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OVERALL CONCLUSION

Humankind's hunger for resources is insatiable. We need oil to power the world's one billion motor vehicles. We use around 20 million tonnes of refined copper annually to produce items such as electric cables and electric drives, and we utilize exotic metals such as neodymium in a wide range of industrial applications. Global consumption of energy has doubled since the early 1970s and, according to the International Energy Agency (IEA) in Paris, is likely to increase by more than one-third by 2035 due to world population growth and development in the major emerging economies of China and India. In consequence, the seas are attracting growing interest as a resource reservoir. The deep oceans host large oil and gas fields and ore deposits. Extracting this mineral wealth is a very appealing prospect.

Although gas and coal will be available in sufficient quantities well beyond the end of this century, oil is likely to be the first fossil resource to become scarce. Oil is currently the world's most important fossil fuel, with a good one-third of production now taking place offshore. The offshore oil industry is well-established.

In the early days, drilling took place solely in shallow coastal waters, but today, the oil industry has conquered the deep. With new geophysical methods of exploration, scientists can now search for oil and gas fields in the seabed and underlying geological strata up to a depth of 12 kilometres below the ocean floor. With these sophisticated methods, many large new deposits have been discovered in recent years, and known deposits have been resurveyed. During the period from 2007 to 2012, 481 major discoveries were made at water depths greater than 1500 metres, accounting for more than 50 per cent of all major offshore oil discoveries. Deepwater production is therefore likely to become increasingly significant. It is interesting that the offshore discoveries are, as a rule, 10 times larger than those discovered onshore.

As the explosion at the *Deepwater Horizon* oil rig shows, ultra-deepwater oil production is an ultrahazardous activity. Wells can only be accessed using special submersible vehicles, so incidents are almost impossible to control. Many causal factors led to the disaster: engineers on board misinterpreted readings from the well, and safety valves which should have closed off the well failed to activate. On the rig itself, the division of responsibilities was unclear. This was doubly problematical because operatives from several different subcontractors were working on board at the same time. Human errors thus went undetected.

In response to the disaster in the Gulf of Mexico, the offshore oil industry has developed special technology, known as capping stacks, for subsea incident response. Capping stacks can be deployed to stop the flow of oil from a gushing deep-water well. They are now on emergency standby at bases in the major oil-producing regions, including the Gulf of Mexico and the coast of Brazil. New regulations have also been introduced for onboard management of oil rigs in the Gulf of Mexico. One person with ultimate work authority on a rig must now be informed about every single step taken by subcontractors.

But these measures are unlikely to go far enough to avoid incidents and damage running into many billions of Euros in future. The tragedy is that the injured parties – such as fishermen and tourism businesses – often face lengthy delays in obtaining compensation because the oil companies and government become locked in legal disputes over the issue of liability. If an oil spill affects neighbouring countries as well, the lawsuits become even more complicated. This situation could be avoided if a straightforward liability regime were established, similar to that which exists for tanker operations. Here, an international convention has been adopted, which places strict liability for damage on the owner of a ship. The owner must therefore cover the costs of the damage. If these costs exceed the amount provided under the owner's insurance, an international fund comes into operation and disburses compensation swiftly without excessive red tape. A similar scheme would make sense for the offshore oil industry as well, but has been rejected by the oil multinationals. In the case of tanker operations, the oil-importing nations pay into the fund and then claim their contributions back from their national oil-processing industry.

Oil production in politically unstable regions, such as some West African countries, raises all manner of questions. Problems arise because profits from the oil industry are distributed inequitably, and due to corrup-

Overall conclusion

tion, there is little sharing of benefits. Very often, it is the local communities in the oil-producing regions that go away empty-handed. In Nigeria, for example, conflicts frequently occur, with various rebel groups fighting for control of the oil industry. Oil spilled from sabotaged pipelines and illegal micro-refineries has polluted large areas of the Niger Delta. In Angola – now the largest oil-producing country in sub-Saharan Africa – there is, fortunately, no open conflict, but here too, the sharing of benefits from oil production is extremely inequitable. There is a very high level of poverty throughout the country, and yet the capital Luanda is one of the most expensive cities in the world.

Methane hydrates – an alternative fossil energy source – are the subject of much discussion at present. Methane hydrates are solid ice-like compounds made up of methane, a component of natural gas, and water. The methane gas that forms hydrates rises from depth to the ocean floor. Most of the methane is produced biogenically by bacterial decomposition in deep layers of sediment, but a smaller proportion originates at even greater depth and is produced thermogenically deep underground by chemical conversion of biomass at high pressure and high temperatures. Methane hydrates form at water depths of around 500 to 3000 metres. Here, the water pressure is high enough, and the seawater temperature cold enough, for methane and the water in the sediment to solidify to form hydrates. The methane becomes so densely compacted that one cubic metre of solid methane hydrate can contain around 160 cubic metres of methane gas. Experts believe that the world's methane hydrates contain 10 times more gas than is available in all the conventional deposits. Methane hydrates are mainly of interest to countries which currently import most of their energy resources. Fossil fuels are particularly expensive in South Korea and Japan, as they have to be brought in by ship. Both these countries have extensive methane hydrate deposits in their coastal waters and are keen to make greater use of them in future. As yet, however, they lack the technology required for large-scale production of methane gas from hydrates.

As methane hydrates act as a kind of cement that binds soft sediment, critics fear that the extraction of methane hydrates will destabilize the continental shelf, potentially triggering tsunamis. According to scientists, however, extraction will be confined to small-scale drilling in shallow areas, thus avoiding major slumps. There is also a fear that ocean warming will release large quantities of methane, a potent greenhouse gas, from the deep seas into the atmosphere. Here too, researchers voice reassurance: according to their data, 95 per cent of all global deposits are found at depths greater than 500 metres and are therefore likely to remain protected against warming for a very long time.

For high-tech applications and modern mass-produced electronic devices such as photovoltaic systems, engines for hybrid cars and smartphones, many different resources are now required, such as metals extracted from ore. These too are present in large quantities in and on the seabed. Metals are found mainly in three types of mineral deposits: manganese nodules, cobalt crusts, and massive sulphides. Large numbers of manganese nodules, about the size of a potato or a head of lettuce, are found on the sediments in some areas of the seabed. They form extremely slowly, over the course of millions of years, around tiny cores – such as fragments of shell – on the seabed. Various processes are involved in their formation, including the precipitation of metals from seawater. There are four major areas of manganese nodules worldwide, the largest being the Clarion-Clipperton Zone (CCZ) in the Pacific, which extends across an area the size of Europe. The nodules contain manganese, iron, and many other metals that are important for industry. Cobalt crusts, on the other hand, are rock-hard deposits that have formed on seamounts. Seamounts are found in marine areas all over the world. Particularly crust-rich seamounts have been discovered in the Prime Crust Zone (PCZ) 3000 kilometres southwest of Japan, with an estimated 7.5 billion tonnes of crusts.

Like manganese nodules, cobalt crusts are formed by the precipitation of chemical compounds containing metals from seawater. Cobalt crusts, which form on the flanks of seamounts, also contain manganese and iron beside cobalt and other metals. Massive sulphides, on the other hand, form around undersea hot springs through the precipitation of sulphide minerals from fluids below the sea floor. Massive sulphides are of interest because they contain high levels of gold and silver. The deposits in the Bismarck Sea near Papua New Guinea appear to offer great potential.

Manganese nodules, cobalt crusts and massive sulphides are important for industry, for various reasons. Many metals are now extracted by what are, in effect, monopolies in a small number of countries, especially China, so resource-poor industrial countries such as Germany and France are keen to become more independent by staking claims to areas of the seabed.

To ensure that marine mining in the international seabed area does not result in countries squabbling over the best claims, it is regulated by the International Seabed Authority (ISA). This UN organization issues exploration licences and also ensures that valuable mineral deposits are reserved for developing countries. ISA regulations governing the future exploitation of marine minerals are currently being developed and are expected by 2016, initially for manganese nodules. Only then can exploitation in the international seabed area begin. It is notable that the protection of the marine environment features prominently in the ISA regulations. Within the future mining areas, the ISA requires zones to be designated for the protection of the seabed environment, with extraction of marine minerals prohibited here. It is the first time in history that rules for the allocation of a resource and for environmental protection have been adopted before exploitation begins. To date, the ISA has issued 12 licences for manganese nodule exploration in the Clarion-Clipperton Zone and one licence for the Indian Ocean.

Whereas the future exploitation of marine minerals in the international seabed area will thus be regulated by a uniform set of stringent rules, no such regime exists for the marine areas under the coastal states' jurisdiction. Although the United Nations Convention on the Law of the Sea (UNCLOS) obliges every state party to protect and preserve the marine environment, pollution is still a routine occurrence in many coastal waters. There is a fear that marine mining will create a new set of environmental problems here. Environmentalists are concerned that large-scale extraction will pose a particular threat to endemic seabed species. Marine biologists are therefore calling for further detailed environmental studies, before exploitation commences, to better assess the risks posed. However, there is a real fear that in some areas, mining operations will commence before these assessments have been completed.

Although chemical analyses show that very few cobalt crusts and massive sulphide deposits are sufficiently rich in metals to make exploitation worthwhile at present, many critics oppose the mining of these resources on principle. Both types of deposit form permanent structures on the seabed, and over time, these have developed into habitats for species-rich biotic communities based on sessile organisms such as sponges and corals. Large-scale extraction, in the biologists' view, can only be justified if mining companies leave some zones untouched as a starting point for the recolonization of harvested areas.

Will large-scale marine mining ever become reality? That remains to be seen. It is likely to be more expensive than onshore mining, but has the potential to avoid land-use conflicts. Over the next two years, the island state of Papua New Guinea plans to work with a mining multinational to extract massive sulphides containing gold and silver in its 200-mile zone, and it is likely that after 2016, manganese nodule extraction will begin in the Clarion-Clipperton Zone. But according to geoscientists, there are still many undiscovered deposits onshore, and theoretically, these could well be sufficient to meet the growing future demand for mineral resources. The most likely scenario, then, seems to be moderate exploitation of offshore marine minerals as a supplement to onshore extraction as required.

Global demand for fossil energy carriers and mineral resources will not decrease in future unless humankind takes action. This not only means developing new sources of supply; it also means devising new technological processes for resource recycling, including the establishment of collection systems and international transport chains. What is needed is a long-term strategy for clean energy and resource extraction for the benefit of future generations. We hope that the *World Ocean Review 3* can make a small contribution to the formulation of such a strategy.