

OPPORTUNITIES OF DEEP-SEA MINING AND ESG RISKS

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Summary

In recent decades, interest in deep-sea mining has been growing, focusing mainly on three types of deposits: **polymetallic nodules**, **polymetallic sulphides** and **cobalt-rich crusts**. These deposits could contain large amounts of minerals, making them an interesting option to meet growing global demand.

Several countries and the European Union have expressed a keen interest in these activities, seeing them as an opportunity to secure their supply of mineral resources and their independence (90% of the metals used in Europe are imported). France has defined a national strategy to support the sector's activities, and the European Union supports several exploration campaigns conducted by European consortiums. Some companies have also positioned themselves in the sector, although no mining activity has started to date.

Deep-sea mining faces several types of hurdles, however. From a **regulatory** standpoint, obtaining permits for exploration and especially for mining is far from simple. Mining in international waters, regulated by the **International Seabed Authority (ISA)**, is in fact currently impossible as the regulations for these activities are incomplete. In **Exclusive Economic Zones (EEZ)**¹, the rules and requirements set by each country must be complied with.

Extracting ores at depths of up to 5,000 metres also represents a major **technological challenge**, notably in terms of dealing with pressure and low temperatures. Apart from an elaborate system to extract polymetallic sulphides, there is as yet no operational mining technology.

Deep-sea mining would especially have significant **environmental impacts**, as has been demonstrated by many scientific reports². Given the broad **lack of knowledge of these environments' ecosystems**, it is difficult to estimate

¹ *EEZ: the zone extending beyond territorial sea and adjacent to it, over which the coastal State has special rights regarding the exploration and use of marine resources, including energy production from water and wind. It extends in a radius of 200 nautical miles (370 km) from the baseline (the mean low water mark, the maritime chart datum)*

² *One can refer notably to Professor Richard Steiner's report on the assessment of the environmental impact of Nautilus Minerals (2009), the CNRS-Ifremer collective expertise on the "Environmental impact of deep sea mineral resources exploitation" (2014), or the reports of the Deep Sea Mining Campaign*

the extent of these impacts and the potential resilience of species following the disturbance caused by mining. According to Yves Fouquet, a geologist at Ifremer, “we have a better knowledge of the Moon than of the depths of our oceans, which make up 71% of the globe’s surface”. **Social impacts** (disturbance to fishing, local customs, etc.) could also be significant, but they remain largely unknown and unexplored. Finally, it is important to remain vigilant about **governance** issues. Deep-sea mining will generate additional revenue for a number of countries, which will require strong institutional and regulatory capacities to manage this revenue and avoid the so-called “**resource curse**”³. The comparison of the impacts of land and deep-sea mining is also a subject of debate.

In order to better understand these issues and establish a situational analysis of current activities, we contacted the main players involved in deep-sea mining, both French and international. In addition to the obstacles cited above, it appears that the development of these activities has slowed due to **low mineral prices**, which already makes existing above- and underground mining operations difficult economically speaking and limits the opening of new mines. An upturn in mineral prices, however, could quickly lead to renewed interest in deep-sea mining, which could offer several **advantages compared to terrestrial mining** (higher metal content, possibility of moving and re-using mining equipment, etc.).

Deep water biodiversity is unique and fragile, and the impacts of mining are largely unknown, but potentially serious. The ESG rating methodology that we propose for companies involved in these activities is therefore based on a precautionary approach.

³ *Resource curse: the resource curse, also known as the paradox of plenty, refers to the paradox that revenue generated by natural resources can have negative consequences on a country’s economy, society and political stability (rise in violent conflicts, corruption, etc.)*

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OPPORTUNITIES AND ESG RISKS OF DEEP-SEA MINING

Introduction

Interest in deep-sea mining started to develop in the **1970s**, focusing mainly on three types of deposits: **polymetallic nodules**, **polymetallic sulphides** and **cobalt-rich crusts**. Although exact details on the resources are not known, these deposits could contain significant quantities of minerals, notably copper, zinc, nickel, lead, indium, cobalt, as well as gold and silver. To take the example of cobalt, global land reserves and resources represent around 13 million tons, while it is estimated there are 50 million tons in the cobalt-rich crusts of the Prime Crust Zone (in the Pacific) and 44 million tonnes in the polymetallic nodules of the Clarion-Clipperton Zone¹ (also located in the Pacific).

Given the quantities of these mineral resources, the question can legitimately be asked whether deep-sea mining is a promising and above all sustainable activity.

Meeting demand and securing supply

Deep-sea mining could respond to a big **economic challenge** on a global scale. Global demand for minerals is set to increase constantly. Demand in developed countries will continue to rise, as “high-tech” minerals such as cobalt, platinum, rare earths and titanium are becoming essential to the development of sophisticated technological products. In addition, growing demand in developing countries such as Brazil, Russia, India and China will compete with that of developed countries. The urbanisation of China and the rest of Asia will notably require significant mineral supplies.

Furthermore, deep-sea mining resources can respond to a major **strategic issue** for European member states keen to secure their assets and become more independent. Europe’s economy is more than 90% dependent on metal imports².

¹ ECORYS, *Study to investigate the state of knowledge of deep-sea mining*, November 2014

² DYMENT (J.) et al., *Les impacts environnementaux de l’exploitation des ressources minérales marines profondes*, *Collective Scientific Expertise, Summary report*, CNRS-Ifremer, June 2014

China is a major supplier, notably producing more than 97% of the rare earths used in the world³. Similarly, more than 40% of global cobalt production comes from the Democratic Republic of Congo. The table below provides information on the main producers of minerals of medium or high economic importance for the EU and present in deep waters.

Ore	Main Producer	Economic importance for the EU	Supply risk
Cobalt	Democratic Republic of Congo (40%)	Strong	High
Copper	Chile (34%)	Medium	Low, critical metal for the United States
Lithium	Chile (41%)	Strong	High
Platinum	South Africa (79%)	Medium	Medium
Rare earths	China (97%)	Strong	High

Source: Ecorys, *Study to investigate the state of knowledge of deep-sea mining* (2014)

To avoid supply crises like the one experienced in 2000, when the boom in mobile phones led to a surge in demand for tantalum, the European Union launched a “Raw Materials” initiative in 2008⁴. This initiative aims to diversify access to raw materials, beyond traditional Chinese, African and South American suppliers. The EU notably finances several research consortiums whose purpose is to acquire more knowledge of deep-sea ecosystems and develop mining technologies, such as the Mining Blue, Blue Nodules and MIDAS projects (cf. “Activities” section).

Many advantages compared to terrestrial mining...

According to the players⁵ engaged in research on deep-sea mining, it would even be more profitable than surface- and underground mining. Terrestrial mining costs are always very high and are tending to increase due to the need to dig increasingly deeper to extract minerals. The competitiveness of deep-sea mining may therefore be acceptable for an industry player, all the more so as mineral concentration on the ocean floor is far greater than on land. Technologically, deep-sea mining would also be less expensive as it is only necessary to recover what is on the surface, without having to dig deep mines. This technique therefore requires no expensive mining equipment, but just one machine capable of pumping

³ ECORYS, *Study to investigate the state of knowledge of deep-sea mining*, November 2014

⁴ *The Raw Materials Initiative: Meeting Our Critical Needs for Growth and Jobs in Europe*, Communication from the Commission to the European Parliament and the Council, available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0699&rid=3>

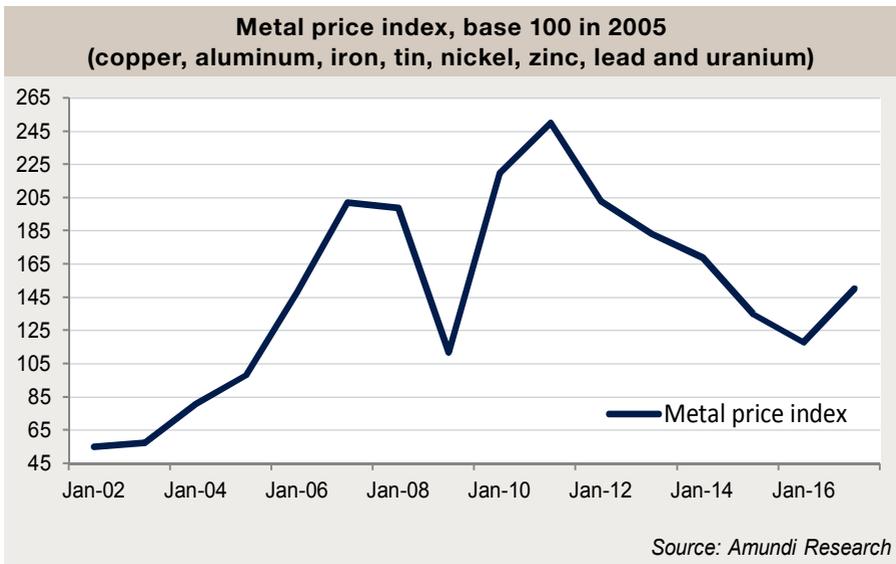
⁵ *Technip and Eramet in France are two cases in point. Cf. “Activities” section for further details*

up deposits to the surface, and a barge. In addition, unlike for terrestrial mining, the equipment can be moved, which means that the investments are not lost after a site has been mined. Finally, once the technologies have been developed and are operational, it is estimated that deep-water sites will be workable in one to two years. This is very fast compared with open-it- and underground mines, which sometimes take ten years to be operational.

Deep-sea mining would therefore be more profitable, particularly for certain types of deposits. Polymetallic sulphides are the ones holding the greatest potential. Their high metal content (up to 8.5% in copper and 16% in zinc, for example⁶) would therefore offset the mining costs. As polymetallic nodules have fairly limited metal content, terrestrial mining could be more profitable in this instance.

... but no operational mines so far

Despite the many advantages and opportunities deep-sea mining seems to offer, the economic climate is currently not ideal for the development of this activity. **Metal prices being relatively low** (cf. chart below), industry leaders are already challenged to generate profits on existing surface- and underground mines. Until the crisis of 2008, deep-sea mining was a hot topic. With the fall in ore prices (cf. chart below), there was a big shift. Industry leaders have a short-term outlook and their enthusiasm soon waned. The scarcity of certain metals such as copper, or their rising prices, could justify renewed interest in deep-sea mining.



⁶ Fouquet, Y. and D. Lacroix (2012). *Les ressources minérales marines profondes : étude prospective à l'horizon 2030*, Editions Quae

Risks and challenges

Deep-sea mining is still an activity that involves significant risks and challenges. It requires **new technologies**, which have not yet been fully developed. In addition, **scientific knowledge of deep-sea habitats and ecosystems** remains very limited. According to Yves Fouquet, a geologist at Ifremer, “we have a better knowledge of the Moon than of the depths of our oceans”. Estimating the potential **environmental impacts** of mining, as well as the **impacts on communities**, is therefore very difficult. For this reason, exploration and mining activities are often impeded by attempts to develop **regulations** that take into account these unknown factors. Lastly, this sector is highly dependent on fluctuations in ore prices, and developing it is not economically viable at this juncture.

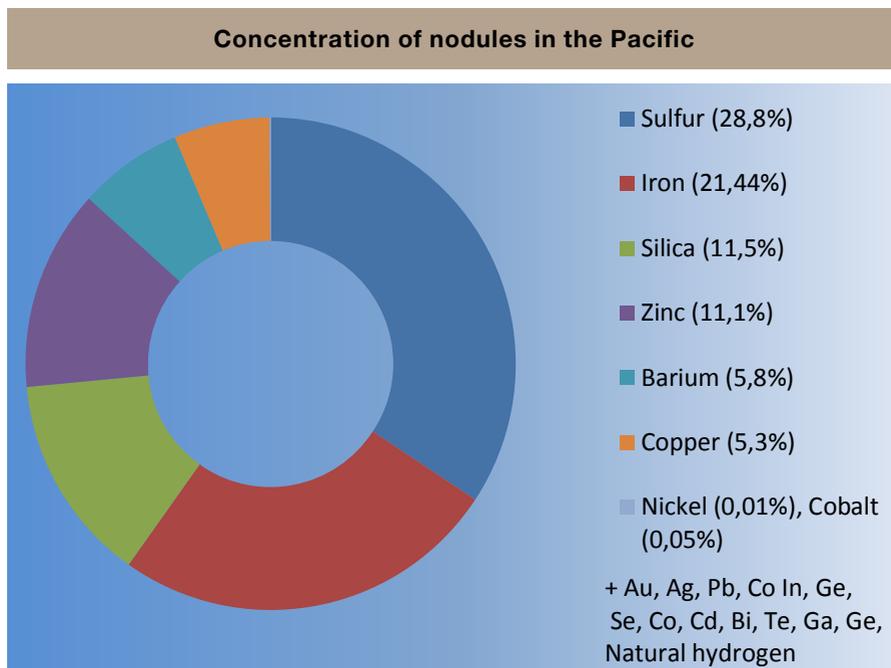
This study was therefore initiated in a bid to identify the various stakeholders of deep-sea mining and to establish a situational analysis of the progress of activities. We wanted to understand the key issues (economic, technological, regulatory, environmental and social) faced by the sector, and how it can, or tries to, address them. The goal is to produce an ESG rating methodology for companies involved in these activities.



I. Mapping of different ore types

1.1. Polymetallic nodules

Polymetallic nodules are pebbles the size of a grapefruit, about 5 to 10 cm in diameter. They are located on abyssal plains at depths of 3,000 to 5,500 metres. These formations are 40% water and 60% minerals, mainly manganese and iron. They also contain many other minerals: copper, nickel, silicon, aluminium, cobalt, rare earths, lithium, thallium, tellurium, molybdenum.



Source: Ifremer, 2011

The largest mass of nodules is located at depths of 4,000 to 5,000 metres, in the **Clarion-Clipperton fracture zone** between Hawaii and the west coast of the Pacific. This area of 9 million km² reportedly contains 34 billion tons of nodules, of which nearly 300 million tons of nickel and more than 200 million tons of copper⁷. According to some experts, nodule deposits contain 6,000 times more thallium, three times more manganese, nickel and cobalt than the entire proven land resources⁸.

⁷ ECORYS, *Study to investigate the state of knowledge of deep-sea mining*, November 2014

⁸ PANGRAZZI (C.), "Le domaine maritime de la France vient de s'agrandir – Pourra-t-on exploiter les richesses des fonds marins?", *Ca m'intéresse*, March 2016

Not surprisingly, it is mainly in the Clarion-Clipperton fracture zone that exploration activities to extract polymetallic nodules are focusing. Of the 16 exploration licences granted by the International Seabed Authority (ISA) for nodule exploration, 15 concern this zone. Moreover, it is interesting to note that the majority of research in the Area concerns this type of deposit (16 ISA exploration licences of a total of 26).

That said, some industry players in deep-sea mining (ERAMET and Technip in France, in particular) consider that this craze for polymetallic nodules is unwarranted. They say that metal contents in these zones are fairly low, making terrestrial mining more profitable in relative terms given the lower mining costs. According to them, the focus should be more on polymetallic sulphides, which contain a mixture of many metals like copper, zinc and even some precious metals, such as gold or silver. This would offset mining costs.

1.2. Polymetallic sulphides (Seafloor Massive Sulphides - SMS)

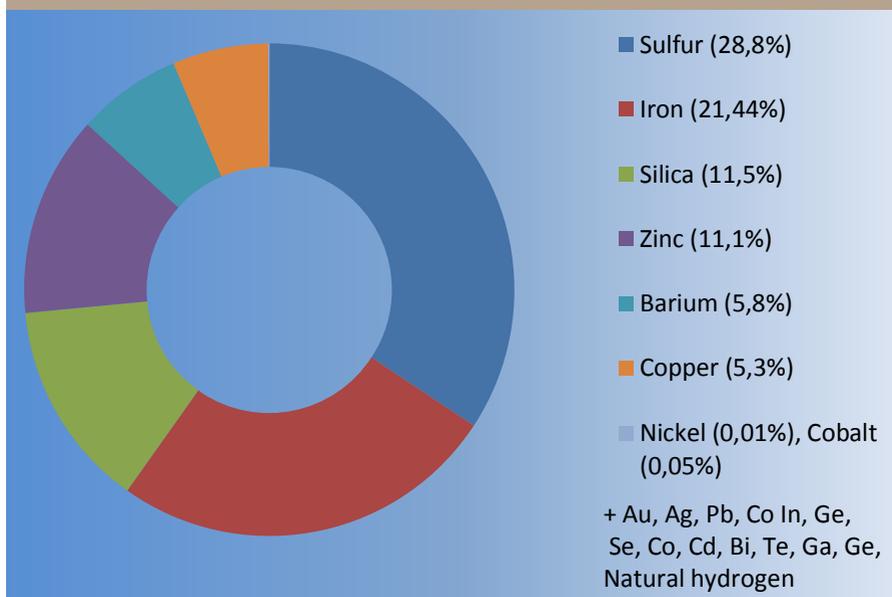
Polymetallic sulphides were discovered at the end of the 1970s. Most of the deposits of potential economic interest lie at depths of 1,500 to 3500 metres, along the 60,000 km of mid-ocean ridges⁹. These deposits look like chimneys of up to 40 metres high, called black smokers. They form on hydrothermal sites, when sea water enters very deep flaws and absorbs heat and metal sulphides. This fluid is then re-evacuated into cold ocean waters. Polymetallic sulphides are generally concentrated in small areas of less than one square kilometre, unlike nodule deposits that extend over large areas. They are mainly located on the East Pacific Rise, the Southern East Pacific Rise and the North Pacific Rise, as well as on the Mid-Atlantic Ridge. More research is needed, but many deposits are also reportedly located along the Indian Ridge.

As mentioned above, sulphides are very rich in metals. The main ones are sulphide, iron, silica, zinc, copper, and barium. Some deposits have a copper content of about 10%; by way of comparison, the major Chilean mines from which most of global production comes contain only 0.5%¹⁰. Turning to precious metals, sulphides can have a gold content of up to 20 grammes per ton. By way of comparison, a content of 1 gramme per ton is enough to justify mining a terrestrial deposit.

⁹ Mid-ocean ridge: underwater mountain range, whose summit is crossed by major fractures

¹⁰ PANGRAZZI (C.), "Le domaine maritime de la France vient de s'agrandir – Pourra-t-on exploiter les richesses des fonds marins?", *Ca m'intéresse*, March 2016

Concentration of sulphide ores in the eastern Pacific zone



Source: Ifremer, 2011

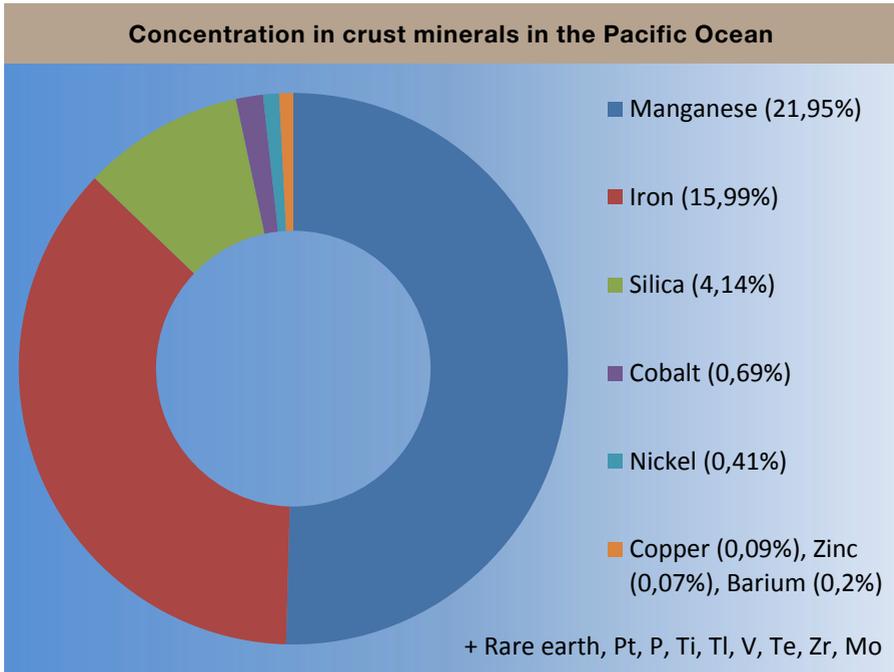
There are fewer exploration campaigns for polymetallic sulphides in the Area than for nodules. Of the twenty-six exploration licences granted by the ISA, six are for polymetallic sulphide deposits. The sites in question are located on the Southwest Indian Ridge, the Central Indian Ridge, and the Mid-Atlantic Ridge. On the other hand, almost all of the licences awarded by States for exploration campaigns in their EEZ are for sulphides. It is also interesting to note that ocean floor mapping missions generally seek to locate inactive hydrothermal sites. Any mining would only be possible on these sites, as the temperature and acidity of the fluids present in active sites would instantly destroy the equipment.

1.3. Cobalt-rich crusts

Cobalt-rich crusts are dense layers ranging from a few centimetres to 25 centimetres. They are located on the flanks of seamounts, at depths ranging from 400 to 4,000 metres. The crusts with the highest content in minerals potentially of economic interest are mainly at depths of 800 to 2,500 metres¹¹. They cover areas of several square kilometres. Much research still needs to be performed, but according to a number of estimates, 6.35 million square

¹¹ Hein, J.R. and Koschinsky, A. (2013): *Deep-ocean ferromanganese crusts and nodules*. In: *Treatise on Geochemistry*, 273-291

kilometres, or 1.7% of the oceans' surface, could be covered with crusts¹². Crusts have been spotted in all oceans, but it is the Pacific ocean, more particularly French Polynesia, that reportedly has the deposits with the greatest economic potential, enriched in cobalt and platinum.



Source: Ifremer, 2011

Crusts are composed mainly of iron and manganese. They also reportedly contain three times more cobalt and five times more platinum than terrestrial deposits. Other metal elements present include titanium, nickel, rare earths, zirconium, molybdenum, vanadium, tellurium, thallium, and phosphorus.

The possibility of mining crusts has been the subject of little investigation and few exploration campaigns have been undertaken. Only four exploration contracts have been granted by the ISA for this type of deposit, all in the Western Pacific ocean. A recent study by the French Institute for Research on Development (IRD) shows that resuming exploration in French Polynesia holds promise¹³.

¹² DYMENT (J.) et al., *Les impacts environnementaux de l'exploitation des ressources minérales marines profondes*, Collective Scientific Expertise, Summary report, CNRS-Ifremer, June 2014

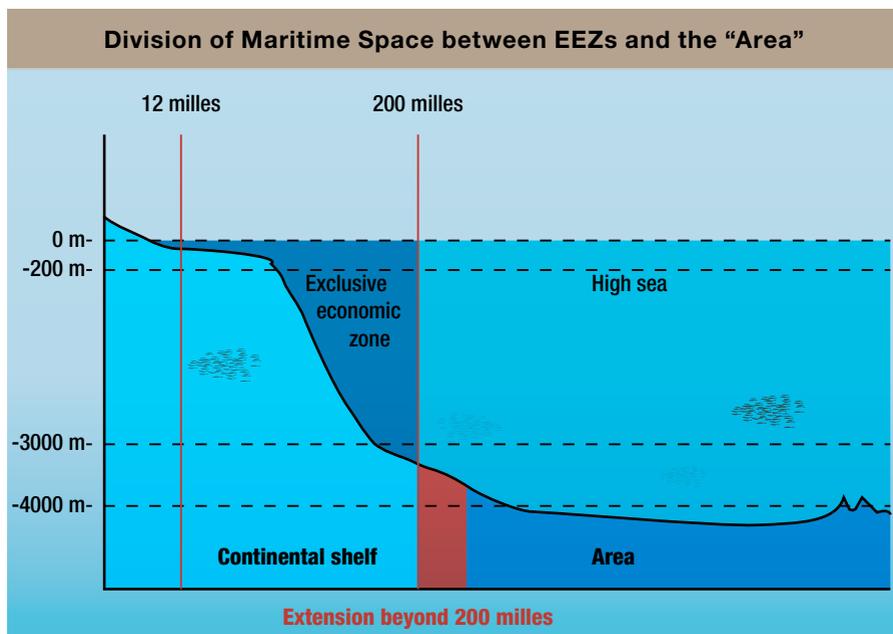
¹³ LE MEUR P.-Y., COCHONAT P., DAVID C., GERONIMI V., SAMADI S., *Les ressources minérales profondes en Polynésie française*, IRD Éditions, 2016

II. Regulations

2.1 Organisation of the Law of the Sea

The **United Nations Convention on the Law of the Sea** (UNCLOS), also called the “Montego Bay Convention”, is a fundamental international treaty adopted in 1982. It recognises the sovereign rights of coastal States on their **Exclusive Economic Zone** (EEZ) and their **continental shelf**¹⁴, as well as the national non-appropriation of resources located beyond national jurisdictions. 166 parties ratified the Convention, including the European Union and its member states. On the other hand, some States such as the United States, Israel and Turkey, have still not ratified the treaty.

The International Seabed Authority (ISA) was formed by the United Nations Law of the Sea in 1994, in accordance with the UNCLOS. Its purpose is to manage and regulate the maritime spaces outside the maritime zones of States, recognised as a common heritage of mankind and referred to as “**the Area**” (cf. diagram below). Its main role is to develop regulations for the exploration and mining of resources in these spaces. It delivers exploration licences aiming to quantify mineral reserves and to assess biodiversity in these waters.



Source: French Navy's Hydrographic and Oceanographic Department (SHOM)

¹⁴ Continental shelf: underwater prolongation of a State's land territory

2.2. Regulation and licencing of exploration and mining

2.1.1. Projects located in the Area

The ISA has already developed regulations for exploration projects and is working on developing one for mining projects. Missing elements notably include how the ISA will collect royalties, profit sharing, and environmental standards. Implementing deep water regulations is challenging given the currently very limited knowledge of this environment. More research is necessary to acquire a better understanding of the ecosystems that live there.

All of the rules and procedures related to deep-sea mining (in particular Annex III of UNCLOS) form the **mining code**. As mentioned above, regulations specific to each type of deposit are available for exploration. The ISA has also published recommendations to help businesses carry out their environmental impact assessment as well as their environmental management plan. The decision to award licences or not rests with the Board of the ISA, composed of 36 members elected by an Assembly, based on a complex set of rules. To date, **26 exploration licences** have been granted. Each licence costs \$500,000 and is valid for 15 years. Companies or States holding these licenses are required to file annual activity reports. Applications for mining licenses will be possible as soon as the regulations specific to mining have been completed. This should be the case by the end of 2017.

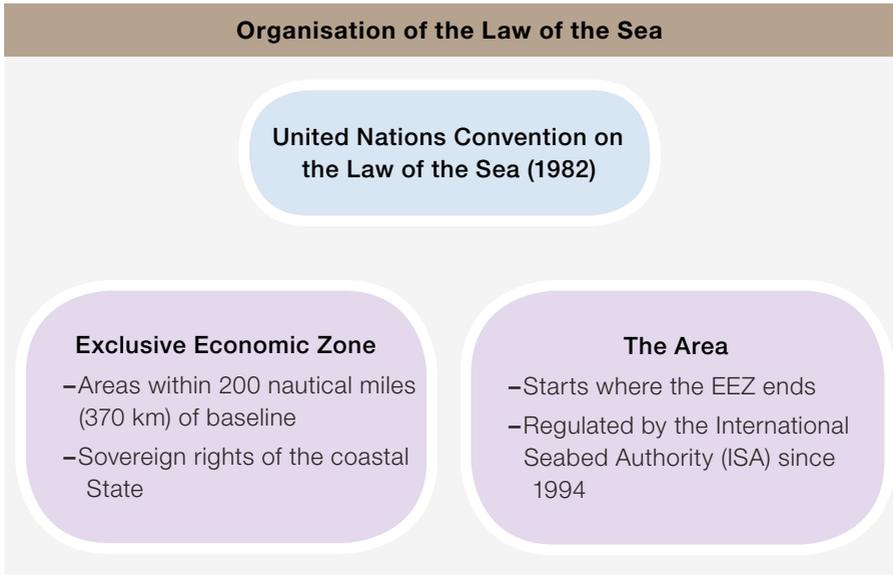
2.2.2. Projects located in EEZs

Exploration or mining projects must comply with national regulations when they are located in a State's EEZ. In many cases, terrestrial mining legislation also applies in deep waters. In Europe, this is the case for France, Italy, the Netherlands, Portugal and Spain. Applying terrestrial mining regulations to deep-sea mining is not necessarily the most appropriate solution. Some issues specific to deep-sea mining are not properly addressed in terrestrial regulations, notably mine closures, waste management, the security measures to be taken, or the rights of impacted communities.

In some instances, the law has been changed in order to include specific references to deep-sea mining, France being a case in point. The existence of specific legislation for deep-sea mining is much less frequent. The United States is one of the few countries to have such legislation. The administration of the Azores also decided to adopt specific regulation on deep-sea mining, although it was later declared unconstitutional.

In order to obtain an exploration or mining licence, companies must carry out an environmental impact assessment, the content and methodology of which being defined by each State. It is then up to the public ministry to decide whether or not to award a licence and to monitor the implementation of the environmental management plan. Obtaining an overall view of the licences awarded by States

poses a challenge as there is no single source or database available, and States and companies do not always wish to make this information public. In 2014, a study identified **26 projects having been awarded a licence in the EEZs¹⁵, of which two for mining**: one to Nautilus in the Bismarck Sea and one to Diamond Fields and Manafa International in the Red Sea (cf. “Activity” section).



2.3. Extension of States’ maritime territory

According to maritime law, a State’s EEZ is set at 200 nautical miles from its coastline, i.e. roughly 370 km. In addition, the UNCLOS allows countries to extend their jurisdiction over the continental shelf up to 350 miles (650 km) if they can prove through geological studies that their land territory extends under water. However, the State only exercises its rights on the seabed and the marine subsoil, the water column remaining in the international domain. Applications for an extension of a State’s jurisdiction on the continental shelf must be approved by the **Commission on the Limits of the Continental Shelf**.

For instance, in October 2015, France was able to extend its maritime area by 579,000 km². With 11 million km², it now has the second-largest EEZ in the world behind the United States. France could further extend its maritime area by 1.5 million km² around its overseas departments and territories, enabling it to move up to first position. Several applications for an extension of the continental shelf have been filed before the United Nations Commission on the Limits of the Continental Shelf. France intends to protect its mining assets in this way. The

¹⁵ ECORYS, *Study to investigate the state of knowledge of deep-sea mining*, November 2014

French Ministry of Foreign Affairs and International Development, using the work conducted by the French Navy's Hydrographic and Oceanographic Department (SHOM), is responsible for negotiations with a number of States in cases where maritime boundaries have yet to be fixed.

2.4. Potential geopolitical issues

France has already entered into agreements on the delimitation of its maritime boundaries with most of its neighbours. In French Polynesia, for example, delimitation agreements have been signed with all the neighbouring States (the Cook Islands, Kiribati and the United Kingdom). Delimitation agreements must still be passed with some States, however, notably with the Samoa Islands for Wallis and Futuna and Vanuatu in New Caledonia. In the latter case, a territorial dispute over the Matthew and Hunter Islands is opposing the two parties.

Deep-sea mining can involve potential conflicts related to the delimitation of States' maritime boundaries. Such conflicts may notably arise when the limits of the continental shelf and of the economic zone between two neighbouring States coincide. This can happen when coasts facing each other are at a distance of 400 nautical miles or less. No case has occurred so far with regard to deep-sea mining. On the other hand, the question has already arisen in the field of hydrocarbons. In this case, shared mining zones for the resources of the plateau straddling the dividing line were implemented. For example, this is what was decided in the French-Canadian agreement of 17 May 2005 for the exploration and mining of cross-border oil fields in the North Atlantic.

As mentioned above, no major geopolitical conflict related to deep-sea mining has occurred so far. However, should the rise in mineral prices lead to renewed interest in these activities, disputes could arise between States over maritime boundaries.



III. Activities: stakeholders and projects

While **26 exploration licences have been granted by the International Seabed Authority (ISA) to date, around twenty have been granted by States for activities in their EEZ.** Only two projects so far have been granted a mining licence, both by national jurisdictions: Nautilus's Solwara 1 project in the Bismarck Sea, and Diamond Fields International and Manafa International's Atlantis II project in the Red Sea. The ISA will be able to start granting mining licences once the regulations on mining activities that it is working on have been finalised.

Most of the licences granted by national jurisdictions are for private companies, and for the exploration of polymetallic sulphides. Private companies are more interested in this type of deposit, while governments and public companies are focusing more on nodules. This is due to the fact that most experts believe that sulphides will be the first type of deposit for which mining will be economically viable, while nodule mining could allow States to secure their supply of some strategic minerals such as cobalt or rare earths.

3.1. Main private initiatives

Private companies involved in deep-sea mining are facing several obstacles. Access to finance is a major challenge, in particular due to the volatility of metal prices. An excessive drop in prices can affect a project's commercial viability. Furthermore, companies have to engage in substantial expenditure to find sufficient resources. Unlike terrestrial mining, the phase of exploration and identification of potential resources is itself very costly. Regulations represent another major obstacle for companies. In several regions, the legislation simply does not exist, while others have specific requirements. In Japan, for instance, a licence applicant must have a Japanese partner, which is not always easy to find.

The vast majority of projects located inside EEZs are run by private companies **Nautilus Minerals** and **Neptune Minerals**.

3.1.1. Nautilus Minerals

Nautilus Minerals is a Canadian company founded in 1987, listed on the Canadian market. Its main shareholders are Barrick Gold Corporation, Anglo-American, Teck Cominco, and Epion Holdings. Its main activity is the exploration of seabed mineral resources.

Nautilus is a major player in deep-sea mining. The company has a very large number of exploration licences in EEZs, and even a licence to operate in Papua New Guinea for the Solwara 1 project. Moreover, Nautilus Minerals is the first private company to have been granted an exploration licence in the Area, through its subsidiary **Tonga Offshore Mining Ltd. (TOML)**. Nautilus collaborates with several technical players, working on the development of advanced technologies. These include **Soil Machine Dynamics**, a British underwater engineering firm specialised in the

design and manufacture of remotely-operated vehicles. Nautilus has also entrusted French company **Technip** with the development of the vertical transport system (Riser and Lifting System - RALS) for the Solwara 1 project, and US company GE Oil & Gas with the construction of the RALS pump to siphon mineralised slurry from the ocean floor.

Solwara 1

In 1997, Papua New Guinea (PNG) was the first country in the world to grant an exploration licence for polymetallic sulphides deposits, to Nautilus Minerals. In 2009, Papua New Guinea gave the company an environmental permit for the Solwara 1 project, followed by a 20-year mining licence granted in 2011. The area concerned is in the Bismarck Sea at a depth of 1,200 to 1,600 metres. Mining was scheduled to begin in 2013 with the goal of extracting 2.17 million tons of minerals, of which 435,000 ounces of gold and 157,000 tons of copper. The mine's expected life span is 30 months, with a maximum output of 5,900 tons of ore per day¹⁶. Mining could be extended to five years or more depending on what minerals are discovered.

In 2009, an independent review of the environmental impacts of the Solwara 1 project by Professor Richard Steiner of the University of Alaska criticised the project's Environmental Impact Assessment (EIA)¹⁷. According to this report, the assessment is too broad to determine the project's real environmental impact. Steiner notably cites an inadequate assessment of the risks associated with the creation of toxic plumes, as well as the absence of a thorough study of the site's ecosystems. The report recommended that the PNG government should not approve the Solwara 1 project. The report was criticised by Nautilus Minerals, which in particular accused Professor Steiner of being funded by environmental activists and having a biased view. The company pointed out that an independent review of the EIA had been funded by the PNG government and carried out by a consulting firm. It is on the basis of this expertise (not publicly available) that the PNG government reportedly granted Nautilus Minerals an environmental licence. Another study by the Deep Sea Mining Campaign in 2012 voiced similar criticisms of Nautilus's Environmental Impact Statement (EIS), also arguing that it failed to properly identify the risks associated with the project and underestimated its impact on local communities¹⁸.

According to Nautilus Minerals, mining poses no risk to ecosystems given the precautions taken by the company. These include the Environmental Impact Statement, the Nautilus CARES programme, as well as mitigation strategies such

¹⁶ STEINER (R.), *Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea, conducted for the Bismarck-Solomon Seas Indigenous Peoples Council Madang, Papua New Guinea, January 2009*

¹⁷ *Ibid*

¹⁸ LUICK (J. L.), *Physical Oceanographic Assessment of the Nautilus EIS for the Solwara 1 Project, Prepared for the Dee Sea Mining Campaign, November 2012*

as the use of underwater robots (drones) that will move the blocks of sediment containing the largest biomass to a temporary refuge area. Nautilus also puts forward an independent analysis by Earth Economics in 2015¹⁹ showing that the social and environmental impacts of the Solwara 1 project could potentially be significantly reduced compared with those of terrestrial copper mines. The project will not cause any population displacements and will have no impact on food production or drinking water reserves, whether they be surface or groundwater. That said, the Earth Economics study was criticised by the Deep Sea Mining Campaign (cf. section “Impacts of deep-sea mining”).

Furthermore, although the Nautilus project has come under much criticism, one should bear in mind that it is the most comprehensive scientific research so far. Missions undertaken as part of the exploration campaign and the environmental impact assessment have provided a great deal of information on deep water biodiversity.

Due to a conflict between Nautilus and the government of Papua New Guinea on their partnership agreement, the project was suspended in 2013. However, Nautilus announced in 2015 that the project was maintained and that it hoped to start production in 2018. The technologies are developed, and Nautilus is now waiting for the arrival of ships manufactured in China. These should be commissioned by the end of 2018, and mining of the Solwara 1 site is slated to begin in 2019. If this mining project turns out to be economically viable, it is very likely that other players will seek to position themselves in the sector.

3.1.2. Neptune Minerals

Neptune Minerals is a US company which was created in 2011 for the exploration and mining of polymetallic sulphides. The company has undertaken projects in seven countries of the Western Pacific (Japan, Papua New Guinea, Solomon Islands, Vanuatu, Fiji, Tonga and New Zealand). The area covered by the exploration licences requested and granted is 175,000 km².

Neptune is committed to developing responsible exploration and mining processes for deep sea resources. Environmental observations and data collection form an integral part of the company’s exploration programmes. Neptune also supports and takes part in several research projects aiming to protect the marine environment. For example, the company is currently working with the University of Ottawa on a geological research programme focusing on the Solomon Islands.

On the social front, Neptune supports and regularly contributes to the Secretariat of the Pacific Community Applied Science and Technology Division (SOPAC) of the Deep Sea Minerals Project. This collaborative project between the Pacific communities and the European Union was founded in 2011. It aims to support

¹⁹ *BATKER (D.) & ROWAN (S.), Environmental and Social Benchmarking Analysis of Nautilus Minerals Inc. Solwara 1 Project, Earth Economics, May 2015*

the implementation of an informed, vigilant governance for deep-sea mining projects²⁰. However, there is little feedback available concerning the relevance and effectiveness of this programme.

3.1.3. Diamond Fields International & Manafa International

Diamond Fields International is a listed Canadian mining company holding multiple terrestrial and deep-sea mining licences (for diamonds in Namibia and nickel in Madagascar, in particular). Manafa International Ltd. is a Saudi holding and investment company with a strong presence in the Middle East. These two companies are not major players in the sector of deep-sea mining, but they are important in the sense that they are preparing to jointly operate one of the only two projects to have received an operating licence, the **Atlantis II project**.

The Atlantis II basin containing the Atlantis II deposit is located in the Red Sea, at a depth of about 2,000 metres. Minerals were discovered there in 1965. In the 1970s, the **Saudi-Sudanese Red Sea Commission** (RSC) was created with the objective of assessing the economic potential of the resources of the Atlantis II basin. Preussag A.G. was tasked by the RSC with undertaking a five-year geological exploration programme and a technical feasibility study. The results showed significant presence of minerals in an area of 57 square kilometres. A Preussag study notably revealed that the Atlantis II basin contained 89.5 million tons of sediment, with contents of 2.51% to 4.91% zinc, 0.47% to 4.91% copper and 59.43ppm to 111.24 ppm silver²¹.

In 2010, the Red Sea Commission was reinstated especially to grant a licence to develop the Atlantis II deposit. The licence was granted to Manafa International Ltd., a Saudi company. Diamond Fields teamed up with Manafa under a joint-venture agreement, Diamond Fields holding a 50.1% stake in the project.

In a feasibility study completed in 2012, Diamond Fields International was planning to start production at the site in 2014 once the technical studies had been completed. The project was suspended, however, due to a conflict between Diamond Fields and Manafa on contractual and performance issues. In November 2016, the **Sudanese-Saudi Standing Committee** held its 12th meeting on the joint mining of natural resources in the Red Sea, with the objective of continuing discussions on how to tap the mineral resources of Atlantis II. Mining the Atlantis II basin therefore remains on the cards but does not appear to be imminent.

3.2. Main public initiatives

In international waters, most exploration or deep-sea mining projects concern polymetallic nodules and are steered by States (this is the case for Korea, the Russian federation, and India) or companies financed directly or indirectly by

²⁰ <http://dsm.gsd.spc.int/> for further information

²¹ <http://www.diamondfields.com/s/AtlantisII.asp>

governments or public funds such as KIOST in Korea, COMRA in China, JOGMEC and DORD in Japan and the Federal Institute for Geosciences and Natural Resources (BGR) in Germany.

States or public companies involved in deep-sea mining mostly rely on domestic firms or organisations to assist them in exploration and mining projects. As part of the BGR exploration campaign, for example, the institute called on the University of Bielefeld for the resource assessment and on the Senckenberg Institute for environmental studies. Similarly, the Indian government entrusted several national institutes with exploration, environmental impact assessment and technological development missions, notably the National Institute of Ocean Technology (NIOT).

3.2.1. European projects



As mentioned in the introduction, the European Union wanted to support the development of deep-sea mining technologies, notably with the launch of the Raw Materials initiative in 2008. The major deep-sea mining projects funded partly by the European Union are:

MIDAS

The MIDAS (Managing Impacts of Deep-sea reSource exploitation) project focused on the environmental impacts of deep-sea mining. Research covered several sites in the North East Atlantic, the Eastern Pacific, the Arctic Ocean, the Mediterranean and the Black Sea. From 2013 to 2016, the project involved 32 European partners from different backgrounds (scientific, industrial, legal experts, NGOs), including Ifremer and the Pierre and Marie Curie University (UPMC) for France. Of the €12 million project costs, €9 million was funded by the European Union.

Research focused on the physical destruction of ecosystems on the ocean floor, the potential impacts associated with the creation of sediment plumes, as well as the possible toxic chemical products that could be released during the mining process and their effect on deep water ecosystems. The project also addressed biological unknowns, such as connectivity between species or the way in which ecosystems can withstand mining operations and then recover.

The results of this research helped develop recommendations on good practices for the mining industry. These include creating conservation zones in nodule-rich areas, as well as zones of particular environmental interest where mining would be prohibited. The consortium also recommends performing mining tests as part of the exploration campaigns before granting any mining licences. The MIDAS consortium worked with European and international regulatory bodies (including the ISA) in order

for these recommendations to be translated into regulations. They should therefore be taken into account in the mining regulation currently being drafted by the ISA.

Blue Mining

Blue Mining is a European consortium made up of 19 industrial companies and research organisations from six European countries, aimed at developing sustainable, effective solutions for the exploration and mining of polymetallic nodules and sulphides. The project covers all aspects of the value chain in this sector, from the discovery of resources to their mining, and also examines the development of the legal and regulatory framework. However, emphasis is placed on the development of a vertical transport system to pump up the minerals extracted from the seabed to the surface. The goal is to reduce the European Union's dependence on imports of mineral resources, as well as to strengthen the mining industry and its technology providers. The project started in 2014 and is scheduled to continue until 2018. Of the €15 million project costs, €10 million are funded by the European Union.

Blue Nodules project

Under the European Horizon 2020 programme, a new European consortium was launched in February 2016 for a four-year period, the Blue Nodules project. It draws on the results of previous European projects (MIDAS and Blue Mining in particular). The project involves 14 industrial partners and researchers from nine countries. It is entirely funded by the European Union, in the amount of €8 million. Blue Nodules examines the challenges related to the creation of a viable, sustainable value chain for the mining of polymetallic nodules. It aims to develop new technologies for deep-sea mining that would minimise environmental impacts. In particular, the project seeks to develop and test new methods to retrieve nodules from the ocean floor, as well as new methods of offshore processing.

Blue Nodules' ultimate objective is to achieve a nodule mining system with low environmental impact, reaching a Technology Readiness Level²² of 6 on a scale of 9. The project's results are expected to be released in publicly available documents, especially for the main sector players. Conferences and workshops should be organised.

3.2.2. France's positioning

Clear political will to support activities

Regarding the waters under French jurisdiction, the State's strategy is to contribute to producing knowledge in order to subsequently engage private stakeholders prepared to explore or even mine the resources identified as promising. France is keen to develop a technological and industrial sector and to strengthen the

²² TRL (Technology Readiness Level) scale: a concept developed by NASA to assess the level of maturity of a technology up to its integration in a complete system and its industrialisation. It ranges from level 1 (observation of the basic principle) to level 9 (validation of the system in a real-life environment).

positioning of French mining companies such as Eramet in deep-sea mining. Finally, the State expressed its aspiration to the industrial development of mineral transformation and mining logistics with the authorities in New Caledonia, French Polynesia and Wallis and Futuna²³.

Wallis and Futuna project

France is focusing in priority on Wallis and Futuna for the exploration of polymetallic sulphides. In the years 2009-2010, France clearly demonstrated its political will to secure its access to raw materials and to take action to capitalise on the marine potential. A French consortium made up of **Technip**, **ERAMET** and the **French Research Institute for Exploitation of the Sea (IFREMER)** received financial state support for three exploration campaigns in the region of Wallis and Futuna, in 2010, 2011 and 2012.

These first scientific explorations contributed immensely to knowledge of the seabed in this area in all its aspects (topography, geology, volcanology, biology, biodiversity), as the samples harvested (fluids, rocks, living organisms) were used to undertake significant analytical work. There were also promising discoveries: several hydrothermal sites that could represent a potential mineral resource were notably identified.

The project is currently held up, however, due to **regulatory constraints**. Exploration and mining licences must be allocated by the local authorities, and those of Wallis and Futuna no longer want to grant any for this area. The consortium can therefore no longer carry out exploration campaigns. Although the authorities are aware of the potential economic benefits in case of mining, deep-sea exploration and mining projects are stymied by local beliefs, as well as local communities' determination to preserve the seabed. In July 2016, ERAMET met with the officials of the Wallis and Futuna local authority and explained the opportunities related to deep-sea mineral mining. The local officials appeared interested, but repeated that local populations would have to be educated about the possible benefits of mining projects and that a consultation process would have to be initiated. For this purpose, it was decided to set up an independent mission to work with local populations, conducted by the **Institute for Research and Development (IRD)**. This mission was slated to start at the end of 2016 but was postponed due to a lack of political will (due partly to the electoral calendar, as the territorial elections in Wallis and Futuna and the French presidential and general elections were to be held in May and June 2017).

It is interesting to note that **State support** plays a key role in the advancement of deep-sea mining activities. Given the many challenges (economic, technological, regulatory, environmental and social), the majority of ongoing activities are those supported by States (in particular countries such as China, Korea, India and the United States).

²³ *Conseil interministeriel à la mer, Stratégie nationale relative à l'exploration et à l'exploitation minières des grands fonds marins, October 2015*

IV. Exploration and mining methods

4.1 Exploration methods

Before deep-sea mining can be envisaged, an exploratory phase is necessary to acquire in-depth general knowledge of the potentially interesting area. Resource assessment is used to determine the viability of a mining project.

Exploration campaigns also provide scientific knowledge on the seafloor and on the ecosystems that live there. The data collected during exploration therefore provides an initial summary status prior to any assessment study on the environmental impacts of a mining project.

Several technologies are used as part of an exploration campaign. Initially, the prospected area is typically explored using **acoustic methods (bathymetry, reflectivity), potential methods (gravity and magnetic), or seismic methods**. In this way, maps of the ocean floor can be re-created. If promising areas are identified, remote-control devices are sent to the bottom of the sea from surface ships. **Autonomous underwater vehicles (AUVs) or remotely operated vehicles (ROVs)** are used during this phase. ROVs collect samples and photos. At each dive, they can collect a few kilos of nodules from an area of 0.25 m² and take pictures of an area of 2 to 4 m². By combining this information, it is possible to estimate the quantity of nodules, expressed in kg/m². In order to fine-tune knowledge of the area, **drilling** is sometimes carried out. This notably makes it possible to assess the volume and quality of deposits and obtain basic environmental information, essential for drafting the environmental impact assessment, which is a pre-requisite to obtain a mining licence.

Interestingly, exploration techniques being judged as little or non-invasive, they do not require an impact assessment within the meaning of the ISA as long as sampling is confined to a part of the area comprising not more than 100 blocks of at most 10 by 10 kilometres.

4.2. Extraction methods

4.2.1. Comparison with other types of mining

Deep-sea mining differs considerably from terrestrial mining. Ore extracted on land is **solid**, while ore extracted offshore is very **liquid and pasty**. Extraction technologies therefore differ, but sector players are considering how to adapt existing onshore mining to offshore mining.

Deep-sea mining involves a number of constraints. Firstly, it must be carried out under water by remote methods, controlled from a floating platform on the surface. Secondly, it is necessary to adapt to each site, as the sites containing deposits may be located at different depths (and therefore different pressures and temperatures) or on different parts of the seabed (slope inclination, curve, etc.).

In order to extract polymetallic sulphides (black smokers), it is also necessary to locate inactive sites, as temperatures are far too high on active sites and this would destroy the equipment. As mentioned above, deep-sea mining nevertheless has some advantages compared to terrestrial mining. In particular, as the equipment is mobile, it can be moved and re-used elsewhere when a site's resources have been exhausted.

Compared with deep-water oil and gas extraction, mining also has its pros. In the first case, operations involve drilling up to 3,000 or 4,000 metres under the seabed, whereas in the second, mineral deposits just have to be collected from the ocean floor.

4.2.2. The different stages of mining

Deep-sea mining is split into several phases: **collecting the ore at the bottom of the ocean, pumping it up to the surface, pre-processing on the ship (separation of water and ore and releasing the water back into the sea), transporting ore back to land, and finally processing.**

Of these phases, the first two are those which constitute the main technical challenge because of their difference with terrestrial mining and therefore the need to develop new technologies. Regarding surface and ground operations, technologies are more mature, as the techniques used in other sectors can be applied.

To recover ore, two techniques can be used: while sulphides and crusts need to be dug out, nodules are simply collected. To bring the ore to the surface, two main vertical transport systems have been developed as part of various research and exploration projects: the air lift system and the hydraulic system. The deeper the deposits, the more complex the vertical transport system. In the **air lift system**, compressed air is injected into the riser, which, by changing the water's density, pushes the metallised slurry up to the surface. This technique has already been tested for polymetallic nodules at water depths of around 4,500 metres. In addition, **hydraulic systems** are considered to be simple, reliable and highly effective in pumping ore to the surface. The required systems already exist, as the same hydraulic pumps are already used for oil and gas drilling in deep waters. As the slurry pumped up does not have exactly the same characteristics, these techniques need to be changed and adapted.

4.2.3. Specificities related to each type of deposit

Polymetallic nodules mining

As mentioned above, polymetallic nodules can simply be collected from the ocean floor, without having to be dug out. As the nodules lie scattered on relatively soft sediment, heavy vehicles cannot be used as they would sink down. The fact that nodule deposits are located at **great depths (typically 4,000 to 5,000 metres)** is another big challenge, as it means using sophisticated lifting systems.

Three mining methods have been tested so far. The first are is a collection system using buckets attached to cables and pulled by one or two barges, the **Continuous Line Bucket system (CLB)**. This technique was tested in 1972 by the Japanese Yoshio Masuda. It consists of an 8-kilometre cable to which buckets are attached at regular intervals. The system is launched from a barge. Although nodules were collected with this system, it was abandoned as it was proven to be hazardous or even dangerous.

The second technique is a collection system using autonomous samplers, the **free shuttle mining system**. With this method, invented by French engineers in 1979, a series of independent vehicles dive to the seabed by dropping ballast and collect nodules. After having retrieved around 250 tons, they rise back to a floating platform on the surface. This technique was also abandoned due to its high cost.

Finally, the last mining technique implemented is the **hydraulic mining system**. It was designed in 1988 by the French group Gemonod. It consists of a semi-submersible surface platform with a 4,800-metre rigid steel tube and a 600-metre flexible hose with a diameter of 38 cm, connecting the end of the tube to a dredge on the seabed. The tube is arc-shaped, enabling the dredge to swerve to avoid obstacles. The dredge collects the nodules and conditions them to be pumped through the hose. This appears to be the method with the greatest potential.

To date, **no mining methods for polymetallic nodules are operational**. The main challenge is the development of a technique to collect nodules from the ocean floor. Projects are being undertaken by research institutes (in particular in South Korea, Belgium, China and Singapore), and several nodule collector concepts have been developed. The most projects are in South Korea, where a nodule collector has been tested successfully in the country's Exclusive Economic Zone. The test was only carried out at a depth of 1,000 metres, however, whereas nodules are found at depths of up to 5,000 metres. Further research is therefore needed, but the first results are already hopeful.

Polymetallic sulphides mining

Mining polymetallic sulphides is **relatively less complicated than for nodules**. Deposits are located at smaller depths (around 2,000 metres for sulphides compared with 4,000 to 5,000 metres for nodules). In addition, unlike nodule deposits, which are spread over large areas, sulphide deposits cover very restricted areas, typically smaller than one square kilometre.

The rock in which polymetallic sulphides is found has strong similarities with coal. This means that coal mining techniques can be used as a basis to develop deep-sea mining equipment.

To date, **the only operational deep-sea mining technique** is used for polymetallic sulphides: the **Riser and Lifting System (RALS)** designed by **Technip for Nautilus Minerals' Solwara 1 project**. This method is very similar

to the hydraulic mining system envisaged for nodule mining. Mining equipment on the ocean floor (Seafloor Production Tools) collects minerals and crushes rock into gravel. A Riser and Lifting System pumps up the ore to a barge through a rigid tube (the riser). The mineralised slurry is pumped up to the surface. The ore is recovered by a production vessel (Production Support Vessel) where the mineralised slurry is dehydrated before being transported to land. Sea water containing sediment and heavy metals is returned to the ocean floor through the riser and can supply the RALS pump with hydraulic power.

The riser system has now been finalised and should be implemented shortly. It is interesting to note that this system was developed for very specific sea conditions, in the Bismarck Sea where there is notably very little wind. As it stands, it would not be suitable for projects located in other areas such as Wallis and Futuna, or for possible projects in the Sea of Japan, for example.

Cobalt crust mining

Mining this type of deposit is **far more difficult technologically than for other deposits**. While nodules lie on a substrate of soft sediment, for example, cobalt crusts are more or less firmly anchored to the substrate. In order to avoid diluting the ore content, the crusts must be recovered without removing the bedrock, so as not to bring it up to the surface.

To date, no conceptual design has been identified to extract cobalt-rich crusts.

The state of progress of technological advances for each type of deposit can be summarised as follows:

	Difficulty of extraction	Site Features	Promising developments?
Polymetallic nodules	Rather easy	Large depth	Promising advances
Polymetallic sulphides	Rather easy	Location of inactive sites	Operational technology
Cobalt crusts	Quite difficult	Crusts firmly attached to bedrock	Not yet

V. Impacts of deep-sea mining

5.1. Deep water biodiversity

Until the middle of the twentieth century, scientists believed that life in deep waters was virtually impossible given the hostile environment (freezing temperatures and lack of light). However, the discovery of hydrothermal vents in the 1970s showed that in reality, deep waters hosted considerable biodiversity. In recent years, more than 500 new species have been discovered²⁴, and many others still remain unknown to this day. According to Yves Fouquet, a geologist at Ifremer, “*we have a better knowledge of the Moon than of the depths of our oceans, which make up 71% of the globe’s surface. So far, we have barely mapped 1%.*”²⁵

In fact, scientific research on deep waters only started 150 years ago given the difficulties of accessing this environment. For many years, research was confined to using surface vessels for dredging, trawling, or coring. Research was confined to the megafauna²⁶ and the greater macrofauna²⁷. The study of ocean biodiversity as a whole only started around fifty years ago, when direct observation via submarines or mobile cameras became possible.

5.1.1. Nodule research campaigns

Several recent research campaigns have sought to map this biodiversity, especially in areas surrounding polymetallic nodules. This is notably the case of the work by the **University of Hawaii (the Abyssline project, for Abyssal Biological Baseline Project)** carried out for the UK Seabed Resources Ltd. exploration contract in the Clarion-Clipperton Zone (CCZ) in the Pacific. The findings were published in **Scientific Reports** journal in July 2016. They talk about abundant biodiversity, with a density of 1.48 animals/m² ²⁸, most of which remain largely unknown. For example, of the twelve species that were brought to the surface within the scope of this project, seven were unknown to science and four belonged to a new genus. In addition, half of the species identified are directly dependent on the nodules that mining would remove.

Similarly, the **European consortium JPI Oceans** was tasked with carrying out a study on the environmental impacts of polymetallic nodule mining. The project began in January 2015 and the first results were published in June 2016. Like

²⁴ KENWAY (S.), *Deep Sea Extractive Activities: Seabed Mining and Deep Sea Drilling, RepRisk Special Report, June 2015*

²⁵ PANGRAZZI (C.), “*Le domaine maritime de la France vient de s’agrandir – Pourra-t-on exploiter les richesses des fonds marins?*”, *Ca m’intéresse*, March 2016

²⁶ *Megafauna: large animals (over 45 kg).*

²⁷ *Macrofauna: animals of 1 mm to 2 cm.*

²⁸ *Scientific reports, July 2016* <http://www.nature.com/articles/srep30492>

other studies, this one found a significant amount of deep-water fauna. In addition, the number of animals could be correlated with the abundance of polymetallic nodules. Researchers found that on average, there were twice as many animals where there were nodules (more than 25 individuals per 100 m², compared with 10 in areas without nodules)²⁹.

5.1.2. Discoveries on polymetallic sulphides

This abundant biodiversity is also present near other types of deposits. Since the discovery of polymetallic sulphides at the end of the 1970s, for example, more than 700 new species have been discovered in these areas³⁰. On average, between 1977 and 2002, two new species were discovered every month. Unlike terrestrial species, organisms living in these environments draw their energy from the minerals gushing from the vents (chemosynthesis) and not from the sun, which makes them unique. Some scientists even argue that it is in this environment that life first appeared on Earth. In addition, due to geographical isolation, many species are found only in just one area.

However, it is important to note that most of the current knowledge concerns active hydrothermal sites, not inactive sites, which are the ones targeted by mining projects.

It is also worth mentioning **Nautilus's Solwara 1 project**. Although it has come under much criticism, particularly concerning environmental and social impact assessments, the missions undertaken to assess the project's environmental impacts have provided a great deal of information on biodiversity in the deep waters surrounding polymetallic sulphides.

5.1.3. Cobalt-rich crusts

Knowledge on the biodiversity surrounding cobalt crusts is even more limited than for the other two types of deposits. Scientific research on these environments was primarily motivated by economic considerations related to fishing practices, and therefore focused on fauna. There is very little data available on biodiversity as a whole. Although knowledge of macrofauna has grown significantly over the past ten years, the meiofauna³¹ and the microbial compartment remain largely unknown.

This abundant fauna is fragile, however, as we shall see in more detail. For example, the JPI Ocean consortium inspected seabed areas that had been scraped to recover nodules several years ago, when regulations on exploration were still non-existent. The results of this research showed that the fauna had still not recolonised these areas.

²⁹ <http://www.nature.com/articles/srep26808>

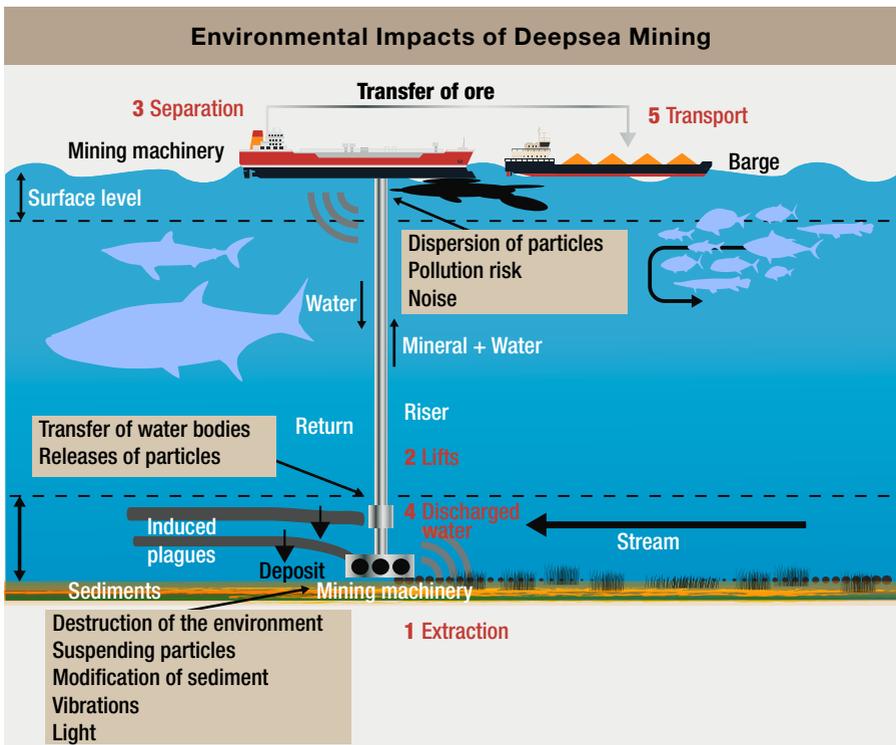
³⁰ GREENPEACE, *Deep Seabed Mining – An urgent wake-up call to protect our oceans*, July 2013

³¹ *Meiofauna: animals whose size is between 0.1 and 1 mm.*

5.2. Environmental impacts

Due to lack of knowledge on deep-sea biodiversity, the impacts of mining on ecosystems are poorly evaluated so far. Similarly, little is known about these ecosystems' faculty to recover after mining operations and the resulting disruption. The cumulative effect of the impacts on the marine environment is also largely unknown.

Exploration or mining operations could have various environmental consequences (summarised in the following diagram): **destroying deep-sea ecosystems, stirring up potentially toxic sediment plumes, impacting species because of the noise, vibration and light induced, or through waste management (notably water discharged after ore separation).** Additional impacts are to be expected in the event of accidents.



Source: CNRS - Ifremer, 2014

5.2.1. Destruction of ecosystems

Deep-sea mining will cause the destruction, both directly and indirectly, of a large number of animals and microorganisms at the bottom of the ocean. Several deep-sea species are particularly vulnerable because of their slow growth rate, their

low resilience to changes in their environment and their slow rate of recovery after disruptions.

Nodules, for instance, can take millions of years to form. Some of them grow by only 1 to 2 mm every million years. In the Clarion-Clipperton fracture zone, they grow by 10 to 50 mm every million years. Extracting nodules would therefore withdraw species' habitat permanently and could cause their extinction, because, as mentioned above, many species are directly dependent on the nodules and are not found anywhere else.

Turning to to polymetallic sulphides, even **Nautilus's Environmental Impact Assessment for the Solwara 1 project** said that the impacts of mining on the ocean floor ecosystems directly concerned would inevitably be "severe" at the scale of the mining site. The assessment also indicated that it would probably take many years for black smokers' development to return to pre-mining levels. Reports by villagers living on the coast near the Solwara 1 project also bore out these impacts. Following the site's exploration campaigns, they notably reported having seen large numbers of dead fish on shore, in particular deep water fish like the emperor fish. Some of the creatures found were deep water animals never seen before³². That said, the causal link was not proven.

5.2.2. Suspended sediment plumes

Removing nodules or other deposits creates sediment plumes on the ocean floor. These plumes are clouds of potentially toxic particles. Toxicity can be particularly high in the case of polymetallic sulphide mining, as it can release dangerous doses of lead, arsenic, copper and other substances trapped in the deposits. This can contaminate the fauna and flora and eventually lead to contaminating the food chain, right up to humans. In addition, fallout from these plumes can cause benthic organisms³³, which are not equipped to handle large amounts of sediment deposit, to suffocate.

Sediment plumes can also occur near the surface, in the case of dispersion from the ship, or if the water is rejected near the surface after ore separation. In this case, particle clouds can reduce light and temperature and impact plankton growth, leading to possible repercussions for the entire food chain.

Finally, it is important to note that the plumes can spread over areas far larger than the mining sites. For example, at the Solwara 1 site, it has been estimated that plumes could potentially spread over a surface of 35 km²³⁴. The way in which the

³² Helen Rosenbaum, *Field Trip to Ramuaina (Duke Of York Islands)*, BFDW, Feb. 15-18, 2016, *Draft Report, forthcoming*, at 7; Freddy Mou, *Dead Sea Creatures Causing Awful Smell in Namatanai*, LOOP PNG, Apr. 13, 2016, <http://www.looppng.com/content/dead-sea-creatures-causing-awful-smell-namatanai>

³³ *Benthic organisms: animals or plants that live fixed to the ground or that crawl on the seabed. They find their food in the sediment and therefore depend on it for their subsistence (definition: Ifremer)*

³⁴ LUJICK (J. L.), *Physical Oceanographic Assessment of the Nautilus EIS for the Solwara 1 Project*, Prepared for the Deep Sea Mining Campaign, November 2012

particles spread is difficult to predict and could even lead to international conflicts, should mining in one State's EEZ result in plumes spreading to another's EEZ, for instance.

5.2.3. Vibration and noise

Deep water species are used to living in silence and are sensitive to acoustic changes. Exploration and mining operations also have an impact on ecosystems through the noise and vibration they involve. The Steiner report tasked with reviewing Nautilus's Environmental Impact Assessment for the Solwara 1 project revealed that sounds from operations could travel up to 600 km from the site. In particular, noise can affect organisms' ability to sense food-fall, i.e. the fall of organic matter that provides an important source of nutrients to deep water species.

Similarly, the vibrations induced by exploration and mining operations can also disrupt ecosystems' functioning. This is particularly the case for large cetaceans and sharks, which may suffer disruptions of their modes of communication, hunting, mating and reproduction. This could increase their stress and cause individuals to become isolated.

5.2.4. Light

Just like noise, the light from exploration and mining operations at ocean floor level will have impacts on deep water species, which are used to living in the dark. This is particularly the case for deep water shrimp.

5.2.5. Water discharge after ore separation

Water released from surface barges after ore/sea water separation can also have significant environmental impacts.

Water discharged (from 25 to 50 metres above the ocean floor in the case of Solwara 1) forms clouds of particles that can contain metals and other heavy pollutants. In the case of Solwara 1, it is estimated that the water released would contain 6,000 mg/litre of suspended solids³⁵. These plumes could have similar environmental impacts to those discussed above. It is interesting to note that the toxicity tests performed by Nautilus showed that water discharged after separation during the Solwara 1 operations would be toxic for deep water species and would need to be diluted 700 times so as to no longer present a toxic risk for these species³⁶.

Moreover, upwelling from the seabed and its subsequent discharge results in transfers of water masses, with differing physico-chemical characteristics, particularly in terms of temperature and salinity. The water discharged could contain

³⁵ STEINER (R.), *Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea, conducted for the Bismarck-Solomon Seas Indigenous Peoples Council Madang, Papua New Guinea, January 2009*

³⁶ ROSENBAUM (H.), GREY (F.), *Accountability Zero – A critique of the Nautilus Minerals environmental and social benchmarking analysis of the Solwara 1 project, Deep Sea Mining Campaign, 2015*

80% of water from the ocean floor and 20% of surface water. These changes in water properties could have significant impacts on marine fauna and flora.

5.2.6. Additional risks

A project's environmental impacts could be considerably aggravated in the event of an accident. Several types of accidents could occur:

- accidental dispersal of ore in the sea during transfers from the ship to the barge;
- loss of barges containing ore: in the case of Solwara 1, a barge would contain 6,000 tonnes of toxic minerals, fuels, and other hazardous materials. Under the project, three to nine barges would travel between the mining site and the shore every week, and the loss of one of them could have serious environmental consequences.

It is regrettable that the possibility of such an accident has not been taken into account in the Environmental Impact Assessment of Solwara 1³⁷, as shown in Professor Steiner's 2009 report. Nautilus Minerals has provided no additional information about the consideration given to these risks since the report's publication.

- possible leaks of oil or hydraulic fluid from the machinery that could affect the entire water column.

Potential accidents associated with natural hazards such as extreme weather events or volcanic activity should also be taken into account in environmental management plans.

Lastly, ore concentration operations carried out on land can also have significant environmental impacts. No mining project having started to date, this last point has not yet actually been analysed, but it is important to keep it in mind. The impacts of ore concentration operations can be expected to be very largely similar to those involved in land mining.

5.2.7. Limiting and managing environmental impacts

Since the first exploration campaigns, scientific and technological research has been striving to find ways of limiting the impact of deep-sea mining on the environment.

Regarding noise, great strides have been made since the technologies initially proposed for the Solwara project, which could generate noise heard up to 600 km under water. Companies remain discreet on this point, however, given the huge competitive stakes. Concerning suspended toxic particles in the form of plumes, several players such as Technip or Neptune are trying to find ways to reduce this

³⁷ STEINER (R.), *Independent Review of the Environmental Impact Statement for the proposed Nautilus Minerals Solwara 1 Seabed Mining Project, Papua New Guinea, conducted for the Bismarck-Solomon Seas Indigenous Peoples Council Madang, Papua New Guinea, January 2009*

impact. They say this problem would be relatively easy to manage. Concerning ecosystem destruction, Nautilus plans to use underwater robots (drones) at the Solwara 1 project to move the blocks of sediment containing the largest biomass to a temporary refuge area.

5.2.8. Impacts of exploration

The impacts of exploration activities are broadly similar to those of mining, but on a much smaller scale. This depends partly on the exploration methods used – the environmental impact might be greater if drilling is carried out, for example. However, the noise impact is potentially greater due to the possible addition of acoustic noise from seismic surveys for resource estimates. Frameworks for noise impact assessment would be desirable, possibly based on those of the oil and gas industry.

5.3. Social impacts

It is often argued that deep-sea mining should not have as many social impacts as terrestrial mining, because it implies limited or non-existent presence on land. Some players consider that as mining is carried out far from coastal waters, coastal communities will be unaffected and therefore do not have to be consulted.

In fact, this reasoning is incorrect as many sites are located relatively close to coastal communities, less than 50 km away. Furthermore, even if the sites are far, the ships still need to go to coastal ports frequently, which significantly increases the risk of leaks and other accidents. We should also bear in mind that pollution is far more difficult to contain and to be prevented from spreading in the ocean than on land. Clouds of toxic particles created by mining could intoxicate fish caught at a distance, or contaminate the food chain right up to humans.

Other potential impacts must be taken into account:

5.3.1. Disturbance to fishing

Deep-sea mining can have a particularly strong impact on fishing. According to a report by Blue Ocean Law³⁸, exploration activities have already hurt the fishing sector in Tonga, a State of Polynesia. These activities have led to the presence of big vessels in Tongan waters, including in and around the fishing areas. The fishermen say the presence of these vessels has disrupted fish populations and forced their own boats to make long detours to find fish in calmer waters. It is interesting to note that these effects were reported when activities were limited to prospecting. According to the Head of the Tonga Fishermen's Association, even minor disruptions can result in fish moving to other waters. The impacts could be even more significant in the case of mining activities. In the example of the Tonga Islands, deep-sea mining could

³⁸ BLUE OCEAN LAW, *Resource roulette - How deep sea mining and inadequate regulatory frameworks imperil the Pacific and its peoples*, 2016

have serious economic and social consequences, because fishing contributes greatly to the country's economy³⁹.

5.3.2. Indigenous culture

Communities living near deep-sea exploration or mining areas are often opposed to these projects due to the implications for their indigenous culture. Traditional beliefs say that the animals and spirits of the sea must not be disturbed. For example, the inhabitants of Lavongai (New Hanover) Island in Papua New Guinea are concerned they will not be able to join their ancestors after death, as the place where spirits are supposed to pass over is located in an area for which Nautilus has been awarded an exploration licence by the Government of Papua New Guinea. Similarly, inhabitants of the islands located around Nautilus's Solwara 1 project expressed sharp criticism, saying the project failed to take into account their deep connection to the ocean.

Deep-sea mining could also alter the development of shark populations and thereby affect a traditional fishing practice, known as "shark calling"⁴⁰. This practice takes place in the villages of Mesi, Tembin and Kontu, and represents an important rite of passage for young men in these communities. In Papua New Guinea, the islands of New Ireland and East New Britain have already reported that exploration activities taking place 30 to 50 km from their coasts are having a negative impact on this practice⁴¹.

5.3.3. Impact on tourism

Also on the islands of New Ireland and East New Britain, near the Solwara 1 site, the locals develop eco-tourism based on the marine environment, especially around Kokopo and Kavieng⁴². Any activity polluting the marine environment or chasing away animals like dolphins, sharks or whales would therefore have a negative impact on ecotourism and future development opportunities.

According to the inhabitants of Papua New Guinea, deep-water exploration operations have already hurt tourism by impacting "shark calling", which has become a tourist attraction (a shark-calling festival is held every year), as well as other cultural customs.

5.3.4. How can potential social impacts be managed?

In order to limit negative impacts on local communities, it is important that these be regularly consulted and that their comments be taken into account.

³⁹ According to the United Nations Foreign Trade Report in 1999, fishing accounted for almost 25% of the country's exports: http://unctad.org/en/docs/tdr1999_en.pdf

⁴⁰ Shark calling: traditional fishing practice consisting in using magic to attract sharks before catching and killing them bare-handed

⁴¹ BLUE OCEAN LAW, *Resource roulette - How deep sea mining and inadequate regulatory frameworks imperil the Pacific and its peoples*, 2016

⁴² BUSINESS ADVANTAGE PNG, "Papua New Guinea tourism receives some attention", February 2014, <http://www.businessadvantagepng.com/papua-new-guinea-tourism-receives-attention/>

The principle of “Free, prior and informed consent” of indigenous people must be applied, and their consent must be obtained before any important decision concerning a project, and any impact on the environment and/or communities. The latter should be consulted, and individuals must feel free from any coercion or pressure on the part of companies and the State. Furthermore, consent must be informed, i.e. the public must have access to all the information necessary to make an informed decision. Companies therefore need to be transparent and to present both the positive and negative impacts of a project, as well as possible alternative projects. Information must be easily understandable and provided by independent experts. However, representative community associations regret that in the majority of cases, even if people are consulted, the decision on whether or not to implement a project is not really theirs to make.

Some companies are trying to implement measures in this respect. This is particularly the case of Nautilus Minerals, which for the Solwara 1 project carried out consultation sessions in several villages as part of its **Nautilus CARES corporate responsibility programme**. More than 5,000 people were consulted.

However, these consultations came under some criticism. The information provided was reportedly highly technical, and the local populations’ questions and comments were mostly ignored. In addition, participants in these consultation sessions were sometimes only selected people⁴³.

Similarly, **Neptune Minerals** states it invites local departmental officers to take part in and contribute to exploration campaigns at sea. The company also says it contributes to the Deep Sea Minerals project of the Secretariat of the Pacific Community Applied Science and Technology Division (SOPAC), founded by the European Union, and which started operations in 2011.

In order to represent the communities and their interests, some community activist groups have been created. This is notably the case of the collective action **Bismarck-Solomon Sea Indigenous Peoples Council (BSSIPC)**, representing the island populations of the Bismarck-Solomon sea. Similarly, the **Deep Sea Mining Campaign** is an association of NGOs and citizens of the Pacific Islands, Australia, Canada and the United States. It was created in 2011 in order to highlight the potential impacts of deep-sea mining on marine and coastal ecosystems and communities. It is important that these groups be regularly consulted and that their comments be taken into account.

5.4. Vigilance with respect to governance

Deep-sea mining will generate additional revenue. This revenue must be managed cautiously in order to avoid the “resource curse” phenomenon. This refers to the fact that revenue generated by natural resources can have negative consequences on a country’s economy, society and political stability. In addition to impacts on the

⁴³ BLUE OCEAN LAW, 2016

environment and local communities, mining tends to cause more violent conflict, political instability and corruption, especially in non-democratic countries. During the interviews conducted for the Blue Ocean Law study, concerns about corruption were particularly mentioned⁴⁴. In Papua New Guinea, for example, many cases of corruption and mismanagement of the region's terrestrial mines have already been reported.

Another sizeable challenge lies in collecting revenues and getting companies to pay taxes. In Tonga and Papua New Guinea, for instance, getting large companies to pay taxes has already proven particularly difficult. According to Blue Ocean Law⁴⁵, terrestrial mining in Papua New Guinea brought very little income to the country, as many companies manipulate their data to avoid paying taxes. Also we have to keep in mind that many Pacific Islands have no sea or air authorities to monitor their waters. This difficulty is exacerbated when mining activities are scattered across the EEZ. This means there is a risk deep-sea mining companies could under-report their activities in order to pay less taxes than they should. This phenomenon has already been observed in the fishing sector, especially when unloading and transfers take place at sea.

To limit these negative impacts, strong **institutional and regulatory capacities are required** in order to manage and correctly distribute revenues from resource extraction. However, managing these additional revenues could be relatively difficult in the Pacific islands, one of the areas most concerned by deep-sea mining. As the islands' median population is only 100,000, governments are small and can only allocate limited staff to the creation and enforcement of such regulations. A good illustration of this problem is the fact that several Pacific Islands have attempted to join initiatives such as the **Extractive Industries Transparency Initiative (EITI)**⁴⁶ but had to give up, as their limited capacities prevented them from fully carrying out the reporting required by this initiative⁴⁷.

5.5. Comparison with impacts of terrestrial mining

As we have seen above, deep-sea exploration and mining operations involve significant environmental and social impacts. It is also worth asking if these impacts are likely to be greater or smaller than those induced by surface- and underground mining.

According to some players involved in deep-sea mining, this activity would have fewer social and environmental impacts than terrestrial mining. This is notably the position taken by Nautilus, which puts forward an independent analysis by

⁴⁴ BLUE OCEAN LAW, 2016

⁴⁵ *Ibid.*

⁴⁶ EITI: standard for transparent management of revenues from oil, gas and mineral resources

⁴⁷ BLUE OCEAN LAW, 2016

Earth Economics published in 2015⁴⁸. This study shows that, compared with three terrestrial copper mines analysed, the social and environmental impacts of the Solwara 1 project could potentially be significantly reduced. The project will not cause any population displacements and will have no impact on food production or drinking water reserves, whether they be surface or groundwater.

That said, Earth Economics' conclusions need to be put into perspective. The Deep Sea Mining Campaign (DSMC) criticised this study, underscoring the fact that comparisons with terrestrial mines were misleading. In particular, apart from the fact that, unlike terrestrial mines, little information is available regarding the environmental and social impacts of deep-sea mining, the DSMC regrets that the terrestrial mines analysed were not further away from inhabited areas. As the mines analysed by Earth Economics were located close to populations, the impacts on local communities were relatively high, especially when compared with deep-sea mining which is obviously carried out at a greater distance from populations. When stripping out this bias, the difference between the social impacts of terrestrial and deep-sea mining would already be far smaller than what is shown in this report.

For others, the impacts of deep-sea mining may be more important than for terrestrial mining. This is the position taken by Professor Richard Steiner in his independent review of Nautilus's Environmental Impact Assessment for the Solwara 1 project⁴⁹. According to Professor Steiner, the rare and unique deep water habitat implies that the environmental impacts of mining are far greater on deep water ecosystems than on those in forests, for example, in the case of terrestrial mining. In addition, as pointed out by the DSMC, deep-water habitats are home to the only known species dependent on chemosynthesis, which represents a unique form of life, new to science⁵⁰.

Clearly, there is no real consensus on the subject. This is mainly due to the fact that the environmental and social impacts of deep-sea mining are still very poorly evaluated to this day given the lack of knowledge. Deep-sea mining differs considerably from terrestrial mining. For this reason, even though it has lesser environmental and social impacts, the aggregate net impacts of deep-sea mining will in any case be greater should operations be developed⁵¹.

⁴⁸ BATKER (D.) & ROWAN (S.), *Environmental and Social Benchmarking Analysis of Nautilus Minerals Inc. Solwara 1 Project*, Earth Economics, May 2015

⁴⁹ STEINER, 2009

⁵⁰ ROSENBAUM (H.), GREY (F.), *Accountability Zero – A critique of the Nautilus Minerals environmental and social benchmarking analysis of the Solwara 1 project*, Deep Sea Mining Campaign

⁵¹ BLUE OCEAN LAW, 2016

Conclusion

Deep-sea mining is still in an exploratory phase and has probably slowed due to low mineral prices. Even on land, opening new mines, or even continuing to operate existing mines, is an economic challenge. However, deep-sea mining activities could become particularly attractive because of the scarcity of terrestrial minerals, which will inevitably drive up prices. Moreover, if Nautilus's Solwara 1 project, which is set to start in 2019, is a success, one can expect other players to quickly move into the sector or take over projects already under way.

The issues addressed in this study raise questions as to how to reconcile economic development, securing the raw materials supply and protecting the environment and communities. Economic development implies an increase in needs for base metals (iron, copper, manganese, lead, etc.), and in the minerals required to manufacture high-tech products (cobalt, platinum, etc.). At the same time, terrestrial deposits are tending to deplete and the discovery of deposits in deep waters in the last few decades has helped increase potential reserves of strategic minerals, reducing the risk of shortages.

Despite the opportunity presented by deep-sea mining, the sector faces several challenges. In addition to economic, technological and regulatory obstacles, there is also a lack of knowledge on the ecosystems in these environments, and on the disruptions that will be caused by mining. Because of these uncertainties, it is difficult to accurately assess underlying ESG risks. In order to preserve this unique environment, we recommend using a precautionary approach when rating companies involved in these activities and to not invest in those that produce no serious studies on their environmental and social impact.

Lastly, it is important to continue to further develop mineral recycling, which ultimately should reduce the need to mine new resources. We encourage companies to adhere to this rationale.

Glossary

International Seabed Authority (ISA): an independent international organisation, created in accordance with the United Nations Convention on the Law of the Sea (UNCLOS) of 1982 and the 1994 Agreement relating to the implementation of Part XI of the Convention. The ISA manages and regulates the maritime spaces outside the maritime zones of States on behalf of the international community.

The United Nations Convention on the Law of the Sea (UNCLOS): also called the “Montego Bay Convention”, UNCLOS is a fundamental international treaty adopted in 1982 that recognises the sovereign rights of coastal States on their Exclusive Economic Zone (EEZ) and their continental shelf, as well as the national non-appropriation of resources located beyond national jurisdictions.

Mid-ocean ridge: underwater mountain range, whose summit is crossed by major fractures.

Deep waters: defined here as marine areas located at depths of more than 500 metres.

Cobalt-rich crusts: one of the three types of mineral deposits on the ocean floor in deep waters, on the flanks of seamounts. They notably contain iron, manganese, cobalt, and platinum.

High seas: column of water and surface waters located above the international seabed area and the extended continental shelf (extending beyond 200 nautical miles (370 km) from the baseline). This is an international maritime area where all States have freedom of navigation, fishing, overflight, as well as freedom to lay submarine cables and pipelines.

Polymetallic nodules (or manganese nodules): one of the three types of mineral deposits on the ocean floor in deep waters. They notably contain manganese, nickel, cobalt, and copper.

Continental shelf: underwater prolongation of a State's land territory.

Polymetallic sulphides: one of the three types of mineral deposits on the ocean floor in deep waters, formed on hydrothermal sites. The main metals they contain are sulphide, iron, silica, zinc, copper and barium.

Exclusive Economic Zone (EEZ): the zone extending beyond territorial sea and adjacent to it, over which the coastal State has special rights regarding the exploration and use of marine resources, including energy production from water and wind. It extends in a radius of 200 nautical miles (370 km) from the baseline (the mean low water mark, the maritime chart datum).

International seabed area (“the Area”): according to the Montego Bay Convention, the seabed and its underground extending beyond the limits of national jurisdictions. Resources (solid mineral, liquid or gas) which are located there are considered as a common heritage of mankind.

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