'

To ensure universal access to affordable sustainable energy by 2030, *Resilient People, Resilient Planet* recommended doubling the rate of improvement in energy efficiency and the share of renewable energy in the global energy mix. More than 50 governments launched new energy strategies in Rio, while private investors pledged more than US\$50 billion towards the report's energy targets. These commitments kick-start the UN's Sustainable Energy for All initiative launched last September. *The Future We Want* notes this initiative and emphasizes the key role energy will play in achieving global sustainability.

The document also recalls that gender equality and women's empowerment are 'central to sustainable development.'

UNESCO organized a side event in Rio on women in science, jointly with the L'Oréal Corporate Foundation. Other events involving UNESCO focused on water cooperation, the theme of the next international year in 2013; biodiversity; education for sustainable development and; indigenous knowledge (*see page 21*).

The preparatory process for Rio+20 culminated in a Forum on STI for Sustainable Development on 11–15 June in Rio which advocated an integrated approach to policy and closer ties between the natural and social sciences. The forum launched Future Earth, a 10-year research partnership involving the International Council for Science (ICSU), International Social Science Council, Belmont Forum grouping major research funders, UNESCO, UNEP and UNU.

For details: [www.un.org/gsp/report](http://www.un.org/gsp/report);  
[www.unesco.org/new/en/rioplus20](http://www.unesco.org/new/en/rioplus20); [www.icsu.org](http://www.icsu.org)

## A **fresh start** for demobilized Rwandan soldiers

Thousands of Rwandans from the District of Rubavu have been left homeless in recent years by flooding and landslides caused by exceptionally heavy rains. In March this year, Noeline Raondry Rakotoarisoa from UNESCO's Man and the Biosphere Programme travelled to Rwanda's Western Province to see for herself how far rehabilitation had progressed in one of the worst-hit areas, Mount Rubavu; 15 months earlier, UNESCO had financed a tree-planting course within the One UN programme for 70 demobilized soldiers, many of them women.

Mont Rubavu is situated in Gisenyi, a city of more than 100 000 inhabitants which shares the highest lake in Africa, Lake Kivu, with the Democratic Republic of Congo. The hillside was once covered in rich vegetation but trees had been felled over time to make room for urbanization and small-scale agriculture. When torrential rains hit in April 2010, there was little to retain the soils. The resulting landslide swept away the homes and livelihoods of 1184 families.

The government subsequently launched a resettlement programme for the homeless. As Mount Rubavu was deemed unsafe for urban development, it was decided to reforest the hillside and turn it into a recreational park.

In December 2010, UNESCO financed a five-day training course for the population. 'Although most of the district's inhabitants are small farmers,' Raondry Rakotoarisoa explains, 'we deliberately targeted demobilized soldiers, in order to give them marketable skills.' The course was run by the Rwanda Environment Management Authority (REMA), which is also supervising the rehabilitation of the site.

The trainees discovered the advantages of levelling the steep slopes into horizontal terraces, in order for the rain to penetrate the hillside rather than running off the surface. The former soldiers were shown how to plant endemic bamboo, which is an excellent anchor for soil and so fast-growing that it can colonize a hillside within months. Ornamental tree varieties like Jacaranda were also planted on the terraces to provide shade, as well as palm trees and fruit trees like papaya. The trainees also learned how to border the terraces using stones recovered from destroyed homes (*see photo*).

The theoretical component of the course included training in how to set up and run a small business, in this case tree nurseries. They were taught how to organize themselves into cooperatives and respond to a call for tenders from REMA for supplying seedlings to the district.

'When I visited Mont Rubavu in March this year,' says Raondry Rakotoarisoa, 'I was pleased to see how far the rehabilitation had come. I met not only the trainees but also the indirect beneficiaries, people who have been employed by the district over the past year to plant Kikuyu grass (*Pennisetum clandestinum*) and reforest the area. Endemic Kikuyu grass is ideal for rehabilitating soils, as it is rich in nutrients. It also produces a soft lawn that, when cut, can be fed to cattle.'

The project is part of REMA's broader plan to build environmental awareness and develop a partnership with the population. It is hoped that the rehabilitation of Mount Rubavu



© REMA

*Rehabilitation of Mount Rubavu was progressing well in early 2011, thanks to the young trainees.*

will stimulate the economy by creating a second tourist attraction to complement Lake Kivu.

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## Germany to host **IPBES** Secretariat

**The German city of Bonn won a bid to host the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) at a plenary meeting in Panama City on 22 April.**

One or more of the four institutional sponsors – UNEP, UNESCO, FAO and UNDP – will administer the IPBES Secretariat once it is physically established. In the interim, all four UN agencies have been requested to continue facilitating the platform.

'Today, biodiversity won,' commented Sir Robert Watson, Chief Scientific Advisor of the UK Department for Environment, Food and Rural Affairs. 'Over 90 governments successfully established the science-policy interface for all countries,' observed the chair of the meeting.

For UNESCO Director-General Irina Bokova, 'the creation of IPBES, just a few weeks away from the Rio+20 conference, sends a strong signal. I hope that this body will allow biodiversity to be better taken into account in sustainable development strategies, as the IPCC has done for climate change over the last 20 years. Biodiversity loss is a key indicator of the changes which are affecting our planet.'

Ms Bokova stated that IPBES 'will provide a more efficient coordination tool between researchers and decision-makers in order to rise to this challenge. UNESCO has supported this process since its inception and will do everything to bring its long experience and mobilize its scientific networks in the fields of water, oceans and biodiversity in the service of IPBES.'

IPBES aims to tackle head-on the accelerating global loss of biodiversity and degradation of ecosystem services by filling existing gaps in knowledge and bridging the gap between policy-makers and accurate, impartial, up-to-date science.

IPBES will:

- identify and prioritize key scientific information needed for policy-makers and catalyse efforts to generate new knowledge;
- perform regular and timely assessments of knowledge on biodiversity and ecosystem services and their interlinkages;
- support policy formulation and implementation by identifying policy-relevant tools and methodologies and;
- prioritize key capacity-building needs to improve the science–policy interface, and provide and call for financial and other support for the highest-priority needs.

IPBES will respond to requests for scientific information related to biodiversity and ecosystem services from governments, relevant multilateral environmental agreements and UN bodies, as well as other relevant stakeholders.

A core trust fund will be established to receive voluntary contributions from governments, UN bodies, the Global Environment Facility, other intergovernmental organizations and stakeholders, such as the private sector and foundations.

For details: [www.ipbes.net](http://www.ipbes.net); [s.arico@unesco.org](mailto:s.arico@unesco.org)

## ICTP aids in Higgs boson discovery

**On 4 July, the European Organization for Nuclear Research (CERN) announced that a new subatomic particle had been discovered that behaves much like the elusive Higgs boson, a much sought-after particle that is expected to explain the existence of mass at the subatomic level. Physicist Bobby Acharya from UNESCO's Abdus Salam International Centre for Theoretical Physics (ICTP) has been participating in this experiment at the ATLAS particle-collision detector.**

He described the announcement as being tremendously exciting. 'Now that we know a new particle is there, we will study its properties in more detail. It probably is the Higgs, which represents the end to a search that has gone on for decades to find the missing piece of the Standard Model of Particle Physics puzzle. For the ICTP, this is an incredibly important result, given the fundamental role that Abdus Salam played in the development of the Standard Model.'

As to what the exact properties of the new 'Higgs boson' are, answers should be forthcoming throughout the year, as these preliminary results use only one-third of the data expected from the Large Hadron Collider (LHC) at CERN this year.

The ICTP and the University of Udine (Italy) have played an important role in the discovery. They have been jointly involved in examining the debris of particle collisions at the LHC to discover new particles like the Higgs boson. The scientists have been looking for the Higgs by removing the data from other particles that behave in similar ways, rather like removing noisy static while hunting for a radio signal. For example, the Higgs, which decays too fast to detect directly, decays into particles similar to those left behind by the decay of a top quark anti-top quark pair. By measuring detailed properties of processes like these, physicists can screen the 'background' data that get in the way while hunting for the Higgs.

For details: [www.ictp.it](http://www.ictp.it)

## Towards an action plan for Andes

**With the glaciers of the Cordillera de los Andes retreating as the climate warms, UNESCO's International Hydrological Programme (IHP) and Man and the Biosphere (MAB) Programme have begun working with Andean countries on an action plan for adaptation. The process kicked off with a workshop in Lima (Peru) on 29–30 May to establish an international network of researchers and policy-makers and identify their respective needs.**

The workshop drew more than 40 participants from Argentina, Bolivia, Chile, Ecuador and Peru, as well as experts from Belgium, China, Spain and the USA.

Three parallel working groups were organized, one on climate change, a second on policy and a third on vulnerability mapping. The meeting noted that countries in the region lacked proper monitoring systems to provide them with information on the impact of climate change on glaciers and water resources and enable forecasting. Participants also identified a need for education and training in glacier monitoring and climate change modelling.

Julio Ordóñez, Director-General of Hydrology and Water Resources at Peru's National Meteorological and Hydrological Service (Senamhi), told the Peruvian newspaper *El Comercio* on 29 May that 41% of ice cover had disappeared from the Cordilleras in the past 30 years and that 81% of the 755 remaining tropical glaciers in the Andes covered less than 1 km<sup>2</sup>.

Peru has set up two monitoring stations above 4000 masl in the past 18 months. The country is home to Huascarán Biosphere Reserve, which also happens to be a World Heritage site and national park. 'The highest tropical mountain range in the world is situated in the Cordillera Blanca,' observes Thomas Schaaf from UNESCO-MAB, 'with 27 snow-capped peaks 6 000 masl, of which El Huascarán (6 768 masl) is the highest.'

The retreat of glaciers in the Andes could have dire consequences for populations downstream. 'Many Andean valleys are seasonally dry and depend on glacier runoff to maintain their extensive mountain ecosystems', explains Anil Mishra from the UNESCO-IHP. 'The glaciers act as water towers, storing water in the form of ice that is released little by little all year round in the form of stream water. In the short term, shrinking glaciers will actually provide a greater flow of water to the valleys but, once they have disappeared, these water towers will be gone for good, causing water shortages in the longer term for agriculture, human consumption and power generation.'

The meeting's recommendations will be incorporated in the work of the Grupo de Trabajo de Nieves y Hielos, which UNESCO helped to create in 2003 to foster research on snow and ice in the region.

The workshop was organized by UNESCO in partnership with the FAO Mountain Partnership Secretariat, the Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN), the Andean Climate Change Interamerican Observatory Network (ACCION), the Grupo de Trabajo de Nieves y Hielos and the Third Pole Environment.

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## Meet *Unescoceratops*!

A new horned dinosaur has been named *Unescoceratops koppelhusae* in honour of the UNESCO World Heritage site in which the specimen was found, Dinosaur Provincial Park in Canada. *Ceratops* means ‘horned face’ in Greek.

The species is named for Dr Eva Koppelhus, wife of Dr Philip Currie. Together with Dr Michael Ryan, he originally described the dinosaur in 1998 as a *Leptoceratops*.

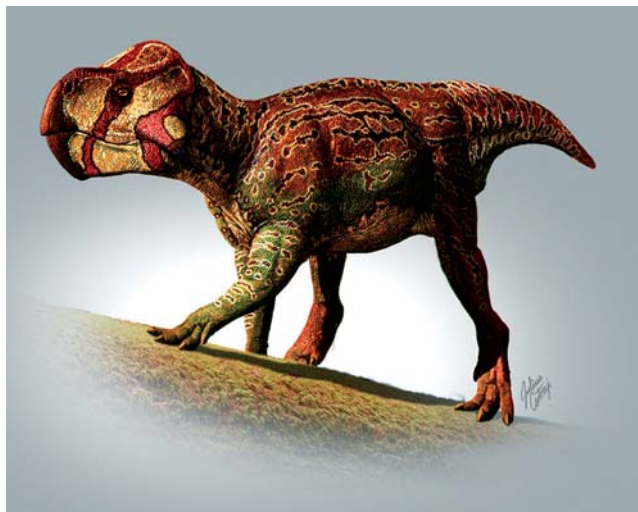
Subsequent research by Dr Ryan at the Cleveland Museum of Natural History (USA) and Dr David Evans of the Royal Ontario Museum in Toronto (Canada) determined the specimen was a new genus and species.

*Unescoceratops koppelhusae* lived during the late Cretaceous approximately 75 million years ago. This herbivore measured about 1–2 m in length and weighed less than 91 kg. It had a short frill extending from behind its head but no ornamentation on its skull. Its beak was parrot-like and its teeth were lower and rounder than those of any other leptoceratopsid. In addition, its hatchet-shaped jaw had a distinct portion of bone that projected below the jaw like a small chin.

*Unescoceratops* is one of two new dinosaur species named on the basis of fossils found in the Canadian province of Alberta. Discovered in 1950, the second is *Gryphoceratops morrisoni*, also from the Leptoceratopsidae family of horned dinosaurs, which lived about 83 million years ago. Based on unique characteristics of the jaw and its size, the researchers believe that *Gryphoceratops* was an adult that did not exceed 50 cm in length. This makes it the smallest adult-sized horned dinosaur in North America and one of the smallest adult-sized plant-eating dinosaurs known.

‘These dinosaurs fill important gaps in the evolutionary history of small-bodied horned dinosaurs that lack the large horns and frills of relatives like *Triceratops* from North America,’ says Ryan. ‘Although horned dinosaurs originated in Asia, our analysis suggests that leptoceratopsids radiated to North America and diversified here, since the new species, *Gryphoceratops*, is the earliest record of the group on this continent.’

For details: [www.cmnh.org](http://www.cmnh.org); [gbogar@cmnh.org](mailto:gbogar@cmnh.org)



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Artist's impression of *Unescoceratops koppelhusae*

## Africa lucid as to path ahead

Six of the ten fastest-growing economies over the past decade are situated in sub-Saharan Africa. Science, technology and innovation (STI) will be vital to maintaining this momentum, yet just two countries have reached the African Union's target of devoting 1% of GDP to R&D. This paradox was highlighted by participants in the First African Forum on Science, Technology and Innovation for Youth Employment, Human Capital Development and Inclusive Growth, which took place in Nairobi on 1–3 April.

The forum was hosted by the Kenyan Ministry of Higher Education, Science and Technology and organized by UNESCO, the African Development Bank, African Union, UNECA and the Association for the Development of Education in Africa.

Recalling that African governments had decided to devote 1% of GDP to R&D by 2010, Kenyan Minister of Higher Education, Science and Technology Margaret Kumar said that, ‘we have taken stock and Tanzania and Tunisia are the only ones that have hit the mark. South Africa is next at 0.94% of GDP.’ She cited the figure of 0.54% of GDP for Kenya.

For South African Minister of Science and Technology Naledi Pandor, ‘it is not a question of ‘constantly reinvent[ing] the wheel. We don't need to constantly develop new programmes, new resolutions. Let us make that which we have agreed upon actually work for the continent.’ This sentiment is reflected in the *Nairobi Declaration* adopted by more than 30 African ministers on 3 April, which essentially reaffirms earlier commitments made by governments, including that of devoting 1% of GDP to R&D.

The diversity of ministries represented at the forum – science, technology and innovation but also education, finance and planning – reflects the growing acknowledgement that STI policies must be integrated in Africa's national and regional development agendas and that the best-designed policies will make no impact if they remain unimplemented or starved of funding.

For the Hon. Margaret Kumar, a major challenge facing Africa are ‘the weak linkages currently between scientific innovation, the private sector, industrialization, job creation and youth development.’

Inventor Victor Kossikouma Agbegenou from Togo would have concurred. During the two-day expert meeting which preceded the ministerial segment, he lamented the fact that there were 1 billion consumers in Africa ‘yet we buy elsewhere’. Africa needed to industrialize production, he said, as private sponsors would not support a new product if it could not be manufactured in Africa.

President Donald Kaberuka of the African Development Bank challenged African nations to move away from finite inherited wealth (like oil and minerals), which could cause economic disruptions. He stressed the importance for Africa of commercializing its own innovations and expanding financial services for innovation.

By 2030, one in four young people would be African, he said, representing the largest work force in the world. ‘We need to step up investments in scientific research at home. The best of us study abroad and stay abroad. We need to find ways to bring our best people back.’ Both he and UNESCO Director-General

Irina Bokova stressed the need to reform education to address the demographic challenge.

‘Science is the engine, fuel and accelerator of sustainable development [...]’, observed Ms Bokova. ‘We must stimulate private investment and support more projects, as these will generate jobs for Africa’s youth.’ She described Africa as a ‘dream continent’ for the development of renewable energy and innovative technologies, with its abundance of wind, sun and flowing rivers.

If innovative products are not being mass-produced, it is not for lack of ideas. Kenyan inventions were exhibited during the forum: Ecopost Ltd showcased a viable alternative to timber that is made from recycled waste plastic; Jomo Kenyatta University of Agriculture and Technology displayed eco-bricks for construction; and Egerton University its natural larvicide to control malaria, as well as a high-yielding, drought-tolerant chickpea variety.

Bicycles and mobile phones inspired a number of inventions. Kisumu Polytechnic showcased a bicycle pump which uses pedal power to irrigate peasants’ fields. Smart Charger Ltd has mounted its cheap mobile phone charger on a bicycle. Inventor Elijah Kupata of Kupata Technologies Ltd won a prize at the forum for his 3G mobile remote camera, which detects the presence of an intruder on one’s property before sending a live video feed to the home-owner through a 3G-enabled mobile phone.

Read the Nairobi Declaration: [www.unesco.org/science/psd](http://www.unesco.org/science/psd)

## Experts from 40 countries trained in STI indicators

**From 23 to 27 April, experts drawn from the ministries and national statistical offices of nearly 40 African countries attended a training workshop on the collection and use of STI indicators, in Cape Town (South Africa). Also on the agenda were discussions on the policy relevance and implications of STI indicators.**

The workshop was organized by the Planning and Coordinating Agency of the New Partnership for Africa’s Development (NEPAD), in collaboration with the UNESCO Institute for Statistics and the South African Department of Science and Technology through its Centre for Science, Technology and Innovation Indicators.

The workshop was part of implementation of the second phase of the African Science, Technology and Innovation Indicators (ASTII) Initiative. ASTII is a flagship programme of *Africa’s Science and Technology Consolidated Plan of Action* (CPA) adopted by the continent’s science ministers in 2005. In January 2007, Heads of State and Government invited UNESCO to work closely with the African Union and NEPAD Secretariat to implement the CPA.

The overall goal of ASTII is to contribute to better STI policies at national, regional and continental levels by strengthening Africa’s capacity to develop and use STI indicators. The ASTII Initiative is supported by resources from participating countries and by a grant from the Swedish International Development Cooperation Agency.

The workshop was a key step towards the release of the second edition of the *African Innovation Outlook*, a continent-wide compendium of statistics on R&D produced through ASTII. The first edition of the *Outlook* was released in Addis Ababa in May 2011.

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## Titanic’s grave now protected by UNESCO

**One hundred years to the day after the *Titanic* sank in the mid-Atlantic Ocean on 15 April 1912, taking 1500 of its 2200 passengers and crew to a watery grave, the wreck has qualified for protection under the Convention on the Protection of Underwater Cultural Heritage. Adopted by UNESCO in 2001, the Convention applies to all traces of human existence having a cultural, historical or archaeological character which have been under water for at least 100 years.**

On this tragic anniversary, UNESCO Director-General Irina Bokova expressed concern at the ongoing destruction and pillaging of thousands of ancient shipwrecks worldwide. The commercial exploitation of the *Titanic* was not a unique case, she said, even if it was an exceptionally visible one.

Since the *Titanic* wreck is located in international waters, no state has exclusive jurisdiction over the wreckage. The newly accorded protection will mean that all States Parties to the Convention will now prohibit the pillaging, sale and dispersion of the *Titanic* wreck and its artefacts. They will take all measures in their power to protect the site, including the seizure of illicitly recovered artefacts and the closing of their maritime ports to ships which violate the Convention.

The wreckage of RMS *Titanic* was discovered on 1 September 1985, during a joint French/US expedition led by Jean-Luis Michel and Robert Ballard. The wreckage was found approximately 340 nautical miles off the coast of Newfoundland (Canada) at a depth of 3.8 km.

In 1986, Dr Ballard returned with his team to the *Titanic* in a submersible, the *Alvin*. They observed that the organic material had disappeared from the wreck but that objects such as dishes, copper and glass had been preserved. The *Titanic* is constructed primarily of steel. The scientists observed that the ferrous-iron structures, such as cast iron, wrought iron and steel, were corroded and draped with structures that Ballard named ‘rusticles’ because they hung like icicles but looked like rust.

Rusticles are complex structures. They contain different species of bacteria and fungi, as well as marine snow, the detritus that falls continuously down the water column in the deep ocean. Over time, the rusticles grow in size, as debris carried in the water currents becomes buried in them, such as sand, small pieces of glass, clay and seashells. In the case of the *Titanic*, the rusticles also contain pieces of coal which were once used to power the liner.

Bacteria feed on the rusticles, corroding ferrous-iron structures in a process known as biomineralization. These iron bacteria are extremophiles, capable of surviving a wide range of pH (acidity) and temperature levels.

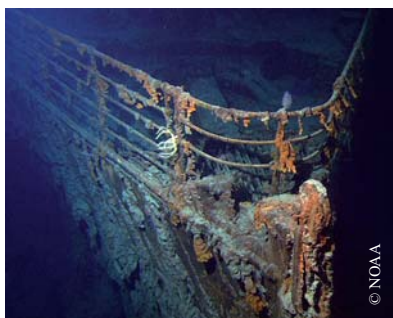
In 1991, a team of Russian, Canadian and American scientists collected samples of rusticles from which researchers



at Dalhousie University and the Ontario Science Centre (Canada) and at the University of Seville (Spain) were able to isolate a new bacterium, which they named *Halomonas titanicae*. They presented their findings to a UNESCO Scientific Colloquium on Factors Impacting Underwater Cultural Heritage in Belgium in December 2011.

Rusticles are not unique to the *Titanic*, of course. They are also found on other shipwrecks made of iron and steel. Rusticles also begin to form on the moorings of oil rigs within a year or two of their being installed in the ocean. The corrosion caused by the formation of rusticles, bacteria and normal processes costs the marine industry millions of dollars. By identifying the *H. titanicae* bacterium, Henrietta Mann and her collaborators have helped to shed light on how rusticles form, knowledge that could help the marine industry. These bacteria could also be used to dispose of old merchant and naval ships and oil rigs in the ocean once they have been cleaned of toxins and oil-based products.

For details: [www.unesco.org/culture](http://www.unesco.org/culture); [u.guerin@unesco.org](mailto:u.guerin@unesco.org)



Rusticles hanging from the bow of the submerged Titanic

recipient prior to an organ or bone marrow transplant (known as the human leukocyte antigen test).

Only Lebanon regulates genetic testing by law (2004). Most countries surveyed could not distinguish between this issue and that of the human genome and gene analysis. Regarding the latter, eight respondents had no regulations whatsoever concerning informed consent, collection and storage of samples, release of results and intellectual property rights: Kuwait, Libya, Morocco, Palestine, Saudi Arabia, Syria, the United Arab Emirates and Yemen.

Organ transplantation is one of the most regulated bioethical issues in the region, with most of the 16 countries surveyed having national regulations or at least some guidelines on essential principles, such as written donor consent, the donor's right to withdraw consent at any time and the prohibition of financial compensation for the donation of organs.

Generally speaking, Islamic scholars agree in their interpretation of the *Qu'ran* that a human embryo should not be considered a person. This stance could be expected to foster a permissive attitude in the region towards the destruction of human embryos as a result of embryonic stem cell research and therapeutic cloning.

However, the only country to authorize human embryonic stem cell research is Egypt, further to a decision by the Egyptian Fatwa Council. Most countries have no regulations, although Jordan is currently drafting a law. Only Lebanon and Tunisia prohibit explicitly both reproductive and therapeutic cloning; in other countries where legislation does not distinguish between the two, current laws tend to be subject to interpretation. A supplementary impediment to research on the human embryo is the lack of suitable facilities and equipment.

Attitudes towards abortion on demand vary greatly from one country to another. It is authorized only in Oman (in the first 40 days) and Tunisia (in the first three months). In Kuwait, Qatar, Sudan and Yemen, abortion can be authorized exceptionally in cases where the pregnancy endangers the mother's life or in the case of foetal malformation. In Algeria, Libya and Sudan, some exceptions are also made for pregnancies resulting from 'certain kinds of rape,' a heritage of past conflicts. Some of the experts surveyed mentioned the need to reform abortion laws.

In many countries where the Christian and Jewish faiths are dominant, there is a long history of searching for a balance between the secular and religious approaches to standard-setting. In the Arab region, however, the bioethical debate is a relatively new phenomenon. 'Bioethics can be a test for democracy,' suggests the study. 'Political, religious and scientific actors should not make decisions concerning bioethical problems independently but rather work together to reach consensus.'

Although the number of bioethics committees has increased in the past decade, the study observes that they remain 'disconnected and lack cohesion.' It states that 'bringing together and introducing reforms to these committees poses a great challenge, due to countries' and authorities' resistance to engaging in pluralistic debate.'

To read the report, see page 24; see also: [www.unesco.org/shs/ethics](http://www.unesco.org/shs/ethics)

## Bioethics urgently needs regulating in Arab world

**A study published by UNESCO's Cairo office (Egypt) has found that there is a legal vacuum in some Arab states on certain issues in bioethics. Although all States have endorsed UNESCO's three declarations on bioethics, the universal principles enshrined in these declarations are not yet sufficiently reflected in national legislation.**

*Ethics and Law in Biomedicine and Genetics: an Overview of National Regulations in the Arab States* is the first comprehensive study on this topic in the Arab world. It is the result of a two-year UNESCO survey of experts from 16 Arab Member States. In the majority of these countries, Islam is the State religion, with Islamic bioethics being rooted in the *Sharia* and *Fiqh*, even if universal principles are also embodied in the legislation and constitutions of some countries.

In Western countries, laws governing bioethics are included in the Civil Code or in the Codes of Public Health. Most Arab countries do not have the latter and replace the Civil Code by Codes of Personal Status, which fall under the jurisdiction of religious courts. 'This makes resolving ethical issues complicated and prevents them from having a serious impact on legislation,' observes the study.

All countries tend to have a permissive position on the use of assisted reproductive technologies (ART), even if this is limited to married couples only. As mixing lineage between unmarried couples is strictly prohibited in Islamic teachings, so is the donation of gametes and embryos. Despite this relative permissiveness, there is no regulation in most countries concerning applications of such technologies as a pre-implantation genetic diagnosis to determine the sex of an embryo, or the use of genetic testing of white blood cells to determine tissue compatibility between donor and



© Sasson Tiram

## Ruth Arnon

# 'The high level of research promotes Israeli science-based industries'

Israel's economy has escaped relatively unscathed from the global economic recession. Gross domestic expenditure on research and development<sup>13</sup> (GERD) fell by just 0.4 percentage points to 4.4% of GDP between 2008 and 2010, maintaining Israel's global lead for the level of commitment to R&D. Most exposed to the financial turbulence has been the business sector (80% of all R&D<sup>14</sup>), owing to its dependence on world markets for its high-tech exports and venture capital. One development that should have strong repercussions for the country's economy is Israel's integration in the Organisation for Economic Co-operation and Development in 2010.

Although the government has recently increased subsidies to business R&D to help it weather the storm, the biggest beneficiary of recent policy changes could yet be the university sector. With scant natural resources, Israel has always cultivated its human resources to drive development. Today, however, this pool is shrinking. The government's six-year plan to 2017 proposes increasing funding for universities and related research by at least 30%, in order to attract more students and woo Israeli scientists back to Israel from abroad, while diversifying the country's industrial base. As if to underscore this ambition, Daniel Shechtman from the Technion – Israel Institute of Technology was awarded the Nobel Prize for Chemistry in October 2011 for his discovery of quasicrystals, a new form of matter.

Here, Professor Ruth Arnon, President of the Israel Academy of Sciences and Humanities, deciphers the intricacies of Israel's unique science system and outlines the challenges it faces in a rapidly changing world.

### What explains the drop in Israel's GERD/GDP ratio from 4.8% to 4.4% between 2008 and 2010?

Preliminary data disclosed by the Central Bureau of Statistics show that the drop in Israel's GERD/GDP ratio is most probably the result of a drop in expenditure on R&D in two key sectors, each of which performed around 30% of R&D in 2008: a cutback of 8.5% in the services sector<sup>15</sup> and of 3% by manufacturing industries between 2008 and 2009.

Statistics on funding of R&D lag behind the statistics on R&D performance. However, we know for sure that by far the greatest part of R&D funding in the above-mentioned sectors is provided by local and foreign businesses, whereas only a small part is financed by the government.

About a year and a half ago, the Council for Higher Education announced the launch of the Israeli Centres of Research Excellence (I-CORE) scheme as part of the government's six-year plan to 2017. I believe that this is an indication that the trend towards a low government share of R&D funding is reversing. This novel programme envisions the establishment of centres encompassing cross-institutional clusters of top researchers in each field and returning young Israeli scientists from abroad, endowed with up-to-date research infrastructure. Four centres are currently operational and over the next four years the number is slated to reach 30 – covering the full range of natural and exact sciences, humanities and social sciences – with a total budget of 1.35 billion New Israeli Shekels (US\$365 million). The ICORE project areas are preselected by the management committee on the basis of a call for proposals and the centres of excellence in those preselected areas are

themselves selected via a peer review process conducted by the Israel Science Foundation (ISF). I-CORE is funded by the Council for Higher Education, the host institutions and strategic business partners.

The main challenges for Israeli science are twofold. On the one hand, we need to support and promote fields of research in which we already excel (*see figure on publication trends*) and to provide scientists with the means to pursue their work and thrive; in many cases, this will involve building sophisticated infrastructure. The second challenge will be to promote translational research; this is particularly relevant to biomedical research, where both clinical research and pharmaceutical research and drug development are attainable goals. For this purpose, it is essential to increase the government share of support for R&D in relation to that provided by private enterprise. Steps in this direction have been initiated by the recent opening of a biomedical and translational medicine division within the ISF.

### Medicine stands out as one of Israel's strengths. How do you explain this phenomenon?

In general, scientists in Israel are research-oriented, including those in the fields of medicine and technology. Furthermore, most physicians, both junior and senior, work in public hospitals affiliated to medical schools. As such, they also occupy university posts and depend on research activity and publications for the advancement of their career. They are, therefore, motivated to do both clinical research and collaborative work with scientists from other fields in the university sector. The

result is very strong medical and biomedical research activity, comprising both basic and translational research.

**Israel is dependent on oil imports and other fossil fuels, yet energy research is a low priority. Is Israel still planning to build a first nuclear reactor? If not, how does it plan to cover its growing energy needs in the coming years?**

I know of no plans at the moment for the construction of nuclear power plants in Israel. I believe that, despite the fact that Israel is considered to be an energy-poor country with few natural resources, it is able to meet its energy needs. A long-term agreement with Egypt, signed about five years ago, for the import of natural gas helped to ameliorate the situation. Despite repeated sabotaging of the pipeline from Egypt to Israel and Jordan over the past year, the agreement is still in force.

In the past two years, significant off-shore gas reserves have been discovered in Israeli territorial waters which may make Israel energy self-sufficient. The Academy was asked by the government to convene a panel of experts, including some of the most senior academic researchers, to consider the full range of implications of this discovery. Among the preliminary conclusions is that the country must enhance the academic study of all aspects of fossil fuels, a subject traditionally understudied in Israel, perhaps due to the seeming lack of domestic applicability until recently.

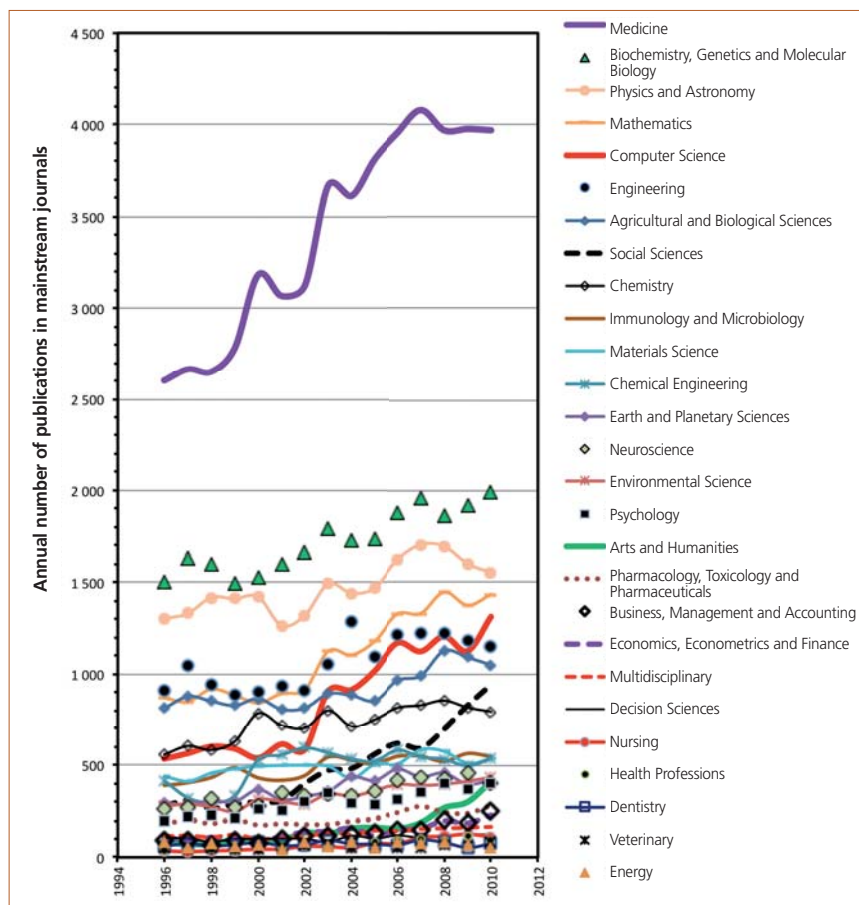
There is an additional potential power source that Israel has in abundance, the more than 300 annual days of sunshine. Israeli researchers are among the leaders for the conversion of solar and thermal energy into electricity. The world's first gas turbine solar thermal power station started generating power in 2009 in the desert near Eilat. The AORA Solar Inc. solar tower is based on technology developed by researchers at the Weizmann Institute of Science.

Recently, the Ministry of National Infrastructure announced it would be expanding its feed-in tariff scheme to include medium-sized solar-power stations ranging from 50 kilowatts to 5 megawatts, thus enabling the production of electricity by private citizens. About 90% of Israeli households already use solar sources, rather than electricity, to heat water for domestic use.

**Together with cut diamonds and high-tech equipment, fruit and vegetables are primary Israeli exports. With Israel's population having risen from 6.6 to 7.7 million between 2002 and 2010 and with the condition of the Jordan River deteriorating, how are Israeli scientists helping to ensure domestic water security today and maintain the level of agricultural exports?**

The Jordan River is a cross-border waterway. Water is abstracted by Syria, the Hashemite Kingdom of Jordan and Israel, with the result that the lower Jordan River is deprived of its freshwater sources. Within the GLOWA Jordan River Project (2004–2011),

**Trends in publications by Israeli scientists, 1996–2010**



Source: Guillermo Lemarchand, based on raw data available at: www.scimagjr.com

scientists and engineers from nearly 40 institutions in Israel, Jordan, the Palestinian Authority and Germany have provided scientific support for sustainable water management in the Jordan River region. To improve the situation further, cooperation with Syria will also be necessary. As Israel opens more desalination plants, it will most likely be able to reduce its abstraction from the Jordan River.

Science-based agriculture and water-saving irrigation techniques have long been among the mainstays of Israeli agriculture, producing, among other things, the cherry tomato and specializing in citrus fruit, including the world famous Jaffa orange. Today's agricultural exports focus more on exotic fruits and cut flowers. It is noteworthy that although the Israeli population more than doubled from 3.2 million in 1965 to ~7.7 million in 2010 and agricultural production grew more than tenfold in New Israeli Shekels over the same period, there was virtually no increase in the quantity of water used for agriculture and almost 70% of the amount currently used is reclaimed water rather than fresh.

**In Israel, 82% of research takes the form of experimental development, compared to 64% in the Republic of Korea,<sup>16</sup> another country known for its high-tech exports. What explains this high proportion in Israel?**

The high level of Israeli basic research and innovation promotes Israeli science-based industries, attracting local and foreign

investors and multinational companies in ICTs in particular. In 2007, such businesses performed more than one-third of GERD and employed about 40% of the researchers in the business sector. The positive repercussion of this situation is the provision of high-level employment to Israeli R&D personnel and the general contribution to national employment and income. The negative repercussion is that Israel foregoes much of the benefit derived from the commercialization of intellectual property created by its scientists.

Most R&D resources in the Israeli business sector are concentrated in three sub-sectors: the software and R&D services sector, with most businesses offering R&D services being engaged in information and communication technologies (ICTs), and the electronics and communication industries. These three sub-sectors employ 39% of all personnel in the business sector. Other sectors to which R&D resources are directed are the biotechnology and pharmaceutical industries. Only a small fraction of R&D workers are employed in essentially traditional industries, such as textiles and plastics.

This extremely high concentration of R&D in ICTs in the business sector points to the high level of risk to which the Israeli economy exposes itself by placing all its eggs in one basket. It is also indicative of an unexploited potential for developing the economy through investment in R&D in other industries, despite the fact that it is well-known that investing in R&D yields an exceptionally high return at the level of the national economy.

#### How many multinational companies have set up R&D centres on Israeli soil and is the trend accelerating?

There are currently 20 global corporations benefitting from grants from the Office of the Chief Scientist (OCS) of the Ministry of Industry, Trade and Labor (MOITAL) under a programme in which the OCS initiates agreements with leading global companies and invites local start-ups to undertake joint R&D programmes with them. Among the 20 are Hewlett Packard, Intel, Microsoft, International Business Machines (IBM), General Electric, Renault/Nissan and Merck.

Scores of additional global companies have established R&D centres in Israel unrelated to the MOITAL programme but there is no central registry of these initiatives. These include AMD, an innovator in semiconductor design, Carl Zeiss, CitiBank, McAfee, Motorola and Qualcomm. The trend appears to be consistently strong.

#### What challenges does higher education face in terms of training scientists and engineers?

The scientific and engineering population is ageing and there is a gap between the predicted demand for scientists and engineers – stemming from economic growth and the retirement of personnel – and the predicted supply of new graduates. In Israel, only 25%

of bachelor's degrees are obtained in the field of natural sciences and technology. This compares with 40% in the Republic of Korea and a ratio of about 30% in most Western countries. Were this trend to continue, it might close the positive technological gap that exists between Israel and its competitors, or even reverse it.

The ageing of scientists and engineers is already apparent in some fields. For example, about three-quarters of researchers in the physical sciences are over the age of 50. The situation is even worse when it comes to practical engineers and technicians.

According to estimates by the Samuel Neaman Institute for National Policy Research, there is a need for about 7000 new engineers each year, with more than half of these (3 600) required simply to replace the retirees. Yet, just 4 906 bachelor's degrees were awarded in engineering and architecture in 2008/2009. As for technical engineers and technicians, the predicted number of retirees alone is estimated at 12 000 and the number of graduates in these fields at about 8 000.

#### What percentage of 18–25 year-olds attend university?

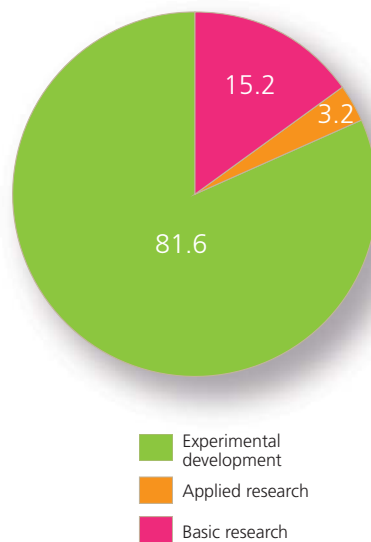
One-fifth (19.8%) of the 21–28-year age cohort was enrolled in academic institutions in 2009/2010, including the Open University. We have used this age cohort rather than that for 18–25-year olds due to the compulsory military service at age 18.

#### The government has launched a policy to increase access for Israeli Arabs and ultraorthodox Jews to higher education, as part of plans to bolster student numbers. How will this scheme work?

In 2012, the Council for Higher Education and the Planning and Budgeting Committee announced the launch of a new programme to increase accessibility to higher education for two groups that have been traditionally underrepresented: the ultraorthodox and Israeli-Arab populations. The programmes are based on three principles: mutual respect and recognition of the unique qualities and needs of the particular sector, maintenance of a high academic standard and choice of programmes leading to a high likelihood of employment. Financial support of the programmes is included in the multi-year agreement for higher education reform between the Ministry of Finance and the Ministry of Education reached in 2010.

Interview by Susan Schneegans

R&D in Israel in 2009, by type of research (%)



Source: UNESCO Institute for Statistics

13 The term R&D refers to civil R&D, as defence R&D is classified in Israel.

14 The business sector both performs and finances 80% of R&D.

15 Startups, Technological Incubators and Commercial Research Institutes, as defined by International Standard Industrial Classification 73

16 Data taken from UNESCO Science Report 2010

# Weathering uncertainty in the Arctic

One of the most novel developments since the last report of the Intergovernmental Panel on Climate Change (IPCC) appeared in 2007 has been the growing collaboration between indigenous peoples and scientists in assessing the impact of climate change on the environment. Nowhere is this change taking place more rapidly than in the Arctic, where temperatures are rising at a rate twice the global average.

During the Forum on STI for Sustainable Development which preceded the Rio+20 Summit, a panel organized by UNESCO on 13 June noted the growing recognition among governments and scientists of the need for indigenous peoples and mainstream science to co-produce knowledge of the impact of climate change, in order to help communities adapt.

The following excerpt from *Weathering Uncertainty*, a UNESCO-UNU publication launched at the forum in Rio, focuses specifically on Arctic peoples. It highlights their remarkable observation skills but also their distress at a phenomenon which is threatening their millennial way of life. As the Yup'ik people from the Bering Sea coast of Alaska put it, 'the weather is becoming an incessant liar'.

Arctic sea ice cover at the end of summer has hit record lows in the past few years, a trend that shows no sign of abating. The Inupiat hunters of Barrow in the US State of Alaska camp and hunt on the vast ice shelf which marks the boundary between land and sea. They use this unstable platform, which is thick enough to support a person between autumn and spring, to hunt the bowhead whale (*Balaena mysticetus*). In a freak accident some decades ago, this landfast ice shelf suddenly shattered due to pressures exerted by wind and current-driven pack ice. The hunters had to scramble to get back to land, abandoning equipment and camps in the process. Forty years later, another large ice platform broke away from the coast, carrying 142 hunters out to sea.

Fortunately, no lives were lost on either occasion but the Inupiat took home key lessons that they continue to transmit about the challenges and risks of hunting in a dynamic sea ice environment. Even though neither of these incidents was specifically related to climate change, it is feared that incidents of a similar nature may become more common as the climate changes.

Climate-related disasters are also a concern for the more than 20 reindeer-herding peoples who live across the circum-polar North. The reindeer kept by the Sami people of northern Sweden feed on lichen-heath pasture. In winter, this pasture is covered by a blanket of snow which herds dig through to reach their forage (*guohtun*). Roturier and Roué (2009) note that the

scourge of every herder is *cuokke*, a pasture locked under a sheet of impenetrable ice. After a warm spell in winter, when snow has melted or rain has fallen, freezing temperatures can quickly cover the landscape with vast sheets of ice that prevent the reindeer from digging down to their food. When these conditions occur, the entire herd may starve if it is not quickly moved to an ice-free zone. According to the Swedish Commission on Climate and Vulnerability (2007), global climate change is expected to increase the frequency of oscillating temperature regimes in winter, which in turn will most likely increase the frequency of disastrous ice conditions on winter pastures.

## Changing seasons

The timing, length and character of the seasons are changing, making weather patterns less predictable. Receding and thinning ice is making travel on frozen seas, rivers or lakes increasingly hazardous, while the changing melt pattern of permafrost in spring is destabilizing roads and community infrastructure, while rendering traditional storage in permafrost cellars obsolete. Coastal communities are severely threatened by erosion, as diminishing pack ice leaves coastlines exposed to increasingly severe storms, forcing some communities to relocate.

The growing variability in snow and ice conditions is having a profound effect on the distribution and migration patterns of many animals, including emblematic Arctic species like the



Using a harpoon to test the thickness of sea ice, an Inuk hunter approaches the ice edge in search of seal near Igloodik in Arctic Canada.

© Nanourak Roué

bowhead whale and the polar bear (*Ursus maritimus*). More southerly species are moving north, such as willow trees (*Salix spp.*), beavers (*Castor canadensis*) and elk/moose (*Alces alces*), while traditional mainstays of Arctic economies, including species of fish and seals, are also on the move. These trends have obvious implications for food security and sovereignty.

Changing weather and shorter winters are altering reindeer and caribou migration and feeding patterns, while shrubs are moving northward into the barren tundra areas, making access to lichen forage a challenge for the herds. It appears that forest fires are becoming more frequent, modifying the migratory patterns of land animals and perturbing indigenous livelihoods.

### A new Eldorado for industry and tourism

Climate change is accelerating other transformations in the Arctic. Industrial development is expanding in response to increasingly accessible non-renewable resources such as oil, gas or minerals and the opening up of shipping corridors through the Northwest and Northeast Passages, which are becoming more navigable as summer sea ice shrinks. Arctic tourism is also on the rise, as the region becomes increasingly accessible to ice-strengthened surface vessels, with or without icebreaker escorts. Climate change may also open up new opportunities for industrial-scale fishing as fleets follow fish stocks northwards into the Arctic.

### 'The Earth is faster now'

For over two decades, Arctic indigenous men and women have been reporting increasingly erratic weather conditions that confound their efforts at weather prediction. Mabel Toolie of St Lawrence Island expressed this unsettling circumstance by saying that 'the Earth is faster now'. Yup'ik from the Bering Sea coast of southwestern Alaska give voice to their dismay by declaring that 'the weather is becoming an incessant liar'.

Yukaghir elders from Russian Arctic say that 'we have stopped trusting nature and nature has stopped trusting us.' No matter how it may be expressed, the phenomenon of increasingly variable and unpredictable weather resonates from one Arctic community to the next across the circumpolar North.

These changes have been particularly evident to Inuit hunters of Clyde River in Nunavut (Canada) since the 1990s. Experienced traditional weather forecasters remark that they feel they have 'lost their skills'. Some hunters now pack additional gear when heading out on the land, recognizing that the weather may suddenly and unpredictably change. Reports by hunters of a specific turning point in weather predictability since the 1990s coincide with recent meteorological analyses.

One change inscribed in the landscape relates to what the Inuit refer to as *uqalurait*, snowdrifts that form parallel to the wind and that serve as a navigational aid for hunters. In the past, *uqalurait* pointed in a consistent direction dictated by the dominant wind. When visibility was poor, hunters could plot a reliable course in relation to the orientation of the *uqalurait* in order to arrive at their destination. Today, however, the dominant wind is reported to have shifted and wind direction is more variable. Hunters now only rely on *uqalurait* for navigation if they have been on the land on a regular basis and have kept track of shifts in wind and in the orientation of *uqalurait*. Young or inexperienced hunters risk getting lost because they may not be aware of this recent variability and may assume that the *uqalurait* are as reliable as in the past.

### Indigenous observing systems

One of the most innovative developments since the last IPCC report in 2007 has been a multiplication of collaborative research efforts involving indigenous peoples and natural and social scientists. These emerging partnerships build upon a long history of joint research and management that, in the Arctic, date back several decades to the land claim processes in northern North America in the 1970s and 1980s.

One example of continuous observation of ecological change is provided by the Nenets in Northwest Russia, who report increases in the height of willow and alder shrubs (*Salix spp.*, *Alnus fruticosa*) in the tundra zone. The reports from the Nenets are independently confirmed by groups of herders on both sides of the Polar Urals, travelling along traditional migration routes used for decades. They are also linked to discernible changes in reindeer management in response

*Reindeer digging through snow cover to graze winter pastures in northern Sweden*



to gains in shrub height. Specifically, herders now in their fifties observe that shrub thickets, which were mostly less than 1 m tall in the 1970s, in many cases now top the antlers of their reindeer (>2 m). This obliges them to keep their animals out of the tall, dense thickets to avoid losing sight of them during the rapid summer migration. In other words, indigenous observers have their own good reasons to develop and maintain observations of their environment, which may not be quantitative but are no less accurate and detailed.

Recent work on indigenous knowledge and climate change observation has been completed within the framework of the International Polar Year beginning in March 2007. One such project, Sea Ice Knowledge and Use: Assessing Arctic Environmental and Social Change (SIKU), involved the establishment of daily ice and weather observations by indigenous monitors in 10 communities in Alaska, Canada and Russian Chukotka between 2006 and 2009. This community-based monitoring was pursued for a fourth year in three Alaskan villages, thus providing an uninterrupted record of indigenous observations covering four consecutive ice seasons.

Overall, the SIKU project produced several hundred pages of local indigenous observations, organized in more than 150 monthly logs. The breadth and accuracy of these observations can be attributed to the vast, age-old Inuit knowledge of sea ice and their highly specialized lexicon.

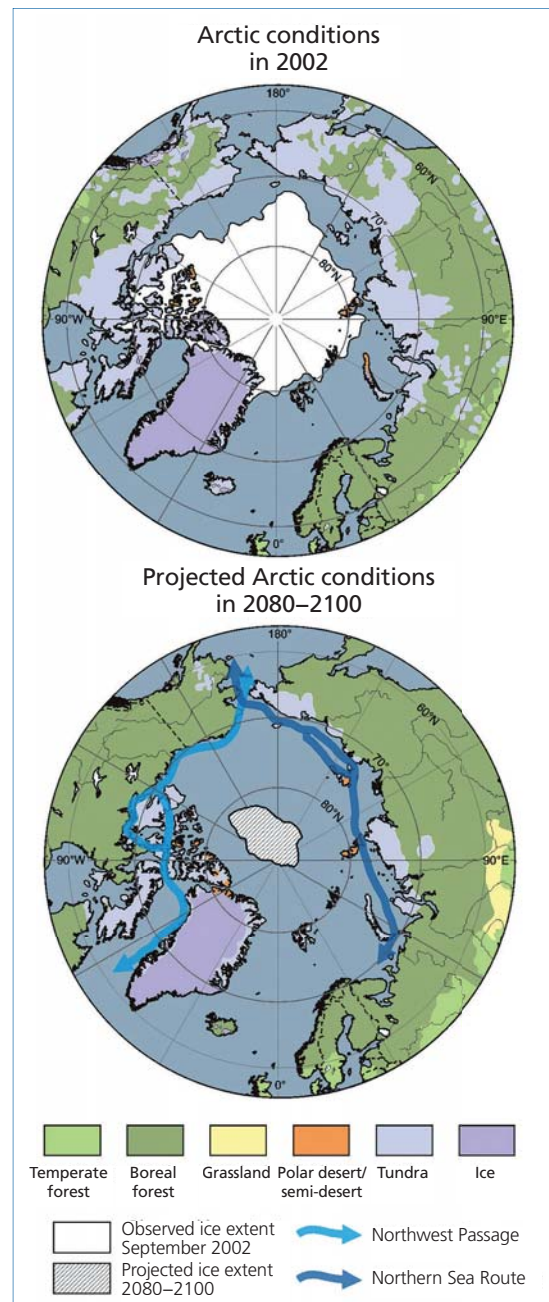
Krupnik and Weyapuk (2010) report over 120 Inupiaq terms for sea ice and associated vocabulary from Wales, Alaska, including almost 75 terms for types of sea ice and ice conditions. Each term is used to designate a meaningful and distinct phenomenon, and thus illustrates the refinement and subtlety with which Inupiat perceive and interact with their local ice environment.

Sea ice vocabularies of similar magnitude and sophistication are reported from Inuit communities across the circumpolar North. These elaborate vocabularies also constitute particularly fine-grained and high-resolution conceptual frameworks for observing ice environments and noting subtle transitions and trends. Many sea ice terms are bundled with information about hazardous conditions and potential sources of danger. Safety and survival on the sea ice is in part managed through the group's ability to share critical information rapidly and efficiently. Being site-specific, local languages serve as vehicles for sharing knowledge and experiences about a dynamic and potentially risky environment that is now subject to rapid and unpredictable climate change.

In another project within the International Polar Year called Igliniit, Inuit hunters recorded their observations of wildlife, sea ice, weather or other environmental phenomena as they travelled across the land. These observations were systematized, made spatially accurate and registered on the spot through the development of a mini-computer equipped with a global positioning system that hunters affixed to their snowmobiles.

Collaborative initiatives such as these, which bring together indigenous and scientific knowledge, make an important contribution to climate change monitoring and adaptation. They provide meticulous and systematic local observations that

### Predicted impact of climate change on the circumpolar North



Source: IPCC (2007) Impacts, Adaptation and Vulnerability, Working Group 2, Fourth Assessment Report

are informed by indigenous experience and understanding. These observations are all the more precious in that they are enriched with information related to subsistence livelihoods and community concerns and needs.

Douglas Nakashima<sup>17</sup>

To read Weathering Uncertainty, see page 24

<sup>17</sup> Head of UNESCO's Local and Indigenous Knowledge Systems (LINKS) programme

# China's palaeo-treasure trove

More than 300 geoparks dot the Chinese landscape, 26 of them forming part of UNESCO's Global Network of National Geoparks. One of these geoparks is home to Peking Man, a 700 000-old specimen of *Homo erectus* whose discovery overturned previous theories about the chronology of human evolution. The geoparks are a veritable treasure trove for anyone curious about past climate or the species which once roamed over China's territory. In April this year, Chinese scientists announced the discovery of by far the largest feathered dinosaur ever found, a carnivorous giant measuring about 9 m in length and weighing 1 400 kg. It has been named *Yutyranus huali*, a combination of Latin and Chinese meaning 'beautifully feathered tyrant.'

In little over a decade, China's geoparks have become a popular and economic success. By the end of 2010, one in three Chinese had visited one. Geotourism generates nearly US\$24 billion a year in revenue and provides 2.4 million jobs. The geoparks have also boosted nearby service industries, as well as agriculture and construction. In return, the government has invested heavily in research and in protecting the parks, including through a massive popularization campaign.



© Xinhua press agency

China has a rich dinosaur fossil record. Many centuries ago, this gave rise to a mythical figure in Chinese folklore that still endures today: the dragon, a symbol of power, strength and good fortune. The dragon is regularly fêted, as here in Jiangxi Province during the Lantern Festival announcing the New Year on 6 February 2009. It is currently the Year of the Dragon.



© Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences

Skull fossil of *Yutyranus huali*. Note the pointed teeth.

## A beautifully feathered tyrant

*Yutyranus huali* was found in northeast Liaoning Province by palaeontologists from the Chinese Academy of Sciences. Incredibly, they uncovered three near-complete skeletons. The new tyrannosauroid is considerably smaller than

*Tyrannosaurus rex* but still 40 times the weight of the largest previously known feathered dinosaur discovered in the same region.

'*Yutyranus* dramatically increases the size range of dinosaurs for which we have definite evidence of feathers,' observes Professor Xu Xing, research fellow at the Academy's Institute of Vertebrate Paleontology and Paleoanthropology and lead author of the study.<sup>18</sup> 'It is possible that feathers were much more widespread, at least among the meat-eating dinosaurs, than most scientists would have guessed even a few years ago. The feathers of *Yutyranus* were more like the fuzzy down of a modern baby chick than the stiff plumes of an adult bird.'

The large size of *Yutyranus* and the downy structure of its feathers would have made flight impossible but the feathers may have had another important function: insulation to keep warm. 'The idea that primitive feathers could have been for insulation rather than flight has been around for a long time,' observes Dr Corwin Sullivan, a Canadian palaeontologist involved in the study. 'However, large-bodied animals typically retain heat quite easily and actually have more of a potential problem with overheating.' That makes *Yutyranus* a bit of a surprise. The explanation may be climate-related. While the Cretaceous Period (approx. 135–65 million years ago, Ma) was generally very warm, *Yutyranus* lived about 125 Ma when temperatures may have been somewhat cooler.





In this reconstruction of Yanqing National Geopark in the Late Jurassic (ca. 150 Ma), we can see four different types of dinosaur track: those of *Deltapodus* sp., an armoured dinosaur (one of the thyreophorans); those of *Asinopodus* sp., a theropod like *T. rex*; those of *Dinehichnus* sp. in flight, an ornithopod, and lastly; those of an unnamed sauropod with its characteristic long neck and tail. These new footprints add to our knowledge of the diversity of dinosaur species, as the more than 5000 footprints discovered in neighbouring Northern Hebei and Western Liaoning of the same geological age all belong to theropods. Note the crocodile in the bottom left-hand corner.

© China Geopark Network

### Walking with dinosaurs

Another new find concerns 1000 well-preserved dinosaur footprints connecting six sites in the core area of Yanqing National Geopark<sup>19</sup> in Beijing, one of two Chinese geoparks applying to UNESCO for membership of the global network<sup>20</sup> in 2013. Dinosaur footprints can give scientists an idea of the dinosaur's size, gait and speed. Was it running? Was it walking on two legs or four? Did it drag its tail? This new discovery provides an excellent evolutionary sample to compare with later species found in the Yixian and Jiufotang Formations in northeastern China and dating from 133–120 Ma, which are known as the Jehol Biota.

### Peking Man

The skull of Peking Man was found in Fanshan Geopark by Chinese archaeologist Pei Wen Chung in 1926, at the Zhoukoudian site 42 km southwest of Beijing. The discovery excited universal interest, for *Sinanthropus pekinensis*, or *Homo erectus pekinensis*, turned out to be a hominin comparable to our African ancestors, suggesting that Peking Man's ancestors had originated in Africa.

Peking Man lived in the Middle Pleistocene epoch, 700 000–200 000 years ago, had mastered fire and used a number of chipped stone tools. Successive excavations in and



© China Geopark Network



© China Geopark Network

Dynamic monitoring system of Mt Tai Geopark

around the cave brought to light bones belonging to 40 individuals. Some 100 000 objects were also found, essentially rough chipped stone tools, traces of domestic hearths, heat-affected stones, burnt bones, ash deposits and the like, as well as fossilized grains.

Not far from the main site, a second cave was found to contain remains of *Homo sapiens sapiens* dating back to between 20 000 and 13 000 years ago, together with necklaces made from teeth, pierced shells and pebbles, bone needles and other items.

Tragically, almost all the remains of *Sinanthropus pekinensis* were dispersed or lost during the Sino-Japanese conflict beginning in 1937. Only the casts exhibited in the site museum could be saved in China. It is some consolation that excavations undertaken since have uncovered a full jaw of Peking Man (1959) and elements of a cranium, or skull (1966), as well as other hominids contemporary with Peking Man – or older: Lantian Man, found in 1963 in Shaanxi Province, and Yuanmou Man, found in 1965 in Yunnan Province. The Zhoukoudian site has been a World Heritage Property<sup>21</sup> since 1987.

### Nurturing a geological treasure

Geotourism in China has been a boon for the local economy. By 2010, geoparks employed 226 000 people, with a further 2 154 600 earning income from the parks indirectly.

The parks generated US\$23.69 billion in 2010, 15% of which came from entrance tickets alone.

In little more than a decade, China has established more than 300 geoparks. The first 11 were set up with the assistance of UNESCO's Division of Earth Sciences in 2000. At the time, dinosaur fossil smuggling was a flourishing trade, with specimens sold on the black market fetching many times a farmer's annual income. Over the past decade, the government has introduced a slew of regulations on fossil sales and smuggling which have managed to curtail the trade but not eradicate it. Officials are hopeful that a more educated population will prefer to report their finds rather than sell them.

The government has invested US\$1.36 billion since 2001 to protect the country's geoparks and promote public awareness. The first step was to establish a database and dynamic monitoring system for each of the geoparks (see photo). The landscapes and infrastructure of geosites were then cleared and restored (see photo).

Research bases have been established in over 200 geoparks. Since 2001, a total of 540 scientific research projects have been completed by scientists from research institutions and universities working in collaboration with their peers from geoparks. A further 175 projects are ongoing, for a total investment of around US\$438 million. In all, scientists have published 3 094 papers on geoparks since 2001.



© China Geopark Network



Geosite in one of the geoparks belonging to the global network, Xingwen Geopark in Sichuan Province, before and after restoration



Summer camp in Shilin Geopark in Yunnan Province, which belongs to the global network

Nearly 700 seminars or summer camps have been organized for the general public by geopark administrators since 2001 and more than 1 700 books explaining the geosciences to the public have been published. The government has also built over 200 geomuseums since 2001. These employ 6 481 professional guides, one-quarter of whom (1 751) are trained geologists.

### The network that might not have been

Today, China has three categories of geopark: global (26), national (140) and provincial. Yet the 'global' category might never have been. As an old Chinese saying goes, 'the road to happiness is paved with hardship'.

In 1999, the UNESCO Secretariat initially proposed an independent programme to the 58 Member States which make up UNESCO's Executive Board, as a means of promoting the preservation and international recognition of geological heritage worldwide. However, the ensuing feasibility study recommended not a separate programme but rather appending the geoparks initiative to an existing UNESCO programme. The study's preference went to integrating the initiative into the World Network of Biosphere Reserves within UNESCO's Man and the Biosphere (MAB) Programme, as opposed to the International Geoscience Programme or World Heritage Convention.

In a surprise turn of events, MAB's International Coordinating Council and its Bureau rejected the proposal. This led the Executive Board to decide in 2001 'not to pursue the development of a UNESCO geoparks programme but instead to support *ad hoc* efforts within individual Member States as appropriate.' UNESCO's *ad hoc* Global Network of National Geoparks was born.

### Spreading the word

China is one of only a handful of countries with geoparks dotted all around the country. Although the UNESCO initiative did not give rise to an independent programme and thus allocated no regular budget, the idea was warmly welcomed by China.

The geoparks concept has been a tremendous success in China. It has boosted the local economy by creating job opportunities while preserving geoheritage and the environment, thus embracing sustainable development. Chinese geoparks will continue to develop but they are also keen to share their experiences of conservation and sustainable development, especially at a time when geoparks are becoming increasingly popular: as of June 2012, the global network counted 88 geoparks in 27 countries. To help countries prepare their



Geomuseum in Xingwen Geopark in Sichuan Province, part of the global network

submissions, UNESCO produced *Guidelines and Criteria for National Geoparks seeking UNESCO's Assistance to join the Global Geoparks Network* in 2002.

Chinese geoparks have signed more than 40 agreements with sister geoparks in Austria, Brazil, France, Germany, Greece, Italy, Japan, the Republic of Korea, Malaysia, Romania, South Africa, Switzerland, the UK, USA and so on. They have also shared their experience of how to develop and manage geoparks at international and regional meetings. In collaboration with UNESCO, the Ministry of Land and Resources organized the First International Conference on Geoparks in Beijing in 2004. This was followed by the first three International Symposia on Development within Geoparks, organized by the Chinese government in collaboration with UNESCO in Yuntaishan (2006), Lushan (2007) and Mt Tai Geoparks (2009).

Some Chinese geoparks have struck out on their own, organizing international symposia themselves on specific themes. Examples are the First International Symposium on Geology and Geomorphology of Granite in Sanqingshan Geopark in July 2007, the First International Forum on Geoparks Interpretation and Sustainable Development in Yuntaishan Geopark in October 2007 and the First International Symposium on Danxia Landforms in Danxia Geopark in May 2009.

Today, it is hard to imagine that, little more than a decade ago, there wasn't a single geopark in China.

Hong Tianhua<sup>22</sup> Zheng Yuan<sup>23</sup> and Zhou Wei<sup>24</sup>

For details: [www.unesco.org/new/en/natural-sciences/environment/earth-sciences/geoparks/members/](http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/geoparks/members/)

18 Source: [www.chinadaily.com.cn/china/2012-04/05/content\\_14985993.htm](http://www.chinadaily.com.cn/china/2012-04/05/content_14985993.htm)

19 See the Chinese Science Bulletin (2012): 57(2-3):144-152

20 The other is Shennongjia National Geopark in Hubei Province.

21 See <http://whc.unesco.org/en/list/449>

22 Deputy-Director and Secretary-General, International Centre on Space Technologies for Natural and Cultural Heritage, functioning under the auspices of UNESCO, and Centre for Earth Observation and Digital Earth of the Chinese Academy of Sciences, Beijing

23 Coordinator, Chinese Geoparks Network, Director of Geopark Promotion and Research Centre, Chinese Academy of Geological Sciences

24 Programme Assistant, International Centre on Space Technologies for Natural and Cultural Heritage and Centre for Earth Observation and Digital Earth

## Diary

## 24 June – 6 July

## World Heritage

36<sup>th</sup> session of World Heritage Committee to select sites. Saint-Petersbourg (Russian Federation): <http://whc.unesco.org>

## 28–29 June

## Great Apes Survival Project

Executive Committee meeting for UNESCO/ UNEP project dating back to 2002. UNESCO Paris: [n.raondry-rakotoarisoa@unesco.org](mailto:n.raondry-rakotoarisoa@unesco.org)

## 5–9 July

## Promoting Biological Sciences for a Better Life

31<sup>st</sup> IUBS General Assembly and intl conf. on biological sciences and bioindustry to promote international collaboration in research and conservation programmes. IUBS, Chinese Academy of Sciences, UNESCO Beijing, Suzhou, Jiangsu Province (China): [b.wang@unesco.org](mailto:b.wang@unesco.org)

## 9–13 July

## Man and Biosphere Programme

Intl Coordinating Committee meeting to assess implementation of Madrid Action Plan (2008) and discuss future of MAB in light of Rio+20. UNESCO Paris: [mab@unesco.org](mailto:mab@unesco.org); [www.unesco.org/mab](http://www.unesco.org/mab)

## 9–13 July

## Radiocarbon

21<sup>st</sup> intl radiocarbon conf. co-organized by French radiocarbon community and UNESCO.

Long used as a 'chronometer' only for calibration, archaeology and palaeoenvironmental studies, <sup>14</sup>C (radiocarbon) is now being used by other scientific disciplines as a tracer of fluxes and processes: hydrology, ocean sciences, medicine, ecology – even forensics, etc. UNESCO Paris:

[h.treidel@unesco.org](mailto:h.treidel@unesco.org);  
[www.radiocarbon2012.com](http://www.radiocarbon2012.com)

## 12–14 July

## Effective tsunami disaster reduction

Monitoring progress in implementation in Pacific island countries. UNESCO-IOC, Govt of Samoa, Apia: [b.alaga@unesco.org](mailto:b.alaga@unesco.org);  
[www.ioc-tsunami.org](http://www.ioc-tsunami.org)

## 17 July

## UNESCO-Equatorial Guinea Intl Prize for Research in Life Sciences

Award ceremony for 1st edition. UNESCO Paris: [bes@unesco.org](mailto:bes@unesco.org)

## 18–20 July

## Promoting women in science in Africa

UNESCO/L'Oréal Corporate Foundation workshop to examine policy options and strategies with women leaders in science. Johannesburg (South Africa): [p.oti-boateng@unesco.org](mailto:p.oti-boateng@unesco.org);  
[www.unesco.org/science/psd](http://www.unesco.org/science/psd)

## 13 August

## MERCOSUR Prize for S&amp;T

Deadline for applications. Theme: Technological Innovation for Health. Details (in Portuguese): <http://eventos.unesco.org.br/premiomercosul>

## 15–28 August

## Course in harmful algal blooms

For scientists and agency staff responsible for surveillance of harmful algal events and their effects. Copenhagen (Denmark): [h.enevoldsen@unesco.org](mailto:h.enevoldsen@unesco.org)

## 10–14 September

## OceanTeacher Academy

Training course in operational oceanography for ocean data managers. UNESCO-IOC project office for IODE, Oostende (Belgium). A second course on grant writing for digitisation projects will follow for marine librarians (17–21 September): [p.pissierssens@unesco.org](mailto:p.pissierssens@unesco.org)

## 11–14 September

## Tsunami early warning and mitigation system

in North-eastern Atlantic, Mediterranean and connected seas. 9<sup>th</sup> session of Intergovernmental Coordination Group. National Oceanographic Centre (UK): [s.belfiore@unesco.org](mailto:s.belfiore@unesco.org); [j.santoro@unesco.org](mailto:j.santoro@unesco.org)

## 20–21 September

## Launch Intl Research and Training Centre for S&amp;T Strategy

Centre to operate under UNESCO's auspices (Category II centre). UNESCO co-organizer with Chinese Academy of S&T for Development, Min. Science and Technology. Beijing (China): [b.wang@unesco.org](mailto:b.wang@unesco.org)

## 25–28 September

## Yellow River

5<sup>th</sup> intl forum for policy-makers and experts. UNESCO co-organizer with Yellow River Conservancy Commission, Min. Water Resources. Zhengzhou, Henan Province (China): [b.wang@unesco.org](mailto:b.wang@unesco.org)

## 24–27 September

The Ocean in a high CO<sub>2</sub> world

3<sup>rd</sup> intl symposium. Scientific meeting on ocean acidification. Monterey (USA): [jl.valdes@unesco.org](mailto:jl.valdes@unesco.org)

## EMERGENCY APPEAL

On 24 June, poachers armed with AK47 rifles attacked the headquarters of the Okapi Wildlife Reserve, a World Heritage site in the Dem. Rep. of Congo, killing seven people, including two rangers. UNESCO and Fauna and Flora International hope to raise US\$120 000, by 31 July 2012 to help the victims' families and repair the reserve's headquarters. Donate: [www.rapid-response.org](http://www.rapid-response.org)

## New Releases

## Tales Set in Stone

## 40 years of the International Geoscience Programme

UNESCO and International Union of Geological Sciences, English, French and Spanish, 140 pp. Describes a wide range of IGCP projects. For details, see page 2.

Download: <http://unesdoc.unesco.org/images/0021/002152/215219e.pdf>

## Ethics and Law in Biomedicine and Genetics

## An Overview of National Regulations in the Arab States

Survey results compiled and commented by Fouad Boustany. Produced by UNESCO Cairo office. Exists in English, Arabic edition planned, 84 pp.

Analyses the findings of a survey of experts from Algeria, Egypt, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen. For details, see page 17 or write to [o.ikebe@unesco.org](mailto:o.ikebe@unesco.org).

Download: <http://unesdoc.unesco.org/images/0021/002152/215207E.pdf>

## A Guide on Adaptation Options for Local Decision-makers

## Guidance for Decision-making to Cope with Coastal Change in West Africa

By Isabelle Niang et al. UNESCO-IOC Manual and Guides no 62. Guide to decision-making to cope with coastal changes in West Africa. Exists in English, French and Portuguese, 52 pp.

This guide was launched during a 12–13 June meeting at UNESCO Dakar office. It concludes the first phase of a joint UNESCO-IOC and UNEP project (2008–2012) funded by the Global Environment Facility focusing on Cape Verde, Guinea-Bissau, Mauritania, Senegal and The Gambia.

The project mapped the risks climate change poses to West Africa's coastline. It found that populations at risk from coastal flooding would rise from one million in 1990 to 70 million in 2080 along the Gulf of Guinea, the Gambian and Senegalese coastline and all the way to Egypt. The study predicts that sea level will rise by 95 cm by 2100, threatening 30% of coastal infrastructure. It also predicts that climate change will displace or shrink more than 80% of coastal habitats.

Download: <http://unesdoc.unesco.org/images/0021/002166/216603E.pdf> (replace the E with F for French and POR for Portuguese)



## Weathering Uncertainty

## Traditional Knowledge for Climate Change Assessment and Adaptation

By D. Nakashima, K. Galloway McLean, H. Thulstrup, A. Ramos Castillo and J.T. Rubis. Co-published by UNESCO and UNU. English only with executive summary that exists also in French and Spanish, 120 pp. See also page 21.

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## UNESCO e-Atlas of Research and Experimental Development

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## The Forests of the Congo Basin

## State of the Forest 2010

C. de Wasseige et al (eds). Publications Office of the European Union. Luxembourg. With UNESCO financial and intellectual contribution. ISBN: 978-92-79-22716-5. Exists in English and French, Spanish edition pending, 276 pp.

The report is divided into four main sections: indicators concerning Central African forests; impact of the informal sectors on forest management in Central Africa; current challenges facing forest management in Central Africa and; landscape management. Boxes introduce the Regional School for Integrated Tropical Forest Management (ERAIFT) founded by UNESCO at the University of Kinshasa (Dem. Rep. Congo) and World Heritage sites.

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