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NEW INDUSTRIES IN THE DEEP SEA

More than 70% of the Earth is covered by the oceans, which have an average depth of four kilometres. In the deep sea there is no light, low temperatures and crushing pressure, yet a wide variety of creatures are adapted to these extreme conditions. New technologies give unprecedented access to deep waters, revealing a wealth of new habitats and organisms, and also presenting opportunities for exploiting new resources. This POSTnote examines the specific cases of deep-seabed mineral extraction, bioprospecting and CO_2 storage. It highlights the difficulties in promoting development of economic opportunities while protecting the deep sea environment.

Background

The first proof that there was life on the deep seabed came from the *HMS Challenger* expedition in the 1870s.[1] However, it has been only in the last 30 years that the diversity and abundance of this life has been realised. It is now known that there are areas in the deep sea that have high biodiversity, including cold-water coral reefs, seamounts (mountains on the seabed) and areas with a high proportion of unique species, such as hydrothermal vents (see Box 1, Fig. 1). These areas support a range of animals and may be important spawning and nursery areas for fish species including commercially important ones. Many species discovered in these areas are new to science and the invertebrate and microbial worlds in particular display tremendous diversity. Despite the increase in knowledge in recent years, currently less than 10% of the deep seafloor has been explored[2].

The deep sea is generally defined as waters below 200 metres. Increased accessibility and the potential for new opportunities have led a number of industries to move into this area. Among the most significant advances in marine engineering and submersible technology is the development of remotely operated vehicles. Oil and gas extraction and fishing have been operating in the deep sea for some time. Deep-sea fishing is currently the most damaging industry operating in the North East Atlantic[3]. This POSTnote focuses on some of the emerging economic opportunities in the deep sea.

Box 1. Hydrothermal Vents

Hydrothermal vents or 'black smokers' are seafloor fissures in the planet's surface where volcanic, super-hot (400ºC), mineral-rich water spews from the ocean floor. They are mainly found in the Pacific, Atlantic and Indian Oceans at average depths of over 2000 metres.

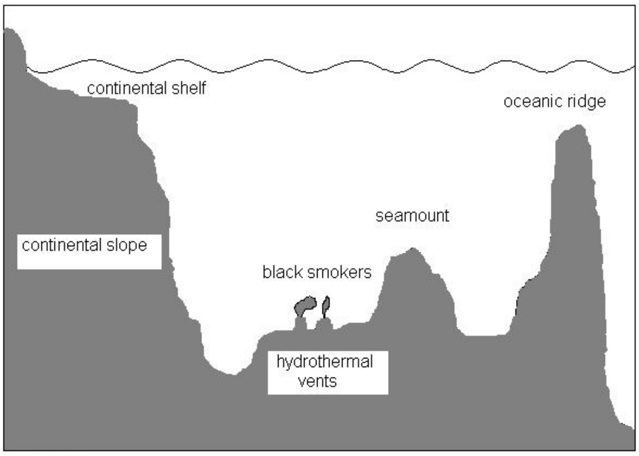
Hydrothermal vents were first discovered in 1977. Since then more than 500 species of animals associated with these vents have been described, with the majority found only in such areas. Hydrothermal vent communities are supported by a food chain based on bacteria that use chemical energy from the vent water (chemosynthesis), rather than energy from sunlight (photosynthesis). The animals found include giant tubeworms that can reach 1.5 metres in length, clams and blind shrimps. Chimneys up to 40 metres in height, made from dissolved minerals in the vent water, can form above hydrothermal vents.

Although there is still much to learn from these habitats, they are already threatened by human impacts. Several countries have moved to protect areas of hydrothermal vents within their national waters, but many lie in international waters where protection is more difficult.

Economic opportunities

There are two major examples of emerging economic opportunities in the deep sea that are very different in scope and impact. These are mining for seabed minerals and collecting marine organisms for pharmaceutical and industrial applications (bioprospecting). There is also the possibility of future CO_2 storage in the deep seabed.

Figure 1. Seabed features to depths >2000 metres



Deep-seabed mineral extraction
As the supply of accessible, high grade, minerals on land decreases, prospectors are increasingly surveying the seabed for metals such as copper, zinc and gold. These form very close to the surface of the seabed. One company, Nautilus Minerals, says that this, together with the higher grade of deep-seabed minerals compared with those on land means that 40 times less material needs to be mined to give the same total yield[4].

Minerals occur on the seabed in two forms:
- Polymetallic nodules, which are small balls of iron, manganese and other minerals that lie on the seabed. The International Seabed Authority (ISA, see page 3) has awarded contracts to a number of countries for their exploitation (mainly in the Indian and Pacific Oceans), although there is currently no commercial activity[5].
- Seabed massive sulphides (SMS) lie at extinct hydrothermal vents and contain copper, gold, zinc and other metals. They are extracted using remotely operated vehicles to scrape the deposits from the seabed and pump them to a barge.

Exploitation of SMS is currently the only economic source of seabed minerals. Most exploration is being carried out within the territorial waters of Polynesia, New Zealand and Japan, rather than in international waters. Nautilus Minerals is surveying areas for mining copper, zinc and gold down to 2,000 - 2,500m. It plans to begin deep-seabed mining of copper in Papua New Guinea waters in 2009. The London-based company, Neptune Minerals, has licences covering an area of 350,000 km^2 within the waters of Papua New Guinea, New Zealand, Japan and Micronesia, and intends to begin mining in 2010.

Bioprospecting
Bioprospecting is the harvesting of living resources, including plants, animals and microbes, for commercial gain. It involves collecting small amounts of samples from a large range of areas, with little or no need to return to the same spot, as samples can be cultured in the laboratory. Areas of high biodiversity are favoured for exploration and to date this has included tropical rainforests and shallow-water coral reefs. Increasingly, the high biodiversity found in the oceans is creating opportunities for the exploitation of living resources in areas including cold-water coral reefs, seamounts and hydrothermal vents.

Soft-bodied invertebrates like sponges and sea slugs have been targeted in shallow waters as they tend to have a range of biochemical defences that may be useful for technological or pharmaceutical applications. The major opportunities in the deep sea arise from the diverse populations of microbes in areas such as hydrothermal vents, where their adaptations to extreme conditions results in novel properties that are likely to favour exploitation.

Currently deep-sea microbes are used as a source for industrial biocatalysts (to speed up certain processes), biopharmaceuticals and antimicrobials. One group of deep-sea microbes (Actinobacteria) produce a compound that inhibits the hospital superbug, MRSA, and a protein that is used as an industrial catalyst. Other compounds may be able to act as an anti-cancer agent. Of the Actinobacteria that have been collected from deep-sea sediments, around 90% are newly discovered species, which suggests there could be many more avenues for industrial and pharmaceutical applications[6]. The economic potential of bioprospecting is summarised in Box 2.

Box 2. Economic potential of bioprospecting
World sales of all marine biotechnology-related products in the year 2000 were estimated at US$100bn[7]. Although the contribution from deep-sea products is relatively small, this is a growing area, with more than 37 patents registered in the USA and Europe. One UK biotechnology company, Aquapharm, estimates that currently 10% of their source material originates from the deep sea, and expects this to increase over the coming years. In the UK, companies commercialising products arising from bioprospecting often enter into public-private partnerships with academic institutes to gain access to deep-sea resources. The UK is currently lagging behind the USA and European countries, such as Spain, in terms of bioprospecting in the oceans. The Natural Environment Research Council has invested £6.9 million in 'blue technology' and estimates the economic benefit to the UK could reach £1bn over the next 25 years, assuming appropriate research and investment[8].

CO_2 storage
Carbon capture and storage (CCS) (see POSTnote 238) to reduce atmospheric CO_2 emissions may rely on geological features deep below the ocean floor for storage of the gas. The OSPAR Convention (see Box 3) has recently been amended to allow storage in the North East Atlantic. Any UK storage of CO_2 would mainly occur in the North Sea oilfields, although there is the possibility that this activity could be extended to areas in the deep sea.

A particular activity that could have a far greater impact on the deep sea environment, although is relatively unlikely, would be an attempt to store or inject CO_2 on the seabed itself. One method involves storing frozen CO_2 in the surface sediments of the deep ocean (>1000m), where the low temperature and high pressure allows the formation of frozen 'hydrates' of CO_2. Frozen CO_2 has a greater storage density than its gaseous or liquid equivalents and is less likely to leak. The cost of transporting CO_2 to the deep seabed is, however, likely to be significant and seabed deposition of CO_2 storage is currently prohibited in both international waters and in the North East Atlantic (OSPAR).

Legislation

Deep-sea habitats are found within both national and international jurisdiction. UK waters run to 3,000 metres in places. The territorial seas of a state extend to up to 12 nautical miles (nm) from the low water mark. In 1982, UNCLOS (see Box 3) defined the area from territorial waters to a limit of 200 nm (or to the edge of the continental shelf, whichever is farthest) as the Exclusive Economic Zone (EEZ) of a country. This allowed signatory states to regulate all aspects of the resources and use of the seas within their EEZ. Beyond the EEZ are international waters where resources are open to all nations. Mineral resources in such areas are regulated by the International Seabed Authority (ISA) that was set up under UNCLOS (see Box 3).

Legislation governing the marine environment is complex within the UK, EU and internationally. There are various regulations to protect marine animals and habitats (see Box 2). Industrial activities are generally regulated on a sector-by-sector basis.

Box 3. International Treaties and Directives

The following apply to the UK marine environment:

- 1972 London Convention: aims to protect the marine environment from all sources of marine pollution;
- 1982 United Nations Convention on the Law of the Sea (UNCLOS): details the legal status of marine resources and allows protection of the marine environment;
- 1992 UN Convention on Biological Diversity (CBD): aims to maintain/improve biodiversity in the oceans and outlines sustainable practice for exploiting resources;
- 1992 OSPAR Convention: signed and ratified by 15 countries in Europe aims to protect the marine environment of the North-East Atlantic;
- 1992 EU Birds and Habitats Directives: require Member States to protect natural habitats and species of wild plants and animals within waters of national jurisdiction through the designation of Special Areas of Conservation (SAC).

The UK Marine Bill White Paper (March 2007) aims to combine all the legislation on activities and conservation in the marine environment into one overarching piece of legislation. It also proposes to increase the network of Marine Protected Areas (MPAs) in UK waters by complementing existing legislation. Up to 24 European MPAs will be designated in the offshore marine area with 7 sites being consulted on later this year. The EU Future Maritime Policy Green Paper aims to co-ordinate EU policy and develop a thriving maritime economy based on sustainable management and increased scientific expertise. The consultation period for the Green Paper closed in June 2007.

Issues

International marine legislation was created before many economic opportunities in the deep sea were feasible. This has resulted in a grey area where there is little protection for important deep-sea habitats. As industry moves into the area, opportunities arise to clarify the legal situation and to protect the marine environment, while still promoting economic development.

Environmental Issues

Certain characteristics of deep-sea animals make them particularly vulnerable to human impacts. They generally have low productivity, growth and colonisation rates and are therefore highly sensitive to disturbance. They also tend to be long-lived and to reproduce late in life, which means that the removal of large numbers of individuals can potentially drive them to extinction.

Deep-seabed mineral extraction

Environmental issues of deep-seabed mining centre on damage to seabed habitats, alteration of geological processes and the release of plumes of material into the water column. Most seabed minerals are found around seamounts and hydrothermal vents that support important communities of animals with high biodiversity. Many aspects of these habitats are not understood. Opportunities for scientific research occur alongside mineral surveying. ISA rules require prior environmental impact assessments of mining activity, while in national waters rules vary between countries.

Bioprospecting

Environmental concerns over bioprospecting relate to the lack of legislation in national and international waters resulting in the risk of overexploiting living resources. The areas targeted by the bioprospecting industry are also important for biodiversity. They can also be well-suited for mineral extraction, resulting in the possible interaction of effects on the environment from multiple uses, the knowledge of which is currently limited[9].

Conservation and research

Many scientists, UNEP and environmental groups, including Greenpeace and WWF, are concerned that industrial activity in the deep sea may be accelerating at a rate faster than scientific knowledge and conservation efforts. For example, in the UK, marine monitoring receives less funding than terrestrial monitoring (£36m a year, compared with £500m)[10]. The House of Commons Science and Technology Select Committee is considering ways to coordinate better the efforts of research agencies and academia. To further advance knowledge it is necessary to establish the levels of biodiversity and the full range of where organisms are found in the deep sea. Until these are known it is difficult to determine whether any deep-sea activities are sustainable.

Scientists and environmental groups believe that a thorough, independent, environmental impact assessment should precede each deep-sea activity. Greenpeace and WWF feel that a globally representative network of MPAs and fully protected Marine Reserves should be used to protect areas from impacts. This would also allow the collection of vitally needed baseline scientific information.

Legislative and investment issues

Deep-seabed mineral extraction

As noted previously, there is a legal framework for deep-seabed mining in international waters through the ISA. However, some companies believe that its current allocation of contracts to particular countries for seabed mining is unfair and that the international seabed should be divided equally between all nations. Seabed minerals in international waters are legally defined as belonging to all nations and are therefore subject to a benefit-sharing scheme through the ISA. The intention is to share commercial benefits with developing countries, especially land-locked ones. The benefit-sharing regime has not been tested in practice, as there is currently no active deep-seabed mining in international waters. It may deter investment in international waters compared with EEZs, due to the increased cost of investment.

As for regulating the environmental impact of deep-seabed mineral extraction, the ISA has developed an environmental framework for the mining of polymetallic nodules in the international seabed. However, at the moment, the only type of commercial mining being undertaken is of SMS, for which no environmental framework has been developed, as it largely occurs in countries' EEZs.

Bioprospecting

There is legal uncertainty surrounding bioprospecting both nationally and internationally. Neither UNCLOS nor CBD (see Box 3) provide a clear framework for bioprospecting in international waters, resulting in unregulated activity. Greenpeace would like to see better regulation to ensure protection of the marine environment. They believe that a new UNCLOS agreement on conserving the marine environment should be created and a benefit-sharing regime should be applied. There is currently no legislation that details whether benefit-sharing applies to marine bioresources. Some companies believe that benefit-sharing of profits would deter bioprospecting. However, there are several ways of sharing benefits, including sharing scientific information and technologies that might permit bioprospecting, without deterring investment.

The legal uncertainty also impacts on the industry. Bioprospecting lacks a legal definition and regulations concerning patents are confusing and inconsistent between countries. The registration of a patent is the most effective way for companies to protect their investment, but uncertainties over definitions and regulations can cause delays, fines or even losses of patents if an incorrect application is made. There are also potential delays or denials in countries awarding surveying rights, which may discourage attempts to conduct bioprospecting alongside scientific research[11].

Companies are concerned that deep-sea bioprospecting could decrease if regulation increases, especially in international waters. The UK government has recently contributed to the EU position on exploitation of marine genetic resources in international waters, and discussed this issue at the United Nations in June 2007. The issues that were covered included benefit-sharing and environmental impacts. The conclusions from the meeting will appear in a UN General Assembly Resolution at the end of 2007, but any changes to international law would be complex and are not likely to happen in the near future.

Overview

- The deep sea is important for biodiversity and rare and newly discovered species.
- Industries moving into the deep sea include mineral extraction, bioprospecting and possibly carbon storage.
- The environmental impacts of these activities are not fully known and further scientific knowledge of the deep sea is required.
- Legislation is complex or lacking for many activities in international waters.
- Improved management and legislation can balance conservation of the environment with economic development.

Endnotes

1 http://www.nhm.ac.uk/nature-online/science-of-natural-history/expeditions-collecting/fathom-challengervoyage/assets/44feat_challenger_expid_1872.pdf

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3 *Quality Status Report 2000*, OSPAR Commission. 2000

4 Schrope, M. (2007) Digging deep *Nature* 447: 246-247

5 http://www.isa.org.jm/

6 Bull, AT (2004) Bountiful Oceans *Screenings* 4/2004 pp 14-16

7 UNU-IAS Report *Bioprospecting of genetic resources in the deep seabed: scientific, legal and policy aspects* 2005

8 http://www.nerc.ac.uk/publications/corporate/economic.asp

9 http://www.greenpeace.org/international/press/reports/bioprospecting

10 *Review of Environmental Monitoring in the UK*, Environment Research Funders' Forum. 2006

11 Hermes : Hotspot Ecosystems Research on the Margins of the European Seas, http://www.eu-hermes.net

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