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Tending to the ailing 'mother river of China', p.16

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IN THIS ISSUE

IN FOCUS

- 2 The thrill of drilling

NEWS

- 10 Poles warming faster than expected
- 10 Denmark gets behind climate change education
- 11 Ten years to save coral reefs
- 12 Awards for exceptional women
- 12 2011 to be Year of Chemistry
- 13 Pierre Auger Observatory inaugurated
- 13 Optics prize for Iranian

INTERVIEW

- 16 Jacques Weber on why the financial crisis is also an opportunity

HORIZONS

- 16 Tending to the 'ailing mother river of China'
- 19 Of shipwrecks, lost worlds and grave robbers

IN BRIEF

- 24 Diary
- 24 New releases

EDITORIAL

The other crisis

Water is too important to be left solely to water professionals. This is the message of *Water in a Changing World*, the third World Water Development Report, presented to the World Water Forum in Istanbul (Turkey) by UNESCO on 16 March, on behalf of 26 UN bodies.

The report hopes to persuade governments to show more interest in their 'blue gold'. Current investment in water is negligible compared to the sums being channelled into the financial crisis and into reducing carbon emissions – even though water supplies will be one of the casualties of climate change. 'Water should be at the heart of policies for agriculture, energy, health, infrastructure and education', insists Olcay Unver from UNESCO, coordinator of the report.

The authors observe that the water crisis will deepen in coming decades if foreseeable problems are not anticipated. Demand for water has never been higher, a trend set to continue as the global population swells to 9 billion by 2050, urban dwellers come to outnumber their rural counterparts, energy production rises, standards of living climb and eating habits evolve. By 2030, nearly half of humanity (47%) will be living in water-stressed areas.

Prosperous societies consume a lot of meat. And thus a lot of water, for it is the water we eat, not the water we drink, which determines how much we consume. Producing 1 kg of wheat requires 800–4000 litres of water, compared to 2000–16000 litres for 1 kg of beef. In 2002, Swedes ate 76 kg of beef each per year and Americans as much as 125 kg. Emerging economies are, in turn, developing a taste for meat. It is estimated that the Chinese consumer who ate 20 kg of meat in 1985 will eat over 50 kg in 2009. This means China will need an additional 390 km³ of water. Yet, as we shall see in a case study taken from the report, managing water scarcity is now the top priority along the Yellow River, the second-longest in China.

Then there is the energy we are 'growing'. It takes 1000–4000 litres of water to produce just 1 litre of biofuel. Biofuel production may still be small-scale – the ethanol share of the transport fuel market was estimated at 4.5% for the USA, 40.0% for Brazil and 2.2% for the European Union in 2008 – but it is rising steadily: after tripling between 2000 and 2008 to 77 billion litres, it should reach 127 billion litres by 2017.

Energy demand could climb by as much as 55% by 2030, nearly half of which may stem from China and India alone. This means that, despite their heavy ecological footprint and social impact, dams are here to stay: electricity generation from hydropower is projected to increase at an average annual rate of 1.7% from 2004 to 2030, an overall increase of 60%. The report argues that water storage in Africa, at just 4% of capacity compared to more than 70% in most of the developed world, will have to increase to serve both energy production and all the continent's other water needs.

How do you persuade governments to act? For economist Jacques Weber, economics holds the key. In this issue, he explains why the current financial crisis is a consequence of the growing scarcity of natural resources – and why this makes it a golden opportunity to 'green' the global economy.

W. Erdelen
Assistant Director-General for Natural Sciences

The thrill of drilling

Even after more than 250 years of geoscientific investigation, it is still fair to say that *terra incognita* (or the unknown) begins just a few dozens of metres beneath our feet. The desire to explore this dark underworld goes beyond an academic interest in understanding the building blocks and structure of the planet whose surface we inhabit. The rocks beneath our feet are the source of the hidden dangers lurking in earthquakes and volcanic eruptions. Deep layers contain information about the face of the Earth millions of years ago, about the climates that once reigned and the geographical distribution of oceans and continents. They hold the secret to how rocks form, how certain minerals become enriched and others depleted, knowledge which can help us to exploit our planet's resources in a more sophisticated and more sustainable way.

'I wish I could go down there and check it out.' What Earth scientist has never voiced this frustration? Drilling may be the only way to compare models with reality but it is also an expensive proposition. The oil and gas industries estimate they spend about US\$5 million to drill a standard hole of 3 km. How, ask many researchers, can one justify such costs to a funding agency, if the results of a purely scientific drill hole are far less certain even than those in the risky business of sinking oil wells?

This is where the International Scientific Continental Drilling Programme (ICDP) comes in. Since its inception in 1996, the programme has funded 25 projects submitted by scientists the world over. UNESCO sits on the Scientific Advisory Board which approved them. Many of these fascinating projects are described on the pages that follow, as we wind up the International Year of Planet Earth with a journey to the Deep Earth.

Today, the deepest drill hole reaches to a depth of 12 262 m. This is roughly one-third of the distance to the bottom of the Earth's crust (35 km), 1/500th of the distance to the centre of the Earth (6374 km) and 1/1000th of the Earth's diameter (12 748 km). Current drilling technology thus barely scrapes the surface. Yet, on this descent to the bowels of the Earth, one rapidly enters a truly different world. At a depth of less than 4 km, the temperature of the rock reaches 100°C, the boiling point of water at the surface. Less than 1% of the way to the

Earth's centre, the lithostatic pressure – the weight of the rocks above you – has already become so massive that it will crush the strongest steel. Gaining access even to moderate depths is therefore a unique and difficult technical challenge.

Making an impact

Impact structures are one of the eight themes of the ICDP. Asteroids travel through space at a velocity of thousands of



Roughnecks connecting drill pipe joints during the drilling project in the Chicxulub crater on Mexico's Yucatan Peninsula



A killer asteroid gives up its secrets

In the search for oil 25 years ago, petroleum geologist Antonio Camargo conducted a geological survey in the sea off the northern Yucatan coast of Mexico. The data he collected revealed gravitational anomalies in the form of giant circles with a radius of almost 100 km near the coastal village of Chicxulub. The rock formations could not be of volcanic origin but could they be the remnants of an impact crater? They were indeed. Camargo had stumbled upon an impact crater that, over 65 million years, had gradually been buried by erosion, thus escaping the notice of field geologists.

Since the find, scientific evidence has accumulated to suggest that the crater was left behind by a killer asteroid associated with the demise of the dinosaurs.

The debris in the crater generated by the enormous heat and pressure during impact is of utmost interest to scientists. It consists not only of Earth rocks from before the impact which have been reworked and melted together by the heat and the shock wave of the impact.

The debris also contains fragments of the impact body itself. Of particular interest are rare isotopes which were abundant during the formation of the Solar System but which have been depleted in the rocks of the Earth during geologic times.

During the winter of 2001–2002, the ICDP authorized a drilling proposal into the impact crater's rim, approximately 62 km off its center. The Yaxcopoil-1 Well was drilled about 40 km southwest of Mérida, Yucatan's capital, to a depth of 1510 m. The top 795 m consisted of post-impact Tertiary carbonate rocks and, in the bottom 615 m, the drill went through pre-impact Cretaceous rocks. Sandwiched between them was a 100-m-thick layer of impactites, rock composed of suevitic and impact melt breccias. They were no longer fresh by any means, as they had gone through significant chemical alteration in the past 65 million years.

More than 900 m of the well was cored and the entire well was logged by means of wireline geophysics to obtain a continuous set of *in situ* petrophysical data of the borehole wall. The recovered rocks and the logging data have since become a treasure trove for geologists.

kilometers per hour. Although the likelihood of one entering into a collision course with Planet Earth in anyone's lifetime is extremely rare, it is by no means nil. During the 4.5 billion-year history of the Earth, many such celestial collisions have taken place. For instance, the fact that the rotational axis of the Earth is tilted with respect to the plane of the ecliptic is most elegantly explained by an impact during our planet's earliest existence. The moon, it is hypothesized, was knocked out of the baby Earth by another such collision.

Asteroids and meteorites have hit the Earth's surface even in recent times, leaving behind unmistakable traces. A total of 174 such impact structures have been discovered by scientists, not only on the continents but also at the bottom of the sea (see for example *A killer asteroid gives up its secrets* and *Taking climate archives from a lake*).

Depending on the size of the celestial body, the effects of a collision with the Earth can be truly devastating. Upon impact, the kinetic energy of the asteroid converts almost entirely into a shock wave and an enormous amount of heat. The inferno can be strong enough to vaporize layer upon layer of the Earth's crust within minutes. The consequences are dire indeed. Not only does the melting leave a deep scar on our planet's surface. Billions of tons of dust and ash are also ejected into the highest layers of the atmosphere, dimming or completely blocking out the sunlight for decades.



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Meet the extremophiles

The record altitude set by birds of prey while soaring effortlessly in thermal updrafts is typically considered to be the biosphere's upper limit. Where humus-rich soil hits bedrock, mostly just a few metres below the surface, may be viewed as its lower boundary. But are these definitions correct? There are many indications that the biosphere reaches much deeper into the interior of the Earth than is commonly thought.

The *extremophiles* were discovered in the 1970s. These microorganisms live under conditions commonly thought to be sterile or at least very hostile to life. Among the first recognized were *thermophiles* in the hot springs of Yellowstone National Park in the USA. These bacteria and archaea can survive temperatures of 50°C or more.

Another kind of *thermophile*, some chemosynthetic archaea, was later discovered around the submarine hydrothermal vents along the Galapagos Rift, a spur of the East



Taking climate archives from a lake

Some of the best climate archives can be found in the sediments of freshwater lakes. They contain a combination of pollen, plant detritus and minerals from which palaeoclimatologists can reconstruct the climatic conditions of long ago.

One prime example is Lake Bosumtwi in Ghana (see *photo*). This almost perfectly circular lake has a diameter of 8 km. Its maximum depth is about 80 m, although lake sediments extend more than 300 m below the current lake bottom. Lake Bosumtwi was formed just over one million years ago by the impact of a large meteorite. Two factors have preserved the lake's sediments in an undisturbed condition, its relatively high crater rim and the fact that no river flows either into or out of it. This makes it unique and ideal for climate studies. As the lake is located in the monsoon zone of Western Africa, its sediments should hold the key to understanding the development of the climate in this part of the world over the past million years.

Between July and October 2004, a floating drill platform was brought to Ghana where more than two dozen holes were drilled into the lake bed. More than 1800 m of sediment core were recovered for climate studies. The longest single core consisted of 294 m of laminated mud. The pollen, detritus and minerals in each layer – a varve – gives insights into the weather and environmental conditions over one year. To scientists, such varved layers are like a book, with each page holding the secret of the former climate.

As Lake Bosumtwi is actually a lake filling an impact crater, several holes were drilled through the sediment into the underlying, 2.2 billion year-old rocks of the West African craton. As in the case of Chicxulub (see *A killer asteroid gives up its secrets*), the layers between the sediment and the basement rock revealed details about the impact itself.

Almost 10 000 km west of Lake Bosumtwi, on the other side of the Atlantic Ocean, lies another small body of water. It holds the key to the history of climate in the tropics of Central America. Hidden in the jungle of the lowlands of northern Guatemala, Lake Peten Itza is something of a complement to Lake Bosumtwi, half a world away. Both lakes are located in the Intertropical Convergence Zone, the region of moist tropical climate, whose position shifts during the year. This leads to a highly seasonable rainfall pattern in both locations. Researchers hope that, by comparing the varves of Lake Peten Itza with those of Lake Bosumtwi, they can find similarities and differences in the climate patterns of tropical Africa and its Central American counterpart.

Again using the drill platform, nine holes were drilled into the sediments of Lake Peten Itza in early 2006. They revealed that, during the last 20 000–30 000 years, the climate in the lowlands of Guatemala had changed rapidly several times, from dry to very moist and back. The most drastic such change occurred at the end of the last ice age, when the glaciers thousands of kilometres to the north melted. Even the onset of human agriculture about 10 000 years ago and the decline of Mayan cultures due to drought are archived in the sediment layers of the lake.

Pacific Rise. These microbes gain their metabolic energy not from photosynthesis but by oxidizing methane or inorganic molecules, like hydrogen sulfide. By now, at least a dozen different classes of *extremophile* have been studied, ranging from *acidophiles* to *xerophiles*. *Acidophiles* are organisms which thrive in extremely acidic liquids with pH levels at or below 3, whereas *xerophiles* can grow in utterly dry, desiccating conditions, for example in the soils of the Atacama Desert between the Andes mountains and the Pacific Ocean in South America.

Currently, the known upper temperature limit for life anywhere in the Earth's biosphere is 121°C. The upper limit has climbed to higher and higher temperatures over the years, as new extremophiles have been cultivated from increasingly hot environments. On the basis of this temperature, one can estimate the limits within the Earth of thermophilic living conditions. As anyone who has ever visited a deep mine knows, it gets hotter the deeper you go. Geothermal gradients,

the yardstick for this increase in temperature, fall in the range of 10–60°C per kilometre. Combining the upper temperature limit for life and geothermal gradients with mean surface temperatures lying between 0°C and 25°C, we find thermophiles could exist all the way down to 12 km below the surface. Methane is most likely to be the 'food' for these bacteria (see *Methane-loving microbes*).

Playing with fire

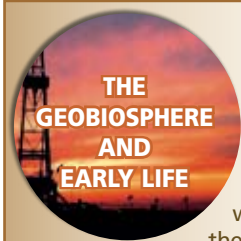
One of the goals of volcanology is to reduce the hazard posed by the approximately 600 active 'fire mountains' in the world. Researchers working in the field have found ways to monitor volcanoes closely enough to detect signs of imminent eruptions. During the last decade or so, many lives have been spared because scientists were able to predict the activity of dangerous volcanoes. Nonetheless, sometimes even the most experienced scientists are still caught in the violence of an eruption.

Only a small fraction of volcanologists need to do their work in the immediate proximity of an erupting fire mountain. Much of what we know today about the inner workings of volcanoes is inferred from the study of rocks and deposits, laid down in eruptions long ago. Through mineralogical and petrological investigations of volcanic and igneous rocks researchers can extract information about the temperature and the chemical composition of the melt in a former magma chamber. Geologic surveys of the immediate neighbourhood of a volcano can determine its reach. Knowing how far lava streams and pyroclastic flows have worked their way down the flank of a volcano in the past can help to determine the extent of possible danger zones in future eruptions.

Volcanic regions are peep holes into the hellfire burning within the bowels of the Earth. Drilling is never easy but to make volcanoes divulge their secrets by penetrating them has its own technical challenges. How do you drill into a rock that was molten only weeks or months ago? How do you keep the restless magma within the Earth from finding your borehole and using it as a conduit for a new eruption?

Scientists and drill operators were literally playing with fire when they sank several drill holes into Kilauea Volcano in Hawaii. It had erupted in 1959 with spectacular lava fountains, leaving behind a lake of molten lava. Within a few weeks, the lake had a thin crust of solidified rock. Only one year after the eruption had subsided was a drill rig

Methane-loving microbes



Methane is a simple hydrocarbon which is abundant in the permafrost regions of the Arctic, not as a gas but – when mixed with water – as a solid, a gas hydrate. Some consider these gas hydrates an important energy source for the future. Others see in them a threat to our current climate because, if the hydrates melt, large amounts of the greenhouse gas methane will enter the atmosphere. It has also been speculated that extremophile microbes are living in these hydrates.

To study these and other questions, Earth scientists drilled three parallel wells into the Mallik gas hydrate field in the Mackenzie Delta of the northwestern Canadian Arctic in December 2001 with the ICDP's support. There, a gas hydrate-rich layer more than 200-m-thick is buried at a depth of 900 m under the permafrost. Methane-loving microbes were found in several cores gathered during the drilling campaign in 2002. As their concentration was considerably lower than expected, the results added to the mystery of extremophiles in the deep biosphere.

Even more exotic than microbes living in gas hydrates is a hypothesis suggested for the Eger Graben, a rift structure in the region where Germany and the Czech Republic border each other. There, researchers found a strong correlation between the intensity of an earthquake swarm and the content of methane in spring water: the more small earthquakes occurred, the higher the methane concentration.

The link between the two seemingly unrelated occurrences is probably bacteria which live deep underground. With each new earthquake, small cracks form in the granite basement of the Eger region. The hydrogen, which forms when natural radioactivity in the rock dissociates water into its two components, can then escape. It in turn is gobbled up by bacteria at depth, which produce methane as a byproduct of their metabolism. The more earthquakes, so the logic goes, the more hydrogen is released, the more the bacteria have to 'eat' and the more methane they produce.

Finding these bacteria and studying their metabolism is one of the goals of a drilling project suggested for the Eger Graben.



Recovering microbiological life from drill cores demands sterile handling and fluid extraction. Other precautions are necessary when drilling, in order to prevent contamination of a drill hole with microbes from the surface

Where does Hawaii come from?

**HOTSPOT
VOLCANOES AND
LARGE IGNEOUS
PROVINCES**

In 1999, a drill rig was set up on the Big Island, to try to solve the mystery of Hawaii's origins. By 2004, the long-cooled lava from Mauna Kea had been penetrated to a depth of 3340 m. The recovered rock samples provide the longest continuous stratigraphic record from any ocean island volcano, dating back at least 600 000 years. This core not only reflects the structure of the volcano itself but is also a detailed sample of the plume. As Mauna Kea slowly moved over the plume, magma of different ages and from various depths reached the edifice and piled on top of each other like pancakes on a plate. Each layer has its own characteristics which, taken together, give a detailed picture of the development of this Hot Spot.

Hot Spots are considered to be responsible not only for island and seamount chains but also for the massive episodes of volcanism which flooded several large areas on the continents. The Deccan Traps, for example, cover a large region in central India, whereas flood basalts are the 'base rocks' of a major portion of Siberia north of 60° latitude. It is deemed possible that mantle plumes were able to burn holes through the thick continental crust then flood the surface with mafic lavae, generating what are now called 'Large Igneous Provinces'. Another such area covers parts of Idaho, Washington and Oregon in northwestern USA. There, according to the Plume-Hypothesis, the Columbia and Snake River basalts are associated with the Hot Spot which currently feeds the volcanoes and geysers of Yellowstone National Park.

Lava flow from Mauna Kea, a mountain which descends 11 km to the bottom of the Pacific Ocean!



Photo: Ph. Bouysse (2007) *Explaining the Earth*
UNESCO/NANE Publishing

into the mantle in these areas. As a consequence, the crust melts and the hot, molten rocks become buoyant and make their way back to the surface, where their eruptions build volcanoes.

Even Iceland, which like Hawaii is an island in the middle of an ocean, is located on a plate boundary straddling the margin between Europe and North America. This is a divergent margin, however, where the two plates move away from each other. They leave behind a region of very thin crust. Molten mantle rocks can easily push through this zone of weakness and give birth to islands like Iceland or the Azores in the Atlantic Ocean. Whether convergent or divergent, the edges of the plates can be considered as the perforated seams in the Earth's crust through which magma can ascend all the way to the surface.

mounted on this precariously thin layer of rock. Researchers wanted to find out if the lava underneath was still liquid. Barely 7 m below the surface, the drill bit encountered molten lava at almost 1100°C, a unique drilling record which still stands more than 40 years later.

Drilling into an active volcanic zone (or Hot Spot) helps not only to understand the fundamental workings of these fire mountains and to mitigate volcanic hazards. Volcanic drilling can also tap the vast reservoirs of geothermal riches and help us to understand how minerals form, a direct consequence of the fire within the Earth (see *From charcoal to diamonds*).

How can volcanism occur far from volcanic zones?

Most of the 600 or so active volcanoes of the world are located at the margins of the big lithospheric plates which make up the Earth's crust. Take the volcanoes of Italy for example, like dangerous Vesuvius near Naples. They are located along the boundary between the African and the European Plates. Mount Unzen in Japan, whose conduit was penetrated by an ICDP drilling project in 2004, lies where the Pacific Plate meets the Eurasian Plate. The volcanoes of the Andes, like giant Cotopaxi in Ecuador and Villarica in Southern Chile, dot the demarcation line between the Pacific and South American Plates.

Volcanism at these convergent margins occurs, according to the theory of plate tectonics, because crust is subducted

Yet, Hawaii is situated far from any of these seams. Between the island chain and the closest plate boundary in California lie approximately 3000 km of nothing but solid Pacific Plate. How in the world, ask many scientists, can volcanism occur so far away from all known volcanic zones?

One clue can be found to the west and north of the Big Island of Hawaii. Looking at the ages of its sisters to the northwest, researchers realized that, the further islands were from the currently active volcanoes, the older they were. The rocks on Maui, the Big Island's immediate neighbour, are about 1 million years old, those under Honolulu on Oahu about 3.5 million years old. This relationship between age and distance continues all along the chain of shoals, reefs and seamounts to the northwest of Hawaii until it reaches 81 million years at the end of the Emperor Seamounts close to the Aleutian Trench.

A magmatic blow torch

About 35 years ago, a hypothesis was proposed to explain this relationship. A narrow plume of very hot, molten magma is supposed to rise from deep within the mantle. Like a blow torch, its melt burns through the oceanic crust above. Although the plate above this 'Hot Spot' moves, the plume itself is extremely steady and very stable. The result is a line of torch holes, an island chain, with volcanoes lined up like a string of pearls. While this sounds logical, it is just a hypothesis and remains to be proven.



Geoscientists tempt fate

In 1985, earthquake researchers Bill Bakun and Allan Lindh from the United States Geological Survey (USGS) decided to tempt fate. They forecast that, within eight years, an earthquake of magnitude 6 would strike along the San Andreas Fault under the small Californian town of Parkfield, halfway between San Francisco and Los Angeles. More than eleven years after the prediction had expired, the town was finally shaken by just such an event. On a Tuesday morning near the end of September 2004, an earthquake with the predicted magnitude of 6 struck, luckily causing no harm.

Given that the quake happened so much later than forecast, one could call the prediction an utter failure. But with hindsight, it may have been the beginning of one of the most interesting endeavors in modern Earth science. The announcement in 1985 created a flurry of excitement. Again and again, earthquake researchers found signals or other parameters which might be interpreted as clues to approaching earthquakes. These ranged from strange behavior in livestock and pets before an earthquake to shifts in the concentrations of gases dissolved in the groundwater.

Parkfield looked like a perfect place to investigate all these hypotheses scientifically. Within a few years of the prediction, the region was riddled with hundreds of instruments set up by scientists from universities, research institutions and government agencies. From water levels in wells to the stresses in the crust, the instruments measured almost every conceivable geophysical parameter, even some that did not appear to have much to do with earthquakes.

The San Andreas Fault is considered to be one of the most dangerous earthquake zones in the world. It has repeatedly produced large, damaging quakes in San Francisco and in the Greater Los Angeles area. Along most of the 1200 km-long fault, no particular pattern has been observed in the timing of events. Parkfield is the exception, with its apparently regular pattern of earthquakes. Although the San Andreas and many other earthquake faults have

been studied for more than one hundred years, researchers still do not have a good understanding of the physical processes which take place directly in the rupture zone of an earthquake. Although modern measurement and modelling techniques allow seismologists to recreate the intricacies of an earthquake rupture *after* it has occurred, they have no tools to determine when, where and how the next temblor will strike. Too few of the physical and chemical conditions within the seismogenic zone of a fault are known to be able to predict what will happen next.

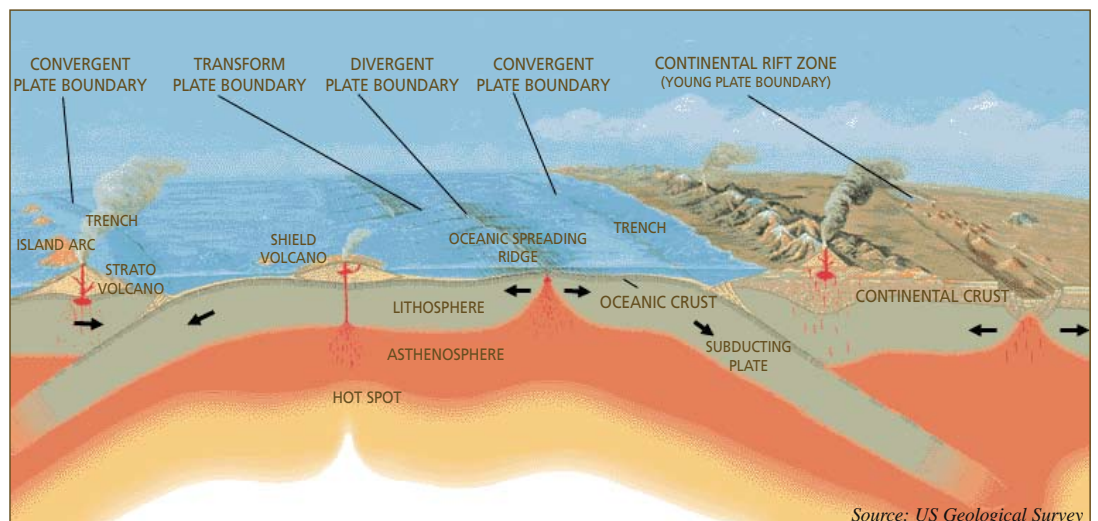
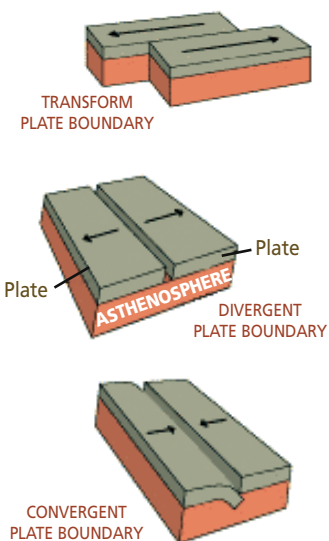
During the years which passed while the Earth's crust under Parkfield sat with hardly a jiggle, a small but determined band of scientists from Stanford University and the USGS drew up more plans: they were going to drill deep into the most famous fault in the world. As no other segment of the San Andreas Fault had been studied as well as the area around Parkfield, the group proposed it as the perfect spot.



A scientist inspects cores drilled through the San Andreas Fault in California

Actual drilling began with a pilot hole in 2002. It was located 2 km from the fault and reached a depth of about 2200 m. In June 2004, drilling on the main hole began just a few metres away from the pilot hole. When the drill bit reached a depth of almost 2 km, project managers diverted it from its vertical path and angled it toward the fault. In August 2005, at a depth of more than 3 km, the drill bit penetrated the fault. Surprisingly, it is not a simple, relatively narrow interface where the neighboring blocks – in fact the North American and the Pacific plates – slide past each other. Millions of years of movement have generated a thick zone of fractured rock and weak crust.

In 2007, three holes were drilled into the earthquake fault zone at various depths, some of them reaching all the way into a volume where small earthquakes occur at regular intervals. The last of these holes will be filled with instruments so that the generation of earthquakes can be recorded right at their origin. This observatory-at-depth within a seismogenic zone is a first for geoscience.



Source: US Geological Survey

The rigid lithosphere is thought to float or move about on the 'soft' zone in the upper mantle, the asthenosphere, causing crustal plates to move. (For a diagram of the main plate boundaries, see *A World of Science*, April 2005)

Underground collisions

It has been less than half a century since the development of plate tectonics. The powerful internal forces which can build and destroy mountains were an important element in the framework of this theory. The engine driving these forces is a set of huge convection currents which – like boiling water in a pot – circulate throughout the Earth's mantle. The crust – actually an ultrathin veneer on the outer surface of this high temperature and high pressure maelstrom – is torn by these moving currents, split into a dozen or so continent-sized plates.

On account of the enormous heat stored within the Earth, the mantle is often described as a 'deep magma ocean of molten rock'. However, while some clear evidence for localized melting has been found, the mantle as a whole is mostly not molten at all. Its rocks, in fact, have the viscosity of glass, a substance commonly thought of as rigid and brittle. But glass does flow, if one has the time to wait long enough: after 100 years or more, a window pane will be measurably, if not visibly, thinner at the top and thicker at the bottom. On a geological scale, such extremely slow flow rates add up to form the convection currents in the mantle. The much cooler and less dense plates of the Earth's surface float on these currents of hot viscous rock.



From charcoal to diamonds

Rocks which have undergone metamorphism at ultrahigh pressures (UHP) have endured conditions that are so harsh – more than 20 000 times the normal air pressure at sea level and temperatures of more than 500°C – that ordinary charcoal turns into diamond and regular quartz into coesite. Whereas standard, low pressure metamorphism is ubiquitous, this UHP process seems to be relatively rare.

To date, only about 20 regions (or terranes) in the world are known to contain rocks which, at one time in their life cycle, have undergone this kind of hypermetamorphism. Such UHP terranes are typically identified by the occurrence of eclogite, the result of high-pressure metamorphism of mafic igneous rock (usually basalt or gabbro) as it plunges into the mantle in a subduction zone. The eclogites typically contain crystals of dark-red garnet and the very strong mineral, zircon. As these crystals in turn contain microdiamonds and coesite as impurities, scientists are sure that they have gone through UHP-transition.

Of the 20 regions which contain UHP eclogites, China has by far the largest. The Sulu-Dabie-Altun Mountain Belt starts north of Nanjing at the coast of the Yellow Sea. It trends first towards the South before turning west, running all the way to the Altun Mountains in Western China. In total, it is more than 4000 km long.

In 2001, the Chinese Continental Scientific Drilling Programme began drilling into this belt to help understand the intricacies of the UHP metamorphism and solve the question of how the metamorphosed rocks move down and up again through the crust. A site was chosen in Donghai County in Jiangsu Province near the eastern end of the giant belt. When the project ended almost four years later, a hole had been sunk 5.1 km-deep into the heart of the mountain belt. In many of the cores brought to the surface by the drill rig, researchers found the products of UHP, namely zircons and coesites. They had been generated by hypermetamorphism about 230 million years ago. The process must have occurred when two plate-like blocks of crust and upper mantle, the North China and the Yangtze block, collided in the Mesozoic. The resulting UHP-metamorphites were brought back up from depth only 20 million years after they had formed. In the samples from the borehole, scientists found more than 50 different kind of minerals, among them native iron, nickel and chromium.

Whereas the UHP belt in China is a relic from the Mesozoic, there are many areas in the world where this process is occurring right now. Somewhere in active collision zones, as in the subduction areas under Japan or the Andes, rocks are being squeezed to the limit, morphing from one form into another. It is a stated goal of ICDP to drill into these regions, not only to excavate rare UHP minerals but also to observe the active mountain-building processes in collision zones which shape the Earth.



©Luigi Burlini

Earth scientists still do not completely understand the actual forces which drive the plate movement. Whatever the driving force, the plates ram into each other or push each other out of the way in collision zones, or convergent margins, as they are called in technical terms. In some of these zones, one plate is squeezed beneath the other in a subduction process. The descending plate can be followed down to 700 km beneath the surface by observing the occurrence of earthquakes.

The deeper the rocks of the Earth's crust are buried in these subduction zones, the hotter they become and the more they are compressed by the pressure of the rock above and by the momentum of the collision itself. In most cases, the pressure finally grows so high that the crustal rocks lose their original identity. As pressure and heat transform the minerals, they rearrange their crystal structure or alter part of their chemical composition. This process is called metamorphism. Since there are metamorphosed rocks everywhere, we know that it must have happened throughout the Earth's history. Every piece of marble, each chunk of quartzite and all gneiss are the products of such changes.

With the help of plate tectonics, researchers can explain with relative ease how pieces of the crust are buried to depths where pressure and temperature are so high that metamorphism occurs. But one of the unresolved puzzles is the question of how the products of such changes, the metamorphites, make it back to the surface of the Earth. What force is able to raise them back up from depths of 50 km or more?



Supercritical water and steam for free

Iceland, where volcanoes and glaciers meet, straddles the Mid-Atlantic Ridge, which is also the tectonic boundary between North America and Europe.

For centuries, Icelanders have made use of the Earth's heat, which they get for free via numerous hot springs.

But it is one thing to bathe in a hot mineral spring on a cold day just south of the Arctic Circle and another to make use of the geothermal energy industrially. In Iceland, many boreholes have been drilled to harvest the heat of the Earth, which, on the island, comes in the form of hot water or steam. More than 80% of single family homes, apartment buildings and offices in Iceland are heated geothermally. Almost 20% of the electricity generated in Iceland is geothermal. The rest is generated from hydropower and only 0.1% of Iceland's electricity is produced by burning fossil fuels.

But even in a country like Iceland, where renewable energy resources play a dominant role, there is room for improvement. There are also fundamental scientific issues regarding the condition and movement of fluids within the Earth's crust to be studied. This is why the ICDP is involved in the Iceland Deep Drilling Project on the Reykjanes Peninsula in the southwest and in the Krafla volcanic field in the northeast of the country. This project was initiated jointly by the government and the power industry of Iceland. Their goal is to improve the economics of geothermal resources by improving the power output of geothermal wells with respect to their drilling cost.

Currently, typical high-temperature geothermal wells produce a two-phase mixture of water and steam at temperatures in the range of 200–320°C. Such a well in Iceland, 2.5 km deep and producing, say, dry steam at about 235°C, may yield approximately 5 MW of electric power and costs about US\$4 million to drill. If one could tap a reservoir with much higher temperatures and pressures, one could drastically improve the electric power output.

One such 'unconventional' energy source is supercritical water. Such conditions are reached when water is heated to at least 375°C and simultaneously pressurized to 22 Megapascal, about 220 times the normal air pressure on the Earth's surface. At this point, the distinction between liquid and vapour vanishes, as water transforms into a completely new phase: it becomes supercritical. A well sunk into such a reservoir could produce up to ten times more electricity than a conventional well at the same flow rate. This gain will very quickly offset the additional cost of drilling, which in Iceland is estimated to be US\$9 million.

Geologists believe that supercritical water plays a very important role, not only in the movement of minerals within the Earth's crust. It may even be instrumental in the formation of ore deposits. Its physical and chemical properties are so different from regular hot water that it leaches out the mineral components in rock more quickly and in completely different ways. Only by drilling into reservoirs of supercritical water can these phenomena be studied. The drilling project in Iceland is a natural laboratory for studying these phenomena, because the goal over the next decade is to drill several wells 4 km and 5 km deep into the supercritical conditions. One test well with a depth of 3.1 km was completed in 2005. At the bottom, the water had not quite reached supercritical conditions but was at least 300°C.



Geysers like this one in Iceland are one manifestation of the enormous thermal energy stored inside the Earth

Not such strange bedfellows

When most people picture drilling into the Earth, they think of wells for oil and natural gas. There is no doubt that, since the first oil boom hit the world in the American state of Pennsylvania in 1859, the vast majority of wells have indeed been sunk either in the search for hydrocarbons or to get the crude oil out of the ground and to the refineries.

When one adds the many holes drilled for the exploration of minerals like coal seams and ore bodies, it is very likely that 99% of all deep wells ever drilled have been sunk not for scientific study but for economic purposes. Taking this, and comparing the deep pockets of the oil and mineral industries to the sparse funding for the Earth sciences, one may very well ask why an organization devoted to the advancement of science and the understanding of the Earth like ICDP has become involved in drilling for natural resources?

'We are not about to compete with industry in drilling wells with a purely economic focus,' says Rolf Emmermann, Chair of the ICDP's Executive Committee. But he points out

the synergies which are inherent when science and industry collaborate. The companies and their field support services have unbeatable experience in drilling and logging wells then interpreting the results. At the same time, Earth scientists have an almost insatiable appetite for probing the unknown. Particularly when drilling deep, or in very rough environments with high temperatures, abrasive rocks or corrosive fluids, both groups can undoubtedly learn from each other.

Could we be standing on the solution to our energy problems?

We all know by now that endlessly pumping crude out of underground reservoirs is not the answer to the energy needs of the future. Renewable sources must replace fossil fuels wherever possible. As in the case of coal, oil and gas, by far the greatest reservoirs of renewables lie within the Earth itself. According to the International Energy Agency's estimate of 2004, twice as much geothermal energy could be tapped using currently available technologies than from all other renewable energy resources – wind, solar, biomass and hydropower – combined. The scientists of this agency also computed the heat stored in the upper 3 km of the continents: about 12×10^{12} Gigawatt hours.

If this 'continental heat' could be harvested completely, it would supply the energy needs of humankind for the next 100 000 years at the present rate of consumption – bearing in mind that the continents cover only about one-quarter of the Earth's surface.



ICDP scientific drilling projects

The completion date is given in brackets

Of course, this heat cannot be extracted completely but at least some of the Earth's heat beneath our feet can be used relatively easily. Currently, geothermal energy is exploited in 24 countries. The world's biggest energy user, the USA, leads the field, producing almost one-third of the total (see also *Supercritical water and steam for free*).

Back to the future

Even if hundreds of holes were to be drilled for scientific purposes, each of them would still only be a tiny pin prick in the Earth's crust. Drilling projects funded by ICDP should thus be at a 'type locality' for globally important questions in Earth sciences.

How to participate

Now into its second decade, the International Scientific Continental Drilling Programme pools the resources of Austria, Canada, Czech Republic, Finland, Germany, Iceland, Japan, Mexico, Norway, Poland, South Africa and the USA. Four more countries are currently negotiating their membership. UNESCO is a member of the Scientific Advisory Group which approves project proposals for programme funding and support. Schlumberger is a corporate affiliate.

To become eligible for programme funding and support, a scientific drilling project must aspire to investigate one or more of the eight themes below. The questions addressed by proposals for drilling with ICDP's help must be substantial. In addition, the proposed drilling location should be a prime example of other, similar structures on Earth which have not yet been adequately explored. Lastly, in writing a proposal, several researchers from different fields of Earth science should cooperate to 'make the most' of one borehole.



For details: www.icdp-online.org; icdp@gfz-potsdam.de; or contact Ulrich Harms: ulrich@gfz-potsdam.de or rmissotten@unesco.org

A whole suite of urgent, fundamental questions about the Earth's past and the processes within our planet can be answered by shallower boreholes. Similarly, sediments can divulge their secrets like their climate archive just a few hundred metres beneath the ground. In some cases, zones where earthquakes originate can be reached 3–4 km below the surface. Sometimes, even the Earth itself moves rocks from the deep lithosphere much closer to the surface in a still poorly understood process.

But there is another, fundamental limitation to even the most extensive drilling: remember, the Earth has a diameter of 12 748 km, yet the deepest existing drill hole reaches a depth of just 12 262 m – roughly 1/1000th of the diameter. However dramatically drilling technology may evolve in the future, digging to a depth of 15 km or 20 km seems to be beyond reach, even according to the most optimistic observers.

Despite all the difficulties, drilling into our planet's crust is one of the most compelling frontiers in Earth science today. This adventure may allow us to solve a few of the many mysteries which have been hiding for millions of years in the dark *terra incognita* deep beneath our feet.

Horst Rademacher¹

This article has been adapted from an ICDP booklet published in 2007, entitled *The thrill to Drill*.

1. Seismologist and freelance science journalist

Poles warming faster than expected

The International Polar Year (IPY) wound up on 31 March after two years of intensive research which has revealed that the poles are warming more rapidly than previously thought. The Year's achievements were presented in a statement released by the two sponsors, the WMO and International Council for Science, on 25 February. UNESCO's Intergovernmental Oceanographic Commission (IOC) was one of a wide range of partners.

Among the knowledge gleaned during the IPY, it now appears certain that both the Greenland and the Antarctic ice sheets are losing mass and thus raising sea level and that the rate of ice loss from Greenland is increasing.

Data from robotic ocean profiling floats deployed within the Global Ocean Observing System coordinated by the UNESCO-IOC, combined with data from instrumented marine mammals and IPY research vessels, confirm that the Southern Ocean has warmed more rapidly than the global ocean average. In addition, the dense bottom water formed near Antarctica has freshened in some locations as a result of increasing melt from the Antarctic ice shelves and ice sheet, and warmed in others.

In 2007 and 2008, the summer minimum extent of Arctic perennial sea ice decreased by about 1 million km² to its minimum extent since satellite records began. In addition, the North Pole region was covered only in relatively thin first-year ice in mid-winter for the first time since observations began. IPY expeditions recorded an unprecedented rate of ice drift across the Arctic basin.

In the North Atlantic, subtle changes in ocean conditions and in the fluxes of heat and momentum between the atmosphere and the ocean have been shown to play a strong role in the eventual strength and trajectories of major storms. These storm systems represent the major atmospheric inputs of heat and moisture to the Arctic. This knowledge will improve forecasting of the paths and intensities of storms.

The change in timing of the type and amount of winter rain and snow as a result of Arctic warming is forcing traditional reindeer herders in northwestern Europe to adapt. Farther east, reindeer herds are experiencing stress from loss of pasture and the blockage of migration routes due to changes in land use and infrastructure developments. Infestation by insects and fungi is growing. Several local communities have joined IPY monitoring networks to collect, exchange and document observations of changes in sea ice, biota, weather and climate in the Arctic.

Pools of carbon stored in permafrost are larger than previously estimated. Moreover, permafrost is degrading much faster than expected, releasing another greenhouse gas – methane – to the atmosphere. Researchers have discovered that methane gas hydrates on the sea floor can escape more easily to the atmosphere as sea-ice cover recedes. IPY research cruises along the Siberian coast observed substantial outgassing of methane from ocean sediments.

Researchers documented 7500 species in the Antarctic and 5500 in the Arctic, including several hundred believed to be new to science. Most of the newcomers are invertebrates. One of the biggest surprises was the discovery that some microbial species occur in nearly identical form in both Arctic and Antarctic ecosystems – polar seas separated by 11 000 km! Other species have developed very differently in these two environments. Yet other species have evolved and expanded their ranges to lower latitudes. For example, new evidence shows that many present-day deep-sea octopuses at more northern latitudes originated from common ancestors that still survive in the Southern Ocean. Studies of present-day ecosystems have also documented recent poleward migrations of terrestrial and marine species in response to climate warming. Two areas of around 400 km² each have been recognized as Vulnerable Marine Ecosystems under the Convention for the Conservation of Antarctic Marine Living Resources and placed on an international register for protection.

For details: k.alverson@unesco.org; www.ipy.org

Denmark gets behind climate change education

On 14 January, Denmark pledged US\$1.2 million towards three UNESCO initiatives in climate change education. This will enable UNESCO to develop its virtual global forum *On the Frontlines of Climate Change* and the coastal monitoring education programme Sandwatch. It will also finance an international seminar on climate change education on 27–29 July.

The Danish funds coincide with growing global concern at the pace and severity of climate change. They come in a year which will determine whether or not the world is ready to make a serious commitment to combating climate change: the Parties to the UN Framework Convention on Climate Change will be meeting from 9 to 17 December in Denmark's capital, Copenhagen, to negotiate the successor to the Kyoto Protocol.

At the International Seminar on Climate Change Education in July, experts from around the world will congregate at UNESCO headquarters in Paris to prepare guidelines for introducing climate change issues into school curricula. These guidelines may be discussed at a side event during the Copenhagen meeting.

Launched in June last year, UNESCO's online forum gives a voice to small island developing states and indigenous communities who are on the frontlines of climate change. The financial support from Denmark will enable the forum to evolve through the establishment of a global database of grassroots observations of the impact of climate change and local strategies for adaptation. Field investigations will also be launched to collect comprehensive data on particularly interesting cases.

UNESCO launched Sandwatch in 2001. An educational programme through which pupils learn how to monitor the health of local beaches with their teachers by applying scientific methods like observation and measurement-taking, Sandwatch has amassed valuable data and information over the years on

the state of the coastal environment. The Danish funds will enable UNESCO to create a standardized online database into which participants in Sandwatch can enter and analyse data. In turn, this database of observations will be used as a benchmark against which to assess the impact of climate change and other phenomena on beaches and formulate policies for better management. In parallel, UNESCO will be working with ministries of education and other authorities to extend the network of schools involved in Sandwatch – currently active in 55 countries – and to urge governments to integrate Sandwatch into national curricula.

Denmark contributes about \$3.7 million annually to UNESCO's programmes in education and communication but this is the first time it has targeted climate change education specifically.

For details: d.nakashima@unesco.org; on the virtual forum: www.climatefrontlines.org; on Sandwatch, see A World of Science, January 2007 or go to: www.sandwatch.org



In this potato field in the Peruvian Andes at 3800 m, Julia is cooking papas or potatoes. In the Andes, glaciers are receding and rain patterns are becoming less predictable. Since the 1980s, agronomists have developed a handful of hybrid varieties of papa which are bigger and require more water to grow than traditional local varieties. Reputed to be more popular in urban markets, the hybrid papas are gradually replacing local varieties.

This erosion of agro-biodiversity means that farmers will be less resilient in the face of climate change, as they will have fewer options for adapting their crops to new climatic conditions. Climate change education can highlight the strengths of local methods of dealing with climate change and reduce outside pressure on local communities to turn away from effective traditional practices

Ten years to **save coral reefs**

Since 1950, the world has lost 19% of the original area covered by coral reefs. Some 15% are in a critical state and could disappear within the next 10–20 years; a further 20% could disappear within 20–40 years. These predictions emanate from 372 coral reef scientists and managers from 96 countries and states. They are summarized in *Status of Coral Reefs of the World: 2008*, a report prepared periodically by the Global Coral Reef Monitoring Network involving UNESCO, NOAA, Reef Check, ReefBase and other partners.

Less than half (46%) of the world's coral reefs are regarded as healthy and under no immediate threat of destruction.

The classifications of 'seriously threatened', 'critical' and 'healthy' do not factor in the threats of global climate change, which are predicted to be inevitable but without clear timelines.

Ocean warming, increasing ocean acidification and more intense tropical storms are now regarded by the world's leading scientists and managers as posing the greatest threats to all of the world's coral reefs. NOAA satellites reveal that tropical oceans have warmed at a significantly higher rate over the past 10 years, suggesting that there are only 8–10 years to turn the tide because CO₂ concentrations in seawater above 450 ppm threaten the existence of coral reefs as we know them. Already, one-third of the world's coral species are at risk of extinction.

Reefs in the Coral Triangle Initiative countries of Indonesia, the Philippines, Malaysia and Timor Leste continue to decline due to overfishing, growing sedimentation and urban and industrial pollution. Half of mangroves have been lost. In northeast Asia, reefs are declining for the same reasons, a problem compounded by bleaching. Here, however, conservation awareness is growing as economies develop and regional cooperation grows.

In the Middle East, reefs in the Red Sea and Gulf of Aden are healthy but those in the Persian Gulf, Arabian Sea and Gulf of Oman are still reeling from a massive cyclone in mid-2007. Corals have also been destroyed by massive coastal development along the Arabian Peninsula.

The largest marine protected areas (MPA) in the world were recently declared in the Pacific. In 2006, the USA upgraded the Papahānaumokuākea marine national monument to highly protected status to take in the 356 892 km² of the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve; in January 2009, the US President braved business leaders to create a protected area in three regions of the Pacific Ocean encompassing about 320 000 km² of remote and relatively uninhabited island chains. These include pristine coral reefs, vanishing marine species and the deepest place on Earth, the Mariana Trench. These regions are: the Mariana Islands in the western Pacific, the Pacific Remote Islands National Monument and the Rose Atoll off American Samoa. The protected areas will extend for 80 km. The largest MPA in the world is the Phoenix Islands Protected Area covering 410 500 km², declared by the Government of Kiribati. This eclipses the Great Barrier Marine Park established in 1975 and upgraded in 2004, which has declared 115 395 km² a no-take zone out of the total 344 400 km².

Two regions have pledged to conserve 20–30% of their marine and coastal habitats by 2020: the Micronesia Challenge launched by Palau, the Federated States of Micronesia, the Marshall Islands, Guam and the Northern Mariana Islands; and the Caribbean Challenge launched in 2008 by the Bahamas, Dominican Republic, Jamaica, Grenada and St Vincent & the Grenadines².

Almost 500 million people are dependent to some extent on coral reefs for food and supplementary income. Of these, 30 million are almost totally dependent on coral reefs for survival.

For details, see page 24; read the report: www.gcrmm.org

2. on the state of Caribbean coral reefs, see A World of Science, April 2008

L'ORÉAL-UNESCO Fellow (by region)	Research project in the life sciences	Host institution(s)
Fina Kurreeman Mauritius	Study of genes specifically associated with rheumatoid arthritis	Harvard Medical School and Women's Hospital, Boston, USA
Nonhlanhla Dlamini South Africa	Study of African traditional medicine used in treating Kaposi's sarcoma, characterized by the abnormal growth of blood vessels which develop into skin lesions (tumours); this form of cancer is common in AIDS patients	University of Florida, Gainesville, USA
Joan Munissi Tanzania	Antimicrobial compounds isolated from cultures of Tanzanian marine-derived fungi	University of Göttingen, Germany
Marie Abboud Lebanon	Development of non-invasive optical imagery of blood vessels which form to irrigate a growing tumour, to locate tumours and improve diagnosis	Université de Bretagne occidentale, Brest, France
Khadjetou Lekweiry Mauritania	Study of transmission of malaria in the capital city of Nouakchott	Institut de recherche pour le développement, Dakar, Senegal
Rima Al-Besharat Syria	Isolation, identification and characterization of beneficial lactic-acid producing bacteria in the Syrian population from traditional consumption of fermented dairy products; study of bacteria's potential use in nutritional supplements	Technische Universität München, Germany
Jingyi Shi China	Study of genetics of acute myeloid leukemia, a cancer affecting white blood cells	Institute of Cancer Research, Sutton, UK
Yean Yean Chan Malaysia	Use of electrochemical DNA biosensors to detect pathogen DNA in a body fluid sample. This new field could lead to inexpensive, portable diagnostic kits for infectious diseases	University of New South Wales, Sydney, Australia
Ishrat Bano Pakistan	Development of magnetic nanoparticles for use in drug delivery	University of Cambridge, UK
Ivana Pešić Serbia	Study and identification of urine proteins, a tool for the diagnosis and prognosis of renal disease	Georg-August University, Göttingen, Germany
Mareike Posner Germany	Study of the resistance of enzyme structures within organisms which have adapted to extreme conditions	Centre of Extremophile Research, University of Bath, UK
Lydia Lynch Ireland	Study of the human omentum as an immunological tool. The fatty omentum hangs over the intestines	Harvard Medical School, Boston, USA
Paula Villar Argentina	Development of a computer-based model of the human heart in 3D	Barcelona Supercomputing Centre, Spain
Bertha Gonzales Frankenberger Mexico	Study of the development of speech and voice-processing in newborns and premature babies	Sainte-Justine University Medical Center, Montreal, Canada, and Amiens University Hospital, France
Cecilia Gonzales Marin Peru	Study of the association between oral infections and medical complications in pregnant women	Queen Mary's School of Medicine and Dentistry, London, UK

Awards for exceptional women

This year's five laureates of the L'ORÉAL–UNESCO Awards for Women in Science each received US\$100 000 on 5 March at a ceremony organized at UNESCO headquarters in Paris. Fifteen young researchers also took home up to US\$40 000 each to pursue their research in the life sciences at a prestigious host institution of their choosing (see table).

This year's laureates are:

• **Africa & the Arab States:**

Prof. Tebello Nyokong, from the Department of Chemistry at Rhodes University in South Africa, for her work on harnessing light for cancer therapy and for environmental clean-up.



• **Asia & the Pacific:**

Prof. Akiko Kobayashi, from the Department of Chemistry at Nihon University in Japan, for her contribution to the development of molecular conductors and the design and synthesis of a single-component molecular metal.



• **North America:**

Prof. Eugenia Kumacheva, from the Department of Chemistry at the University of Toronto in Canada, for the design and development of new materials with many applications, including targeted drug delivery for cancer treatments and materials for high-density optical data storage.



• **Europe: Prof. Athene M. Donald,**

from the Department of Physics at the University of Cambridge in the UK, for unravelling the mysteries of the physics of messy materials that range from cement to starch.



• **Latin America: Prof. Beatriz Barbuy,**

from the Institute of Astronomy, Geophysics and Atmospheric Sciences at the University of São Paulo in Brazil, for her work on the life of stars from the birth of the Universe to the present time.



This year, the jury was presided by Egyptian-born Prof. Ahmed Zewail, Nobel Prize for Chemistry in 1999.

For details: r.clair@unesco.org; www.forwomeninscience.com

2011 to be Year of Chemistry

The United Nations has proclaimed 2011 International Year of Chemistry and placed UNESCO and the International Union of Pure and Applied Chemistry (IUPAC) at the helm of the event, in a resolution adopted at its 63rd General Assembly in New York in December.

The resolution was submitted to the United Nations by Ethiopia after being endorsed by UNESCO's Executive Board. The Year will be celebrating the achievements of chemistry and its contribution to knowledge, environmental protection and economic development.

'We hope to increase public appreciation and understanding of chemistry', declared IUPAC President Prof. Jung-Il Jin. 'Raising public awareness about chemistry is all the more important', added UNESCO Director-General Koïchiro Matsuura, 'in view of the challenges of sustainable development. It is certain that chemistry will play a major role in developing alternative energy sources and in feeding the world's growing population.' Molecular transformations are central to the production of food, medicines, fuel and countless manufactured and extracted products.

The Year will mark the 100th anniversary of the award of the Nobel Prize in Chemistry to Maria Skłodowska Curie in 1911, thus also providing an opportunity to celebrate the contribution of women to science. It was also in 1911 that the International Association of Chemical Societies (IACS) was founded to foster international scientific communication and cooperation among chemists by standardizing nomenclature and terminology. The IACS was succeeded by IUPAC in 1919.

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Pierre Auger Observatory inaugurated

On 14 November, the Pierre Auger Observatory was inaugurated in Malargue, Argentina. The observatory is exploring the mysteries of the highest energy cosmic rays – charged particles showering the Earth at energies 10 million times higher than the world's highest-energy particle accelerator. Launched more than a decade ago under the auspices of UNESCO, the observatory is a network of 1600 sensors spread over 3000 km² in Argentina.

The Auger Observatory is a 'hybrid detector' employing two independent methods to detect and study high-energy cosmic rays. One technique detects high energy particles through their interaction with water placed in surface detector tanks. The other technique tracks the development of air showers by observing ultraviolet light emitted high in the Earth's atmosphere.

It was at UNESCO headquarters in 1995 that international collaboration in support of the project formally got off the ground after Argentina's offer to host the southern Pierre Auger Observatory was gratefully accepted by all parties. On 13 October 1998, the finance board of the Pierre Auger project met at UNESCO headquarters to work on the agreement underpinning the organization, management and funding of the project. The meeting was graced by the visit of then President of Argentina, Carlos Menem, who announced that construction of the Pierre Auger Observatory could begin early the following year. The project formally came into being in March 1999 with the signing of an agreement two months before construction of the detector began in Argentina.

The project is named after former UNESCO Science Director Pierre Auger (1948–1958), who died in 1993. He is perhaps best-remembered for orchestrating UNESCO's key role in the founding of the European Organization for Nuclear Research (CERN) near Geneva, which launched the Large Hadron Collider on 21 October last year. Pierre Auger's scientific speciality was



© Pierre Auger Observatory

One of the 1600 surface detectors against a backdrop of the Andes mountain range. Each detector is independently operated on just 20 watts of solar power. Signals from the detector are automatically transmitted via a radio link to the central observatory

experimental physics, in the fields of atomic (photoelectric effect), nuclear (slow neutrons) and cosmic ray physics (atmospheric air showers). After his service with UNESCO, he served as Director of the Cosmic Physics Service at the French National Centre for Scientific Research (1959–1962) and as Director-General of the European Space Research Organization (1962–1967).

The Pierre Auger Collaboration involves about 350 scientists from Argentina, Australia, Bolivia, Brazil, the Czech Republic, France, Germany, Italy, Mexico, the Netherlands, Poland, Portugal, Slovenia, Spain, UK, USA and Vietnam. Nobel Laureate in Physics, James W. Cronin, of the University of Chicago (USA), conceived the Pierre Auger Observatory, together with Alan Watson from the University of Leeds (UK).

Now begins the project's second phase; this includes plans for a northern hemisphere site in Colorado (USA) and enhancements to the site in the southern hemisphere.

For details: www.auger.org; m.alarcon@unesco.org

Optics prize for Iranian

Dr Saifollah Rasouli of the Institute for Advanced Studies in Basic Sciences in Zanjan (Iran) is the winner of this year's Gallieno Denardo Award sponsored jointly by UNESCO's International Centre for Theoretical Physics (ICTP) and the International Commission for Optics (ICO).

The Gallieno Denardo Award is given to researchers under the age of 40 from developing countries. The annual award includes a cash stipend from ICO worth US\$1000, as well as full financial support from the ICTP for the winner to attend a future training event at ICO and to give a seminar on his or her work.

Dr Rasouli was recompensed during the annual Winter College on Optics in Environmental Science for scientists from developing countries, run by the ICTP from 2 to 13 February this year. The award cited his creative use of special laser interferometry to study atmospheric turbulence, which offers greater resolution over some more conventional methods. Dr Rasouli's work has many practical applications ranging from weather monitoring to improving the fuel efficiency of aircraft and automobiles.

For details: <http://prizes.ictp.it/ICO>; pressoffice@ictp.it



Jacques Weber

'The crisis can be an opportunity to rethink the global economy'

With the financial and economic crisis tightening its grip around the world, many researchers, organizations and institutions are being galvanized into action. Terms like Green Deal or Global New Green Deal are circulating and, with natural resources becoming more scarce, there is talk of creating a tax system based on ecosystem services. Here, the economist and anthropologist Jacques Weber, Director of Research at the International Centre for Agricultural Research for Development (CIRAD) in France, analyses the ins and outs of an idea that is gaining ground: a shift towards green economics, to ensure that the global economy emerges from the crisis on a surer footing than before.

What is your analysis of the current crisis?

I can think of no precedent, which is why any reference to the crisis of 1929 strikes me as misleading. We haven't yet seen the effects of the present crisis on the global economy and no-one can predict how long it will last. The poorest countries will of course bear the brunt, as usual.

Already, more and more countries are close to a suspension of payments, even the wealthiest among them like Iceland and even Ireland. A growing number of banks are on the verge of bankruptcy, forcing States to nationalize them. Almost everywhere, unemployment is on the rise; China lost more than 20 million jobs between September 2008 and January 2009, almost the equivalent of the active population in France. There is a real fear that the implosion of economies and the social dramas they engender will cause a social meltdown.

The current crisis is indubitably financial in origin and would have happened sooner or later. But the fact that it came after steep price rises for petrol, minerals and food suggests that the crisis is one of objective rarity of non-renewable and renewable natural resources. It is the *expression* of this crisis that is financial.

Could the crisis be a blessing for sustainable development?

If the crisis is a result of the growing scarcity of natural resources, the ailing economy can be an opportunity to tackle this scarcity directly to make sure the problem doesn't recur. It can be an opportunity to rethink both the global economy and national economies, and to redefine international institutions to serve the cause.

It can be a chance to devise new distribution mechanisms at the global level for the benefit of those countries which consume the least; this would herald the end of international 'aid' for development, decided at a country's pleasure, the end of charity, in a word, the end of the arbitrary and its replacement by mechanisms based solely on rigour and justice.

In the capital system as we know it, wealth is created by destroying nature (the *natural capital*). If I destroy a site, I create 'added value' and GDP consequently rises. In the remodelled capitalist system, the destruction of nature would

become very costly; conversely, the maintenance or augmentation of the *natural potential* would be highly profitable.

Are companies ready for the principle of polluter pays?

The principle of 'polluter pays' is not punitive. It is about getting the person who continues to pollute to finance those prepared to invest in reducing their pollution. It is thus a question of incentive and redistribution. Ideally, the tax would be sufficiently high for it to be 'good business' to invest in reducing pollution.

Companies are becoming aware of their dependence on the living world and of the growing scarcity of the natural resources that generate their profits. They are already trying to minimize the impact of their activities and to design a specific accounting system for their activities that encompasses biodiversity and ecosystem services. This said, even if companies understand the soundness of remodelling the economy on the natural potential, it is by no means certain that they will grasp all the potential implications for their organization, markets and profit structure. Then again, who could at this stage? We need to sit down and analyse the situation collectively.

How can we shift to a green economy?

The abolition of taxes on labour and their replacement by eco-taxes is one measure. The instigation of a tax on energy covering the entire process from production to consumption, which we could dub 'tax on added energy', is another. In the latter case, energy consumption is penalized at each stage of the process to encourage energy-savings and the development of 'clean' energies.³ It is not a case of piling on new taxes but rather of substituting taxes which favour conserving the natural potential for existing taxes which encourage its destruction.

What do you mean by 'abolition of taxes on labour'?

I mean all the charges which are a burden on labour. In France, these charges represent nearly 50% of a person's gross salary. The Professional Tax paid by companies is a source of revenue for local bodies but weighs on salaries. When President Sarkozy announced last February that he was doing away with the Professional Tax and replacing it with an ecotax, he was

following the same logic as me : replacing a cost burden on labour by a cost burden on the consumption of nature – encompassing soil fertility, fisheries, forestry, tourist spots...

What would this ecotax achieve?

Direct or indirect taxation – through carbon emissions trading, quotas, etc – of the consumption of nature would contribute to the battery of measures enabling us to shift regulations towards maintaining or improving the natural potential.

Today, the price of the fish in your plate is fixed according to the cost of the labour involved in bringing it to you from the sea. The fish itself has no value. A system of transferable quotas indirectly attributes value to that fish. For fisheries, ‘individual transferable quotas’ exist in many countries. These transferable rights can relate to quantities, to zones, to the fishing season and so on. For soils, the variation in an indicator of fertility can serve as the basis for a tax; for forests, the right to fell trees can be sold to a third party via a bidding process, with the loss of this right in the event of non-respect of one’s obligations; for tourism in fragile areas, a visiting right can be put in place for a given number of tourists via a bidding process among operators, again with the loss of this right in the event of non-compliance. In each case, all or part of the value of these rights is used to help those still on the outside looking in to adapt to the system.

In Germany, the success of wind energy seems to have had a perverse effect on the carbon emissions of Eastern Europe, with German companies selling their credits to polluting industries in Poland and elsewhere. Carbon trading falls within the Clean Development Mechanism (CDM) adopted under the Kyoto Protocol. Is it effective?

You illustrate the well-known fact that a market without rules is not the law of the market but the law of the jungle! The CDM seems to be getting out of control. It needs to be evaluated. To get back on track, the market needs broad regulation.

Carbon trading is an interesting tool, as long as the emissions are truly controlled and not simply left to the declarations of vested interests. To my mind, it is a question of using the market as a tool, as opposed to becoming the tool of the market. However, no tool is perfect or self-sufficient on its own. Depending on the objectives, actors and nature of the issues, a combination of instruments will be required.

President Correa of Ecuador has proposed that OPEC impose a tax on the price of oil to enable oil-producing countries to develop alternative energy sources, an idea inspired by economist Herman Daly. What do you think of this idea?

It could be part of the toolkit. But I propose something different: taxing energy from production to consumption. The measure proposed by President Correa relates only to the price of oil at the production stage. The measure I propose – and I don’t claim to be the sole author! – takes up Mr Correa’s idea but expands it to encompass the entire global economy. This would have the result Mr Correa expects but with the added advantage of a strong incentive to reduce energy consumption.

Unfortunately, the quest for ‘clean’ energies too often overshadows the urgency of saving energy.

A tax on added energy supposes the existence of an international institution with the power to collect and redistribute this tax internationally in a way that is inversely proportional to energy consumption. This would incite people to save energy, with tax earnings being redistributed to those countries which consume the least energy, the poorest ones.

International organizations are indispensable for discussion among nations. They have engendered major projects like those executed by UNESCO. But they have no power to regulate or implement the rules decided by States, *a fortiori* when it comes to surveillance or sanctions, without which there can be no regulation. Let’s hope that the next G20 in April tackles this issue head-on and comes up with an international system that can manage economic instruments like the tax on added energy, among others, at the global level. Without this deep reflection, there can be no reshaping of the economy and the current system will reproduce the present crisis on a greater scale next time.

Perhaps we need a new institution resulting from the merger of existing ones: UNEP, FAO, UNDP... But above all, we need an institution invested with the power to implement the decisions made by States within a system of global regulation. This in itself would be something radically new in our globalized economy.

How do you see the role of research and UNESCO’s role in this new paradigm?

Research is at the heart of all these ideas for reshaping the economy. For the moment, this international reflection is being done outside a framework which would make it truly effective and cumulative. It is time to put together an international working group comprised of economists known both locally and globally for their expertise in resources and environment, and to ask them: What is the feasibility of shifting from the current regulatory system to a green economy? What would the consequences be of such a shift? How do you go about remodelling global and redistributive regulations?

Countries like Haiti will not pull themselves out of their appalling poverty without reconstructing the ecological foundations that are indispensable for sustainable development. Years ago, I said that this could be UNESCO’s Abu Simbel⁴ of the 21st century and I stand by what I said. The organization which invented biosphere reserves has a chance to embrace this issue by hosting the working group. In so doing, it would bask in the glow of having demonstrated its special utility in this crisis.

Interview by Meriem Bouamrane

Read also the post-G8 (June 2007) interim report

The Economics of Ecosystems and Biodiversity:

<http://ec.europa.eu/environment/nature/biodiversity/economics/>

³ *Energy-savings at one end should not mask overall energy consumption. We often read that electric cars are ‘clean’. In fact, they are clean to drive. But their batteries still need charging, via either a nuclear or thermal power station. Between the time the fossil energy enters a thermal power station and the car’s ultimate use, 60% of the energy has been lost!*

⁴ *The rescue of this Nubian temple in the 1960s was one of UNESCO’s greatest success stories of the 20th century*

Tending to the ailing 'mother river of China'

The Yellow River is the second-longest river in China after the Yangtze River and the sixth-longest in the world. Home to 110 million people in 2000, it is the cradle of northern China's civilizations and the centre of China's current political and socio-economic development: the basin produces 6.8% of the country's GDP.

Affectionately known as 'the mother river of China', the Yellow River is also plagued by prolonged droughts, floods, sedimentation and severe pollution. This year's drought is shaping up to be the worst in half a century. What effect will a warming climate have on the water supply, in a region whose rapidly growing population may tip the balance at 121 million by 2010? In the meantime, the health of ecosystems is deteriorating as booming agricultural,

industrial and urban sectors all vie for resources which are being stretched to the limit.

The following case study was prepared by the Yellow River Conservancy Commission (YRCC) for *Water in a Changing World*, the Third World Water Development Report released on 16 March. The YRCC acknowledges that both it and relevant ministries are going to have to strike a balance between competing sectors and take remedial measures if they are to protect 'the river mother of China' – and safeguard the future of more than 120 million Chinese.

The Yellow River originates on the Qinhai–Tibetan plateau in western China. From here, it runs for 5500 km across the vast North China Plain, traversing nine provinces before draining into the Bo Hai Sea about 250 km south of Beijing (*see map*).

The average temperature in this mountainous zone varies during the year from 4°C to 14°C. More than 60% of precipitation falls between June and September each year, during the crop-growing season. In the 1990s, rainfall was about 7.5% below the average for previous decades owing to drought (*see overleaf The drought decade*).

Xu et al⁵ predict that annual temperatures in the basin could rise by as much as 3.9% by 2080 and rainfall by 8.7%, although they expect stream flow to drop over the same period. There could be a critical water shortage in the basin



Water sampling in E-Ling Lake near the source of the Yellow River

in the coming century if more efficient use is not made of water, via better management and the adaptation of technology. The following are some of the main challenges.

Overexploitation of groundwater

Water demand in the basin grew sharply between 1949 and 2006 from 10 billion m³ to nearly 38 billion m³. Since tube wells were introduced in the 1950s, their number has grown to 380 000. By 2000, 11 billion m³ of groundwater was being extracted annually. Overexploitation of groundwater in the large and medium-sized cities in particular has become a serious problem. Once known as 'the city of springs', Jinan for example watched its springs dry up in the 1990s. Overall, groundwater levels have dropped significantly in 65 locations due to extensive withdrawals.

The river is becoming undrinkable

The quality of water has paid the highest price for a booming economy and rapid industrialization coupled with population growth. The amount of untreated sewage being dumped into the Yellow River has doubled since the 1980s to 4.2 billion m³ per year. The river receives over 300 pollutants and only about 60% of its course is now fit for drinking.

Under the Water Pollution Protection Law, a legislative framework for protecting water resources was under preparation in 2009. Regulations and effluent standards have also been formulated. In parallel, the Water Resources Protection Law on the Yellow River is being modified.



©Dong Baohua

Glacier lake at the source of the Yellow River on the Qinhai–Tibetan plateau



The Yellow River has a catchment area of 795 000 km². In 2000, about 26% of the basin was urbanized. It lies in two different climatic zones: arid and semi-arid continental monsoon in the north-west and semi-humid in the south-east

An excessive use of water for irrigation

Between 1951 and 1987, many structures were built on the river for flood control, hydropower and irrigation. In the 1970s, large dams were constructed in the upper basin, a soil conservation campaign brought in new terrace croplands on the Loess Plateau in the middle reaches and irrigation diversions were substantially expanded in the lower reaches. By 2000, there were over 10 000 reservoirs in operation, 23 of which involved large dams, with a total storage capacity of 62 billion m³ – exceeding the annual basin runoff. Hydropower production in the basin currently amounts to 40 TWh per year.

The expansion of irrigation has been rapid: from 8000 km² in 1950 to 75 000 km² in 2000. Although demand for irrigation stabilized in the 1980s and agricultural water use has decreased since 2000, in accordance with the *Yellow River Water Allocation Scheme*, agriculture still accounts for 84% of total water consumption, followed by industry (9%), households (5%) and environmental use (2%). When consumption exceeds water availability, the deficit is met by using groundwater outside the basin or by recycling.

With industrial demand and environmental awareness growing, even as supplies reach their limit, pressure is building to increase the efficiency of agricultural water use. The YRCC has instituted a plan to reduce basin agricultural water consumption by 10% by 2010.



On these terraced slopes on the Loess Plateau in the middle reaches of the Yellow River basin, lines of green plants anchor the soils. This traditional local method prevents soil erosion and conserves water. The green plants also provide local communities with an alternative source of income to farming

It would be difficult to grow rice in the basin without irrigation, however. The main crops in the basin – wheat, maize, and soybean – give 50% higher yields or more with irrigation. It is these increases in yield and production that have driven the expansion of irrigation in the basin since the 1950s.

However, the development of irrigation is now widely believed to have reached its limit. It is felt that rainfed crop production (45% of the total) should be given higher priority in the next phase of basin development, as water becomes unavoidably scarce in the basin.

Managing sedimentation

The Yellow River gets its name from the colour of the heavy sediment concentration that it transports while flowing through an extensive loess plateau covering 640 000 km². The loose soil of the plateau is easily eroded; it is then carried into the Yellow River and its tributaries in massive quantities, particularly during the intense summer rainstorms.

The average sediment load that the river carries is 1.6 billion tonnes per year. Of this, only about 25% is carried to the sea, the rest being deposited on the riverbed. Owing to this sedimentation, the riverbed has risen at an average rate of 5–10 cm per year and the dykes have been periodically raised in response. The impact of sedimentation on channel dynamics has made managing the river difficult, especially in its lower reaches.

The YRCC has made flushing out the heavy load of sediment its most critical environmental priority, in tandem with protecting biodiversity and sustaining the wetlands and fisheries at the mouth of the river. The minimum flow required to flush out sediment is calculated as 14 billion m³, with an additional 5 billion m³ being necessary for other environmental requirements. However, it is difficult to ensure the required minimum environmental flow in the river when surface waters are already being used to the maximum.

Coping with floods and drought

Millions of lives have been lost to floods and drought during the long history of the Yellow River basin. From 206 BC to AD 1949, 1092 major floods were recorded, along with 1500 dyke failures, 26 river rechannellings and 1056 droughts. The flat North China Plain, which was formed by alluvial deposits from the Yellow River, has always been prone to floods.

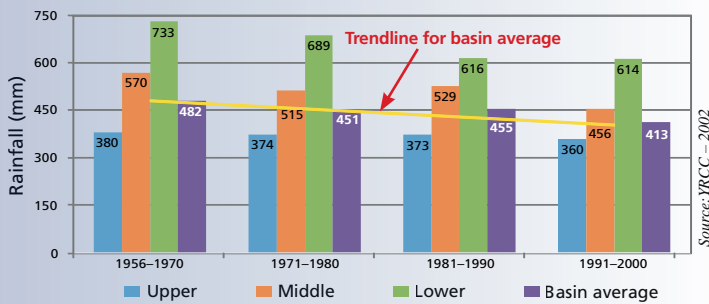
The drought decade

In 1987, the State Council of China established a Yellow River Water Allocation Scheme to balance available supply and actual demand better by setting a cap on water abstraction of 37 billion m³ per year for average runoff of 58 billion m³. The provinces in the middle reach of the basin were allocated 22% of the available flow, the remainder being split equally between the provinces of the upper and lower reaches. The allocation is revised annually to reflect seasonal variations in water resource availability.

During the 1990s, however, this scheme was sorely tried: drought prevailed throughout the North China Plain, including the Yellow River basin. Two main tributaries, the Wei He and Fen He, were reduced to a trickle. Runoff dropped by 24% and flow in the lower reaches of the river to just 14% of the long-term annual average. From 1995 to 1998, for some 120 days each year, there was no flow at all in the lowest 700 km of the river. This had serious repercussions, including extreme water shortages in downstream provinces, the inability to flush sediment out to sea and impaired sustainability in the delta ecology and coastal fisheries.

Since 1999, the scheme has managed to prevent the riverbed from drying up completely, although flow levels are sometimes so low as to be largely symbolic.

Managing water scarcity is now the number one priority in the Yellow River basin. Given the growing imbalance between supply and demand, it is difficult to meet any new water demand from one sector without lowering supply to the others. It is clear that hard choices will have to be made to address these diverging needs. Since agriculture is by far the largest consumer of water, one unavoidable conclusion is that water supply to agriculture must be reduced and new ways found to make agricultural water use more efficient.



Rainfall in various reaches of Yellow River basin, 1956-2000

Following the establishment of the People's Republic of China in 1949, master planning for flood control and the construction of numerous hydraulic structures significantly reduced this vulnerability and losses due to floods. Embankments, reservoirs and flood retention areas were all established to increase flood control and enable drought management. The structural flood control system in China is designed basically for the discharge capacity of the maximum flood recorded since the 1950s for large rivers and for five- to ten-year flood frequency for smaller rivers.

Non-structural flood control measures have been improved, mainly by developing and applying flood forecasting and warning systems and by implementing laws, regulations, policies and the laws of economics. These measures include managing river channels and controlling settlement in

flood-prone areas. The YRCC and the provinces of Shanxi, Shaanxi, Henan and Shandong have jointly set up a Yellow River flood control and drought relief headquarters.

Controlling a growing thirst

In the 1990s, the central government passed a slew of laws to alleviate water scarcity nationwide and ensure the pursuit of China's economic miracle, at a time of growing public environmental awareness. This legal arsenal includes the Water Law, the Soil and Water Conservation Law, the Flood Control Law, the Environmental Protection Law, the Fisheries Law, the Forestry Law and the Mineral Resources Law. In 2002, a new Water Law emphasizing integrated water resources management hailed a transition from engineering-dominated, demand-based development to a resource-oriented strategy focusing on water availability.

Established in 1946, the YRCC manages the Yellow River basin on behalf of the Ministry of Water Resources and the State Council. The YRCC prepares and implements the basin water development plan, decides on the allocation of water resources at the provincial level and is in charge of constructing and maintaining structures – except large dams – for water resource development and flood prevention.

Since 2000, the YRCC has developed a water-use plan based on medium- to long-term supply and demand patterns to balance available water supply and demand from the various sectors. Annual water use plans are issued to users to ensure there is an adequate supply for priority areas, especially in the event of drought. The YRCC has also established regulations encouraging household users to install water-saving devices, farmers to adopt water-efficient practices and industry to promote techniques minimizing water use and waste discharge. It has also established a market pricing system.

Today, a legal arsenal is in place to curb water pollution and overuse, via a holistic approach that addresses the needs of all stakeholders. In parallel, efforts are being made to strike a balance between the water demands of competing sectors. Will this suffice to restore the 'river mother of China' to her former glory? Only time will tell.

The preparation of this case study was facilitated by UNESCO's office in Beijing under the Spanish Millennium Development Goal project to develop a China Climate Change Partnership Framework.

- Xu, Z. X.; Zhao, F. F.; Li, J. Y. (2006 or 2007) Impact of climate change on stream flow in the Yellow River Basin: www.ifwf2.org/addons/download_presentation.php?fid=1077

Of shipwrecks, lost worlds and grave robbers

Over the centuries, entire cities have been engulfed by the waves and countless ships have perished at sea. Their remains constitute a precious archaeological heritage of the greatest cultural importance. Many of these sites have not been touched for centuries or even millennia. Moreover, due to the lack of oxygen, organic material like wood is often much better preserved underwater than on land. This makes these sites unique.

On 2 January, the UNESCO Convention on the Protection of Underwater Cultural Heritage entered into force, three months to the day after being ratified by a 20th State⁶. 'From now on, it will be possible to offer legal protection to the historical memory in underwater cultural heritage, thus curtailing the growing illicit trade by looters,' rejoiced UNESCO Director-General Koichiro Matsuura.



Inspecting the wreck of the Italian steamer Teti, off the Island of Vis in Croatia

© D. FRKA/UNESCO

Whereas a wealth of archaeological sites have been discovered on land over the past century, the world's seas, rivers and lakes have jealously guarded many of their secrets. The development of sophisticated technology that includes submersible crafts, diving suits and sonar, is making these sites more accessible, even at great depths.

Gold fever

Archaeological finds in recent decades have fired the public imagination and galvanized the scientific community – but also awakened commercial interests and an irrational gold fever in treasure hunters.

In 1995, for example, the remains of a 16th century vessel were spotted by a diver off the Coast of Playa Damas near what is now Panama. It is thought that the vessel could be the *Vizcaína*, one of two ships Italian explorer Christopher Columbus lost in these waters in 1503. Unfortunately, the ship was left to the mercy of a treasure hunting company (see overleaf 22 on map).

In 2007, an American treasure-hunting company furtively recovered 17 tons of silver and gold coins from the Spanish shipwreck *Nuestra Señora de las Mercedes*, before flying the bounty out of Gibraltar. Spain is now trying to retrieve its heritage in court (see 28 on map).

Filling the gaps in the history books

Many submerged traces of human existence are much better preserved than those on land. This is due to the lack of oxygen and light, coupled with – until recently – their relative inaccessibility. These sites can shed light on the rise of human civilizations and at times remedy the lack of a written record. What kind of bows did the archers of folk hero Robin Hood

Photo: Wikipedia Commons

(pictured) use, for example, when they robbed the rich to help the poor in medieval England? The bows found in King Henry VIIIth's battleship, the *Mary Rose*, which sank in 1545 during an engagement with the French navy, have solved the mystery (see 2 on map). Similarly, the excavation of Chinese wrecks which sank in the 15th century off the Kenyan coast has provided proof of ancient trade between China and Africa.

Other mysteries remain intact. Seven hundred years ago, Kublai Khan, leader of the Mongol tribes which controlled most of Asia at the time, decided to conquer Japan. As the Mongols were not accustomed to fighting at sea, Kublai Khan forced thousands of Chinese to build the requisite fleet. In 1281, 4400 ships carrying over 70 000 men set out for Japan – only to vanish without a trace (see 14 on map). The legend of a divine wind, still alive in Japan, suggests that the fleet may have been crushed by a storm or tsunami. Archaeologists are now searching for its remains.

Traces of the development of navigation techniques and human understanding of the Universe have been found on the sea floor. Among these rare objects are several astrolabes recovered from shipwrecks. Astrolabes were used to locate and predict the positions of the Sun, Moon and stars; they also helped to determine the hour from the local latitude. The first known analogue computer was recovered in 1900 from a Greek shipwreck which sank around 100 BC. The mysterious Antikythera mechanism is believed to have been used to calculate astronomical positions and eclipses of the Sun and Moon (see 7 on map).

Many sites bear silent testimony to historic naval battles. Examples include Salamis, opposing Persia and the Greek city states in 480 BC, or the Battle of Lepanto in 1571 opposing the Ottoman fleet and a coalition grouping the Republics of Venice and Genoa, the Papacy and Spain.



1) **Pile dwellings on Loch Tay**
Pile dwellings built on lakes in Ireland and Scotland were constructed on small natural or man-made islands, in lakes, rivers or swamps. The humid environment favours preservation of organic material, like the 2500 year-old butter found in the remains of a pile dwelling on Lake Loch Tay! (reconstructed here)



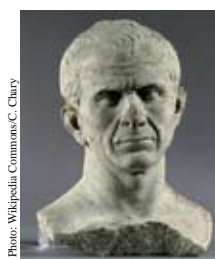
2) **Mary Rose** (see description p. 19) – Wooden bows found on the English battleship, the Mary Rose, were still in perfect condition after passing four centuries at the bottom of the sea.



3) **Viking ship barrier**
Roskilde, ancient Viking capital of Denmark, was located in the Roskilde Fjord west of Copenhagen. To protect this important trading centre from seaborne assaults, the Vikings deliberately sank five ships in the Fjord near Skuldelev to block the navigation channel. (Pictured is a reproduction)



4) **Rheingold: the 'hoard of the Barbarians'**
More than 1700 years ago, the 'hoard of the barbarians' sank into the Rhine River. With more than 1000 artefacts made of silver, bronze, brass and iron for an overall weight of more than 700 kg, it represents the biggest find of metal from Roman times in Europe.



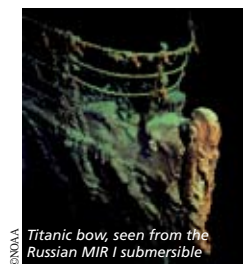
5) **Caesar's bust**
In 2008, a marble bust depicting Julius Caesar was discovered in the Rhône River in Arles (France). The life-sized bust has been tentatively dated from the time Caesar founded Arles in 46 BC.



28) **The wreck of Nuestra Señora de las Mercedes** (see description p. 19) – The sinking of Nuestra Señora de las Mercedes in the Mediterranean in 1804 caused Spain to join forces with France against England.



27) **'Seahenge'**
The holy sites Holmes I and II have been nicknamed 'Seahenge' (after Stonehenge). Located in marshes on the English coast, 'Seahenge' consists of periodically submerged timber circles with small split oak trunks which form a circular enclosure.



26) **The wreck of the Titanic**
The luxurious passenger liner sank on 14 April 1912 on her maiden voyage from Southampton (UK) to New York (USA) after hitting an iceberg in the North Atlantic Ocean, with the loss of 1517 lives owing to an insufficient number of lifeboats. The wreck was rediscovered in 1985.



25) **The wreck of USS Monitor**
The United States Ship Monitor pictured in this engraving was the first iron-clad warship. Her low freeboard and heavy turret made her unseaworthy and led to her foundering during a storm in 1862 in the Atlantic Ocean near North Carolina in the USA, with the loss of 16 crewmen.



24) **Port Royal in Jamaica**
Founded soon after the English wrested Jamaica from the Spanish in 1655, Port Royal was a haven for rich merchants, notorious pirates and affluent planters by the time it was destroyed by an earthquake in 1692.

23) **Aktunkaab, the cave of hands**
'The cave of hands', or Aktunkaab in Mayan, is a dry cave in the state of Yucatan in Mexico. It has over 300 hand prints in positive and negative formats which date back about 15 000 years.



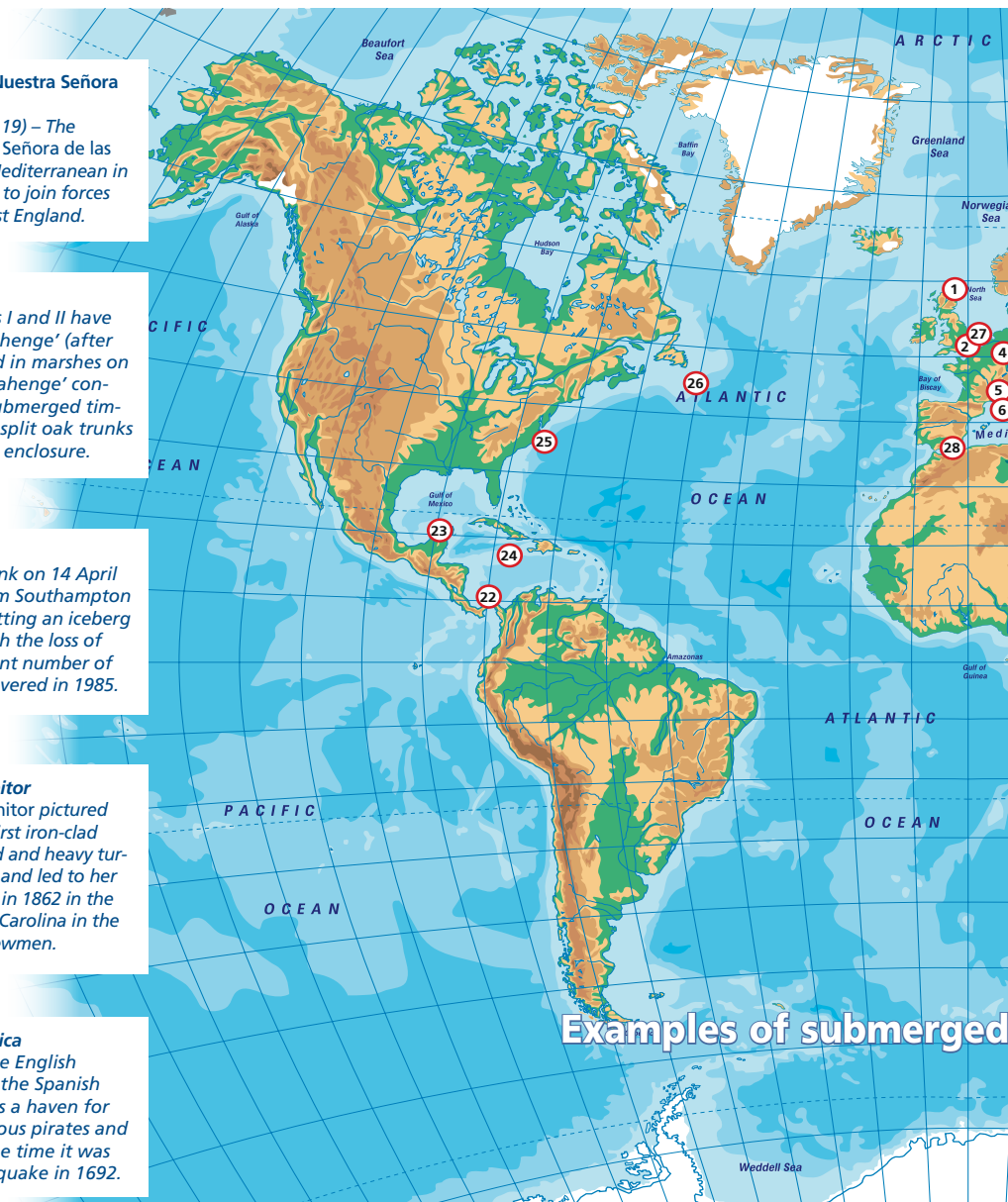
22) **The wreck of Christopher Columbus' ship Vizcaina** (see description p. 19)
Italian explorer Christopher Columbus lost nine ships in the Atlantic Ocean on different expeditions, including the Gallega and the Vizcaina in 1503, near what is today Panama. In 1995, a diver found what could be the Vizcaina, containing cannons, anchors and ceramics from the 14th and early 15th centuries. Despite being the oldest wreck ever found off the coast of America, it was left to the mercy of a treasure hunting company.



21) **The Oranjemund wreck**
A 16th century Portuguese shipwreck containing over 2300 coins and numerous artefacts was discovered in 2008 by miners searching for diamonds. The best-preserved of its period outside Portugal, the wreck was archaeologically excavated under the supervision of the Namibian government for later exhibit in a museum. It was found on the Skeleton Coast, so-named for the danger the Namib desert presented to stranded seamen.



20) **Dwarka**
Dwarka is one of India's oldest and most venerated pilgrimage sites. Legend has it that this holy city was entirely swept away by a great wave long ago. Excavations of Dwarka began in the early 1980s when marine archaeologists found underwater stone walls and six layers of ruins.



Examples of submerged

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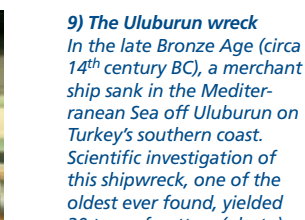
© AFP/Corbis/Iconica

© Vener Karmach, Roskilde Viking Museum

Courtesy of the Historical Museum of the Palatine, Speyer, Germany/ Peter Jung-Bretzner

Photo: Wikipedia Commons/C. Chury

Photo: Wikipedia Commons/Baahjan



6) Cosquer Cave
Nowadays, the entry to the Cosquer cave near Marseille in France lies 37 m under water. Its walls are covered by paintings made by humans 27 000–19 000 years ago. They represent animals, hands and an exceptional engraving of a 'killed man'. The paintings may bear testimony to mutilations, sacrificial rituals or disease.

7) The Antikythera wreck
A wreck containing fragments of sculptures and other artefacts was discovered by sponge divers near the Greek island of Antikythera in 1900. The most celebrated find, dated to about 100 BC, is a mechanism (photo) now considered to be the world's oldest analogue computer. Used to calculate astronomical positions, the mechanism may have been based on the work of Archimedes.

8) The story of Noah's Ark
(see description p. 22)
At the end of the Ice Age about 7500 years ago, melting glaciers caused sea level in the Mediterranean to rise until it flooded the Black Sea, a lake at the time. This event may explain the great deluge described in the Bible. A submerged Mesolithic settlement discovered near Sozopol bears testimony to the tragedy.

9) The Uluburun wreck
In the late Bronze Age (circa 14th century BC), a merchant ship sank in the Mediterranean Sea off Uluburun on Turkey's southern coast. Scientific investigation of this shipwreck, one of the oldest ever found, yielded 20 tons of pottery (photo), gold and silver jewellery, bronze tools and weapons, as well as traces of fruit and nuts. The remains of the ship, which may have been Cypriot, are now housed in the Bodrum Museum of Underwater Archaeology.

10) Ancient Carthage
Carthage was founded by the Phoenicians in the 9th century BC in the Gulf of Tunis, destroyed by the Romans in 146 BC and again during the Muslim conquest in 698 AD. Parts of the harbour and city have been found off the coast. Houses once rose six storeys high at this World Heritage site.



11) Apollonia
Apollonia in Libya was founded in the 7th century BC by the Greeks as a port for nearby Cyrene, now a World Heritage site. Cyrene was later romanized and remained a great capital until an earthquake in 365 AD submerged parts of the city and harbour.

12) Ruins in the Bay of Alexandria
(see description p. 22) – Alexandria was Egypt's most important harbour and cultural centre during Ptolemaic times. The ancient lighthouse of Pharos (pictured) and other submerged remains have been discovered in the eastern harbour. It is planned to build an underwater museum.

13) Caesarea harbour
The port of Caesarea was built on Israel's Mediterranean coast in about 10 BC by King Herod to honour his Roman patron, Caesar Augustus. It was the first major project to use concrete that would set under water. Today, it is an underwater museum: equipped with a waterproof map, divers can view 36 sites to admire the lighthouse ruins, anchors, pedestals and even a Roman shipwreck.

14) Kublai Khan's fleet
(see description p. 19)
What caused Kublai Khan's fleet of 4400 ships to vanish without a trace en route to invade Japan seven centuries ago? Archaeologists hope to solve the mystery.

15) The Tek Sing wreck
When Tek Sing, one of the last Chinese Junks, sank off Indonesia's coast in 1822, she took almost 1500 people with her. In 1999, over 300 000 pieces of porcelain from the Tek Sing were salvaged off Indonesia's coast by treasure hunters, who destroyed the wreck in the process.

cultural heritage around the world

A World of **SCIENCE**, Vol. 7, No. 2, April–June 2009

19) Mahabalipuram
A group of sanctuaries founded by the Pallava kings was carved out of rock along India's Coromandel Coast in the 7th and 8th centuries. It is known for its rathas (temples in the form of chariots), mandapas (cave sanctuaries) and seven pagodas, six of which seem to have been submerged by the sea. During the 2005 tsunami, their remains and an ancient port were uncovered at this World Heritage site.



18) Nanhai No. 1
Nanhai No. 1 is a 1000-year-old vessel which sank during the Song Dynasty (960–1279 AD) off China's south coast, on the Marine Silk Road connecting China with the Middle East and Europe. Raised in 2007, the wreck and its 60 000–80,000 precious pieces of cargo will be displayed in an aquarium with the same water quality, temperature and environment as its original resting place.



17) Baiheliang's hydroglyphs
The Baiheliang (White Crane Ridge) is a stone riff submerged recently by the new Three Gorges Dam on the Yangtze River. It features some of the world's oldest hydrological inscriptions, which recorded 1200 years of changes in the water level of the river. An underwater museum is under construction.



16) Aboriginal fish traps
(see description p. 23)
The Ancient fish traps at Brewarrina in the Darling River have strong spiritual and symbolic associations for Aborigines.



Photo: Ministry of Culture

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© Vine Scarella

The loss of Napoleon Bonaparte's flagship, the *Orient*, was a factor in France's defeat against the English at the Battle of Abukir Bay in Egypt in 1798 (see photo). The wreck has since been rediscovered lying on the seabed.

Millions of time capsules

It is estimated that over 3 million wrecks lie spread across the planet's ocean floors, some of them thousands of years old. A shipwreck functions as a time capsule, providing a complete snapshot of life on board at the time of sinking.

Not all shipwrecks tell a tragic tale, however. They may also form part of wreck barriers (so-called block ships), sunk deliberately to prevent the passage through a river, bay or canal. Some block ships were sunk to defend the waterway against the entry of attacking enemy forces (see 3 on map) – or by the attacking forces to cut off the escape route of a defending navy.

Other sunken wrecks were not designed to float but to fly or cross land. Sunken aircraft and train and car wrecks have been found on sea- and lakebeds.

Sunken cities

The remains of countless ancient buildings and settlements are now submerged. Some owe their fate to subsiding soil, others to earthquakes, flooding, landslides or erosion. Some were deliberately built on the water, like today's *kampongs* in Malaysia, villages built on piles.

The legend of the sunken city of Atlantis dates back to the writings of Greek philosopher Plato about 400 BC. Whereas Atlantis has never been convincingly located, some sunken cities have come to light. The remains of the ancient city of Heraklion bear testimony to the rising waters that engulfed it. Heraklion was the principal Egyptian port for trade with Greece before the founding of Alexandria by Alexander the Great in 332 BC. Situated about 25 km east of modern-day Alexandria, Heraklion was submerged 1200 years ago after earthquakes caused massive flooding on the Nile. Two thousand years ago, Alexandria



Photo: Wikipedia Commons

The Orient exploding after being hit by British guns during the Battle of Abukir Bay in August 1798, as depicted by Arnald George. The loss of much of the French fleet effectively stranded the French army in Egypt

counted half a million inhabitants. Famous finds in the bay include the remains of the Pharos lighthouse (see 12 on map), built in the 3rd century BC, and the palace of Pharaoh Cleopatra VII (69 BC–30 BC). Vestiges of Port Royal in Jamaica have similarly been rediscovered by underwater archaeologists (see 24 on map).

Ice-Age landscapes

Some of the world's best-preserved prehistoric landscapes have survived at the bottom of the North Sea. Dating back approximately 50 000–60 000 years ago, they contain traces of hunters' kills and prehistoric camp sites, as well as the remains of thousands of mammoths, woolly rhinoceroses and other Ice-age mammals. In the southern North Sea, 200 Stone Age⁷ bone, antler and flint artefacts made by anatomically modern humans have been discovered.

There are approximately 20 000 Stone Age sites hidden in the Baltic Sea. Some 9000 years ago, Denmark, Sweden and the UK formed a single continent and the Baltic and Black Seas were lakes. When warmer temperatures melted the icecap at the end of the Ice Age, rising sea levels submerged numerous human settlements, forests and coastlines. Artefacts found include pottery, log boats, timber remains and even textiles, seed and arms.

A submerged coastline lying 17 m below the waters of the Black Sea provides evidence of a flood 7500 years ago which may explain the story of Noah's Ark (see 8 on map). According to the *Bible*, God told Noah to build a boat for his family and pairs of every animal species, to save them from the great deluge that was about to punish humankind for its sins. A freshwater lake at the time, the Black Sea lay 100 m below the level of the Bosphorus. Scientists posit that, as the climate warmed, melting glaciers raised the sea level of the Mediterranean until the waters broke a natural dam at the Bosphorus. This theory is supported by the remains of submerged Mesolithic settlements found off Turkey and the find of an ancient log boat at another site.



Greek bronze statue of a young athlete 192 cm tall resting off the Island of Vele Orjule in Croatia. The statue dates from the 1st or 2nd century BC

The Convention on the Protection of Underwater Cultural Heritage

Adopted by UNESCO's Member States in 2001, the Convention defines 'underwater cultural heritage' as 'all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years...' This definition includes structures, buildings, artefacts and human remains, the remnants of vessels and aircraft, as well as their cargo, and prehistoric objects. Pipelines, cables or installations still in use and placed on the seabed would not qualify as 'cultural heritage', for instance, nor would fossils. The benchmark of 100 years of age does not, however, limit States Parties from protecting younger remains, such as the submerged remains of battlefields from both world wars (1914–1918 and 1939–1945).

The Convention sets out to protect underwater cultural heritage and facilitate cooperation among States Parties. It does not regulate the ownership of shipwrecks or sunken ruins. Nor does it modify the jurisdiction or sovereignty of States. It encourages the development of underwater archaeology and responsible public access to submerged heritage. It also provides a framework for preventing illicit trafficking of relics from such sites. Unlike the World Heritage Convention, protected sites are not inscribed on a particular list, so as not to reveal their precise location.

The Convention is based on four main principles:

- ✓ the obligation to preserve underwater cultural heritage;
- ✓ the recommendation of *in situ* preservation (i.e. under water), as a preferred option, before deciding on any recovery;
- ✓ the rejection of commercial exploitation of this heritage; and
- ✓ the encouragement of cooperation among States to protect the precious submerged legacy, promote training in underwater archeology and raise public awareness of the importance of sunken cultural property.

The Convention's Annex establishes Rules concerning activities directed at underwater cultural heritage. These rules target professionals and State authorities. They are widely endorsed by archaeologists, who look forward to seeing the Annex set professional standards for intervention at sites.

For details: www.unesco.org/culture/en/underwater

Divers registering human remains in Chan Hol Cave in Mexico's Tulum area (Chanhol means 'small hole' in Mayan.). In another cenote nearby called Naharon, divers discovered a female skeleton which they dubbed *Eve of Naharon*; she has been carbon-dated to 11 670 years of age. The bone structure of *Eve of Naharon* is more consistent with that of peoples from Southern Asia, shedding doubt on the theory that the Americas were settled by peoples from Northern Asia

These finds give precious insights not only into the face of the planet in the Ice Age but also into what the future could hold if sea levels rise considerably again.

'Seahenge' and other religious sites

Many seafaring or coastal populations used the oceans or rivers as burial sites, like the Vikings. These Scandinavian explorers, merchants and pirates raided and settled vast expanses of Europe between the 8th and 11th centuries AD. There is also the example of Alaric, king of the Visigoths, a 'barbarian' tribe, who is known to have sacked the city of Rome in 410 AD. Legend has it that Alaric was buried in the Busento River in Italy. The site has been searched for in vain.

Some ancient water-related religious sites are still in use, like the fish ponds in Hawaii. Others have long been forgotten, like 'Seahenge' on the English coast (*see 27 on map*).

From submerged caves to fish traps

Underwater cultural heritage also encompasses artefacts and traces of ancient human life preserved in caves which were always submerged or flooded when sea level rose. Traces of human activity have been found in a painted cave in the Mediterranean Sea (*see 6 on map*) and in the Mexican cenotes, karst caves open to the air which have filled with water over time (*see photo*).

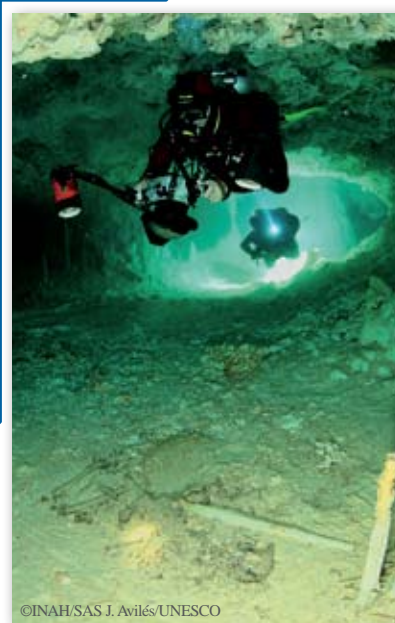
Many ancient populations built fish traps, which are some of the oldest extant working technology. Fish traps range from artificial rock pools surrounded by low walls constructed using beach cobbles to stone walls several hundred metres in length. Others were built using timber stakes wrapped in plant material and placed in the middle of a stream, in an estuary or near the coastline. The fish were usually herded into the impounded area, from whence they could be retrieved. Fish traps have been found on the South Western Cape coast of South Africa, north Wales and Denmark, the Pacific Islands and Hawaii, Canada and Australia (*see 16 on map*).

Filling a legal vacuum

All of the treasures described on these pages qualify for protection under the Convention on the Protection of Underwater Cultural Heritage, with the exception of those less than 100 years old (*see box*).

The aim of the Convention is to help fill the legal vacuum surrounding submerged archaeological sites. From now on, countries will have at their disposal an effective tool for protecting their subaquatic cultural treasures, provided that as many States as possible rally to the cause by ratifying the Convention.

Ulrike Guérin and Katrin Köller⁸



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6. Barbados, Bulgaria, Cambodia, Croatia, Cuba, Ecuador, Lebanon, Libyan Arab Jamahiriya, Lithuania, Mexico, Montenegro, Nigeria, Panama, Paraguay, Portugal, Romania, Saint Lucia, Slovenia, Spain, Ukraine
7. The term Stone Age is used by archaeologists to designate a vast pre-metallurgical period from which mostly only stone tools survive. The Stone Age began with the advent of the first Homo species about 2.5 million years ago and ended with the advent of copper smelting about 5000 years ago. It is divided into the Palaeolithic (Old Stone Age), Mesolithic (Middle Stone Age) and Neolithic (New Stone Age)
8. Secretariat for the Convention on the Protection of Underwater Cultural Heritage: u.guerin@unesco.org; k.koeller@unesco.org

Diary

2-8 April

Access and benefit-sharing

7th meeting of Ad Hoc Open-ended Working Group of Convention on Biological Diversity, UNESCO Paris: www.cbd.int/doc/?meeting=ABSWG-07

6-24 April

Negotiation and mediation for water conflict management

Course proposed by UNESCO's programme From Potential Conflict to Cooperation Potential and UNESCO-IHE. For current and future water managers, decision-makers, students, etc. Delft, Netherlands: l.salame@unesco.org

1-5 May

Basic issues in evolution

Symposium marking 200th anniversary of Charles Darwin's birth. Co-organized by UNESCO, IUBS, Istituto Veneto di Scienze, Lettere ed Arti, Venice (Italy): w.erdelen@unesco.org; bernardi@scn.it; www.iubs.org

4-7 May

Sustainable land use and ecosystem conservation

Intl conf. of Sino-German project on Ecological Research for Sustaining the Environment in China (ERSEC) to exchange and integrate research results. Min. of S&T, Min. of Education, China Agricultural University, UNESCO Beijing: www.unesco.org/beijing-new/index.php?id=3079

24-29 May

Biosphere reserves

MAB International Coordinating Council meeting to approve biosphere reserves and MAB award-winners. Jeju Biosphere Reserve (Rep. Korea): mab@unesco.org; www.unesco.org/mab

3-5 June

International Hydrological Programme

43rd session of Bureau, UNESCO Paris: a.tejada-guibert@unesco.org; www.unesco.org/water

8-26 June

Intergovernmental Oceanographic Commission

Executive Council meeting and Assembly: www.ioc.unesco.org

9-11 June

Localizing products

A sustainable approach for natural and cultural diversity in the South? Scientific symposium involving UNESCO-MAB, IRD, CIRAD, MNHN, IDDRI, etc. UNESCO Paris: www.mnhn.fr/colloque/localiserlesproduits/index_va.php

30 June - 2 July

Managing hydroclimatic risk in the water sector

Training session for Ethiopian, Djiboutian and Sudanese water professionals. Co-organized by UNESCO and IRI. Addis Ababa (Ethiopia): a.mishra@unesco.org; (Addis Ababa) a.makarigakis@unesco.org

2-5 April

100 hours of astronomy

IAU event designed to entice as many people as possible to look through a tele-scope at an ideal time for early evening observation: when the Moon goes from the first-quarter phase to the gibbous stage (meaning it bulges outwards). For details of this cornerstone project: www.100hoursofastronomy.org/

16-20 June

Space education and astronomy

Intl space education workshop for secondary pupils and teachers followed by pilot teacher-training workshop in astronomy (18-20 June), UNESCO in cooperation with IAU, Salinas (Ecuador): www.unesco.org/science/earthsciences/space_education

23-27 June

Space education and astronomy

National space education workshop for secondary pupils and teachers in followed by pilot teacher-training workshop in astronomy (25-27 June), UNESCO in cooperation with IAU, Lima and Cuzco (Peru): www.unesco.org/science/earthsciences/space_education

Year-long cornerstone projects: *Cosmic Diaries* (blog written by astronomers from five continents); *Portal to the Universe* (online in 2009); *Dark Skies Awareness* (alerting to the visual nuisance of bright city lights); *She is an Astronomer* (tackling bias and misconceptions about careers for women); *Astronomy and World Heritage*; *the Galileoscope* (giving up to 10 million people worldwide their first look through an astronomical telescope); *Galileo Teacher Training Programme*; *Universe Awareness* (for very young children from underprivileged environments); *From Earth to the Universe* (using public parks, metro stations, etc to bring astronomical images to the public); and *Developing Astronomy Globally* (for schools, universities and the public in regions with little astronomy): www.astronomy2009.org/globalprojects/cornerstones/



New Releases

Water in a Changing World

Third World Water Development Report

Produced by World Water Development Programme comprised of 26 United Nations bodies. Two single-wrapped volumes sold as one: main report (336 pp.) with CD-ROM; and 20 case studies: 88 pp. English only. Co-published by UNESCO Publishing and Earthscan, UK. ISBN:(UNESCO): 978-92-3-104095-5, €45.00; (Earthscan): 978-1-84407-840-0 (paperback) and 978-1-84407-839-4 (hardback). See editorial and case study of China, p.16. Read the report: <http://webworld.unesco.org/water/wrap/wvdr/index.shtml>

Managing Water Resources

Methods and Tools for a Systems Approach

Slobodan P. Simonovic. *Studies and Reports in Hydrology series, UNESCO Publishing/Earthscan, €43.00, ISBN 978-92-3-104078-8, English only, 680 pp.*

Describes the interdisciplinary 'systems approach' and its application to contemporary water resources management. Includes programmes and exercises on an accompanying CD-ROM. For students and professionals.

Rising tides

BBC Earth Report produced with support of UNESCO, European Union's EuropeAid office and UNEP. English only. First broadcast on 5 March. Branton Burrows Biosphere Reserve in the UK and Malindi Watamu Biosphere Reserve in Kenya share common problems: climate change and sea-level rise are affecting their coastlines and threatening their wildlife habitats. Has fast is sea-level rising? And what will the consequences be? These biosphere reserves have teamed up to map climate change scenarios for use in devising adaptation strategies. To view: www.tve.org/earthreport/index.cfm?cat=thisweek; www.unesco.org/mab

Indigenous Knowledge

Seven posters launched by UNESCO's Local and Indigenous Knowledge Systems (LINKS) programme at National Cultural Centre of Vanuatu, December 2008. Available in English, French, Spanish and Bislama (Vanuatu). Illustrated with case studies and images from around the world the posters introduce important concepts and issues relating to knowledge in indigenous societies today. Educational, they strengthen awareness of the many opportunities and challenges facing indigenous knowledge-holders. Download or request a poster: www.unesco.org/links; d.nakashima@unesco.org

International Research Centre on Karst

Guo Fang (Ed.) Booklet produced by Intl. Research Center on Karst. English, 28 pp.

Gives the background to the centre, which was set up in 2008 under the auspices of UNESCO within the International Year of Planet Earth. Describes its objectives, functions, facilities and Governing Board. See also *A World of Science*, July 2008. Discover the Centre's website: www.ircck.edu.cn; request a copy from: rmisotten@unesco.org



Volga Kits

Produced by UNESCO Moscow and Coca-Cola HBC Eurasia with Astrakhanskiy Biosphere Reserve within Living Volga Programme. Exists in Russian, with parts in English. Pictured is *Let's Save the Volga!* in Russian. Contain brochures on the environmental situation in the region, a strategy and action plans for raising environmental awareness. Also include sets of postcards and posters on rare species of fauna and flora, a map of biosphere reserves of the Volga Basin, a press kit and leaflets describing the ecological behaviour of different stakeholder groups.

Target a wide audience. For details: e.veritina@unesco.ru; www.unesco.ru/en/articles/2004/e.veritina11032009142850.php (page in English)

European Geoparks

'Coffee table' book published by UNESCO Earth Observation Section and European Geoparks Network, sold via Natural History Museum of Lesvos Petrified Forest, €35.00, ISBN: 978 960 7646 91-0, English only, 176 pp.

Reaches out to the broad public, contribution to Global Geoparks Network and International Year of Planet Earth. Non-scientific, with articles on all European Geoparks. Prefaced by UNESCO Director-General Koichiro Matsuura and Walter Erdelen. To order a copy: www.europeangeoparks.org; www.lesvosmuseum.gr; for details: m.patzak@unesco.org and lesvospf@otenet.gr

Status of Coral Reefs of the World: 2008

Edited by Clive Wilkinson. Produced by Global Coral Reef Monitoring Network, English only, ISBN:1447-6185, 298 pp. See also p.11.

For details: clive.wilkinson@rrrc.org.au; m.hood@unesco.org; read the report: www.gcrmm.org

The Future of Drylands

C. Lee and T. Schaaf (eds), UNESCO Man and the Biosphere series, UNESCO Publishing/Springer Verlag, €95.00, ISBN 978-92-3-104052-8, English only, 872 pp.

Proceedings of Intl. Scientific Conference on Desertification and Drylands Research held in Tunis (Tunisia), 19-21 June 2006. See also *A World of Science*, October 2006.

Towards Sustainable Agriculture

UNESCO-SCOPE-UNEP Policy Brief N°8, in English only, 6 p.

Contains key findings of the International Assessment of Agricultural Knowledge, Science and Technology for Development and illustrates ways of addressing these. Highlights relevant policy and institutional responses: www.unesco.org/mab; mab@unesco.org

Agriculture at a Crossroads

Seven printed volumes marketed by Island Press from the International Assessment of Agri-cultural Knowledge, Science and Technology for Development, a three-year project involving World Bank, FAO, UNDP-GEF, UNEP, UNESCO, WHO: a Global Summary for Decision-makers (US\$95), a synthesis report and five regional assessments (US\$65.00 each): Central and West Asia and North Africa (vol. I); East and South Asia and the Pacific (II); Latin America and the Caribbean (III); North America and Europe (IV); Sub-Saharan Africa (V).

For details, see *A World of Science*, July 2008. Download PDFs: www.agassessment.org Order a copy: www.islandpress.org/iaastd - Institutions from developing countries may request a complimentary copy from UNESCO while stocks last: g.calvo@unesco.org; s.arico@unesco.org

International Year of Astronomy: www.unesco.org/iya2009; www.astronomy2009.org

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