

Deep sea mining – What makes it different to offshore oil and gas applications?



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ABSTRACT

Due to an increase in industrial demand and limited availability of mineral resources on land, it is imperative to explore and exploit the resources available on the seafloor. A pragmatic approach must be adopted in assessing, exploiting and utilising these resources by completing comprehensive research and exploration prior to deep sea mining activity. If looking at existing offshore oil and gas industry, it will be same depth, similar challenges and only different in materials. Since this industry has been developed in technologies, legislation and environmental law, which will be compared with deep sea mining; what makes it different?

The main objective of thesis is to perform an assessment in all aspects of deep-sea mining and to find out what is different with offshore oil and gas applications. The research will be started study on the seabed and its resources, seabed law, background and framework of international seabed authority which is authorized for producing deep sea mining licenses, current rules and regulations for exploration and exploitation. environmental effects from mining activity and its management plan. One of current ongoing projects is chosen as case study and will be examined on proposed seafloor production systems as show in below figure. Comparison with offshore oil and gas applications is based on Llyod's Register current offshore units rules and concluded what is equivalent and what is missing. Results from the comparison are produced with remarks which LR have to do in the future. Finally, conclusion is made with overall work through this study.

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LIST OF ABBREVIATIONS

AC	Auxillary Cutter
BC	Bulk Cutter
CAPEX	CAPital EXpenditure
CCZ	Clarion-Clipperton Zone
CM	Collecting Machine
DNV	Det Norske Veritas
DP	Dynamic Positioning
DWP	Dewatering Plant
DEC	Department of Environment and Conservation
DSMA	Deep Sea Mining Alliance
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIR	Environmental Impact Statement
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
FPSO	Floating Production, Storage and Offloading
HMS	Her Majesty's Ship
IMMS	International Marine Minerals Society
IMO	International Maritime Organisation
IMT	International Maritime Tribunal
ISA	International Seabed Authority
MIDAS	Managing Impacts of Deep-seA reSources
NMMT	National Masterplan Maritime Technologies
OPEX	OPerating EXpenditure
PNG	Papua New Guinea
PSV	Production Support Vessel
RALS	Riser And Lifting System
ROV	Remotely Operated Vehicle
RTP	Riser Transfer Pipe
SCRs	Steel Catenary Risers
SMS	Seafloor Massive Sulphides

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SPT

Seafloor Production Tool

UNCLOS

United Nations Convention of the Law of the Sea

1 INTRODUCTION

Forecasts of global trends and transformation processes in the next 25 to 50 years outline sustainable development, power and economy transitions from West to East, growth of the world's population and technological progress that lead to severe energy, mineral, food and water scarcities. These resources supply uncertainties lead to controversial debates on seabed exploitation. In fact 71% of world is covered by oceans with the seabed being proposed to provide significant amounts of needed minerals, bio-organisms and energy.

These resources and its environment are vastly unexplored. For a long time it has been believed that the seabed with its extreme temperature, salinity and light conditions bears no use to mankind. The HMS Challenger expedition between 1872 and 1876 changed this view significantly and discovered mineral rich polymetallic nodules on the seafloor. Further research expeditions in the 1960s and 1970s identified thriving marine life and seafloor massive sulphides in and around hydrothermal vents in deep sea waters. Marine life on the seabed may hold future life-sciences or energy solutions. One example is macro algae cultivation, which is now being developed for biofuel, food and fertilizer applications. However, the feasibility of exploiting seabed resources is subject to the engineering solutions and their economic prospects.

Deep sea mining is a relatively new mineral retrieval process that takes place on the ocean floor. Ocean mining sites are usually around large areas of polymetallic nodules or active and extinct hydrothermal vents at about 1,400 - 3,700 m below the ocean's surface. The vents create sulfide deposits, which contain valuable metals such as silver, gold, copper, manganese, cobalt, and zinc. The deposits are mined using either hydraulic pumps or bucket systems that take ore to the surface to be processed. As with all mining operations, deep sea mining raises questions about potential environmental impact on surrounding areas. Environmental advocacy groups such as Greenpeace have argued that seabed mining should not be permitted in most of the world's oceans because of the potential for damage to deep sea ecosystems.

The international law-based regulations on deep sea mining are contained in the United Nations Conventions on the Law of the Sea from 1973 to 1982, which came into force in 1994. The convention set up the International Seabed Authority (ISA), which regulates nations' deep sea mining ventures outside each nation's Exclusive Economic Zone (a 200-

nautical-mile (370 km) area surrounding coastal nations). The ISA requires nations interested in mining to explore two equal mining sites and turn one over to the ISA, along with a transfer of mining technology over a 10- to 20-year period. This seemed reasonable at the time because it was widely believed that nodule mining would be extremely profitable. However, these strict requirements led some industrialized countries to refuse to sign the initial treaty in 1982.

1.1 Motivation

Forecasting the market for demand and supply of minerals and metals is a complex task. History has shown us the failure of the overly optimistic market forecast in the late 1970s in terms of consumption levels and prices, which effectively delayed full-scale commercial deep-sea mining for more than 30 years (Antrim 2005). The attention grew back in the last decade with marine mineral mining being in research and commercial focus again and there have been many developments over the past two decades. These include improvements in political and legal issues related to international waters, the growing economies of BRIC (Brazil, Russia, India and China) and other developing nations, a growing interest in renewable energies and green technologies which triggers more demand in certain types of minerals, and rapid progress in oil and gas technologies for deep water. These factors combined with issues such as rising demand and consequently rising prices of minerals and commodities worldwide, and uncertainty of land-based mineral supplies, contribute to our motivations for this study on deep-sea mineral recovery.

The rising demand in minerals has driven metal prices up. The market trends of copper, cobalt, nickel and manganese have risen dramatically over the last 10 years. The price of copper for example, has tripled while those of cobalt, nickel and manganese have doubled since 2002 (ISA 2008a). Each of the four minerals experienced a steep rise in price before 2007 followed by a steady decline during the 2008 economic crisis. Nevertheless, as the global market is recovering, so are the metal prices. This trend of increasing metal prices makes the mineral markets an attractive investment for both private and government enterprises. At present, under the United Nations Convention on the Law of the Sea (UNCLOS), any country or deep sea mining company that wishes to exploit the seabed needs an exploration contract from ISA. There has been a dramatic increase in the number of

applications for such contracts. Five years ago there were just six projects in international waters, now there would expect to be 26 by the end of 2014.

Renewable energies and green technologies have been developed progressively to reduce the amount of pollution. Both sectors will inevitably trigger huge additional demands in certain type of minerals once their applications are firmly commercialised. One example is the transition to hybrid (petro-electric) automobiles of green technologies. This whole design uses the concept of an on-board battery to power the propulsion. The current raw mineral for battery is nickel, and the alternative is cobalt. Either one of these two types of battery would significantly increase demand of nickel and/or cobalt (Antrim 2005).

The world's undersea reserves are estimated to include 10 billion tonnes of polymetallic nodules. On average, the most promising of these deposits will break down to about 30% manganese, 1.5% nickel, 1.5% copper, and 0.3% cobalt. In short, the ocean floor is home to a staggering quantity of useful minerals and these deposits also contain smaller traces of rare earth elements. Many of these are used in electronics and in the manufacture of 'clean technologies', such as wind turbines and hybrid cars. These elements are technically by-products of the mining process, but they are driving a lot of new commercial interest. Japanese geologists estimate that a single 2.3 km² patch of seafloor might contain enough rare earth materials to sustain global demand for a year.

Another interest in deep sea mining is motivated from the oil and gas sector. Rising demand and prices of hydrocarbon and shortage of shallow water reservoirs push offshore exploration and drilling to deeper water, which nowadays easily ranges from 1,000 m to over 3,000 m. Technologies in offshore engineering have been developed for deep water. One of the applications suitable for deep-sea mining is the technology of riser, a pipe system connecting a drilling platform to a reservoir well. The same technology can be applied to deep-sea mining to transport the extracted minerals vertically from the seabed to the surface for further processing.

1.2 Objectives

The specific objectives of the study and all the assessments are presented as follows.

1. Study the geological features of sea bed and its marine minerals resources which could be extracted for commercial production.

2. Assess with international organization's rules and regulations which is currently published for exploration and exploitation.
3. Examine the benchmark work of other classification societies.
4. Study on the environmental impacts resulted from deep sea mining and mitigations plan to recover the environment.
5. Make a case study on ongoing projects and their sea floor production system.
6. Compare the proposed seafloor production system with the application tools which are used in Offshore Oil and Gas industry.
7. Draw the results that what can be applied in deep sea mining and what is missing in current LR offshore rules and regulations.

1.3 Comparison between Land-based Mining and Deep Sea Mining

Comparing land with deep-sea mining, it is obvious that to conceptualise and execute, the latter will be more costly. There are also further challenges for deep-sea mining in terms of environmental, geo-political and legal-social issues, which will be discussed subsequently. However, there are several advantages to deep-sea over land mining, which are briefly summarised as follows:

- Smaller footprint due to less overburden

Open excavation in the case of land mining means that each operation normally leaves considerable footprints during and after the mining process. This is mainly because of the need to remove a large amount of overburden, under which the resources are locked. The footprint in the case of deep-sea mining would be smaller as most of the resources are either lying on the seafloor or buried by only several centimetres of sediments or clay.

- Less permanent infrastructure

Each land mine requires permanent infrastructure such as roads and towers. This is not the case for deep-sea mining as everything is controlled from the surface via movable floating ships or barges. Thus, there will be less permanent infrastructure needed. Once a plot of seabed has been fully mined, all the facilities can be easily moved and deployed to another 23 area. In terms of long-term capital cost, deep-sea mining may be compatible with or cheaper than land mining.

- Less populated ecosystem to be affected

It is generally accepted that the open mining approach on land, which includes activities such as deforestation, disturbs the local ecosystem of the exploited area. Birds and other species have to find new habitats, and it is unlikely that they will be able to re-occupy the mined area due to the substantial footprint left behind after the operation. Deep-sea mining, on the other hand, will impact upon a smaller populated ecosystem near the seafloor, where the absence of light prevents photosynthesis. There will however be some effects on the ecosystems of local species, such as benthos, which manage to survive without sunlight. Nevertheless, the overall impact is significantly less in comparison to land mining; the smaller footprints left by deep sea mining could allow the ecosystem to re-occupy the habitat.

- Rich in mineral diversity

Land mining is usually conducted for one single mineral, for example coal, gold, nickel, etc. A particular type of mineral is more uniform in a certain area, such as nickel in Russia and cobalt in Congo. On the other hand, there are diverse elements in each deposit from the deep sea. Hence, multiple minerals can be obtained from a single mining operation. Manganese nodule is a clear example. Nodules are multi-mineral ores containing manganese, iron, nickel, cobalt, copper and some rare earth elements (REEs). (B Agarwal, P Hu, M Placidi, H Santo, J J Zhou, 2012)

1.4 Outline of the Report

The following paragraphs give a brief summary of the sections within this book.

Section 1 introduces the history of deep sea mining, presents the motivation and objectives and concludes by presenting the overall structure of the publication at hand.

Section 2 starts with a definition of seabed that is used throughout this book. It introduces the geological features of seabed, relevant mineral deposits located on the seabed and their prices on the market in economic view, the environment and ecosystem that are discussed for exploration and exploitation.

Section 3 presents an overview of the legal environment of deep sea mining industry by introducing the legal authorities in place and their current rules and regulations in national and international waters.

Section 4 assesses the international research activities around the world where exploration or environmental research is done. Then, the German nodule mining activities in Pacific Ocean is approached and European Union (EU) funded consortium and their events are presented.

Section 5 discusses the general environmental impacts arising from deep sea mining and examines the previous experience of nodules exploration test. The potential impacts, mitigations and residual impacts of Seafloor Massive Sulphides (SMS) of Solwara Project are assessed.

Section 6 reviews the Nautilus Minerals Inc. Project as case study and made assessments on the seafloor production systems of SMS deposits including Production Support Vessel (PSV), Riser and Lifting System (RALS) and Seafloor Production Tools (SPTs). Moreover, environmental impacts and mitigations on Solwara 1 Project are reviewed. Then, legal and environmental regulations of the exploration used in Solwara Project are discussed.

Section 7 compares the sea floor mining tools with current Oil and Gas applications tools and discusses what is missing and what can be applied in offshore rules and regulations which LR is established.

Section 8 concludes with overall work of the above chapters.

2 THE SEABED AND ITS RESOURCES

2.1 Introduction

In the following sections we have defined the terms "Seabed", "Exploitation" and "Exploration". This gives an overview of the resources available on the seabed and uses of some of the metals which can be derived from subsea minerals. Furthermore, original environment conditions and ecosystems of marine resources are presented and economic analyses of raw materials which can be extracted from marine resources are discussed with appropriate graphs.

2.2 Definitions

2.2.1 Seabed

It is important to know the geological features of the sea bed to understand the offshore mineral deposits and design engineering systems for exploration and exploitation of their resources. Generally, the seabed varies significantly from the inshore areas to the greatest depth of the ocean in diverse landforms including mountains, valleys, canyons, trenches and underwater volcanoes. The seabed can be categorised into five zones as described below and illustrated in Figure 2.1 (Trujillo and Thurman, 2011).

- Continental shelf
- Continental slope
- Continental rise
- Abyssal plain
- Mid-ocean ridge.

Continental Shelf: Geologically, the continental shelf is defined as an area from the coast to water depths of 100 to 200m. The seabed on the continental shelf gently inclines seawards at an average slope of about 0.1° . Near major estuaries large amounts of sediments are deposited onto the seabed. The continental shelf is proposed to contain 80% of 7 resources, while the seabed beyond the continental shelf (roughly 80% of the seabed) is proposed to contain 20% of resources.

Continental Slope: The continental slope is a connection area bridging the continental shelf and abyssal ocean. The water depth changes significantly over a short distance with a steep slope of 4° . Along the continental slope there are many underwater canyons that cut into the

continental shelf, which are important channels for the water exchange between the shelf and the open ocean water. Due to the accumulation of sediments, turbidity currents occur sporadically, so called underwater avalanche.

Continental Rise: The continental rise begins seaward of the continental slope and runs down to a depth of around 3500m, at a flatter gradient than the continental slope.

Abyssal Plain: The abyssal plain is the flat seafloor area at water depths from 3,000 to 6,000m in high seas. At the sea bottom the environmental conditions are unique with high pressure, darkness and temperatures of approximately 3 °C.

Oceanic Ridge: The oceanic ridge is a continuous volcanic submarine mountain chain that goes around the worlds' oceans including the Mid-Atlantic Ridge, Pacific-Antarctic Ridge, East Pacific Rise, Mid-Indian, Southeast and the Southwest Ridges. The main features of sea bed are shown in Figure 2.1.

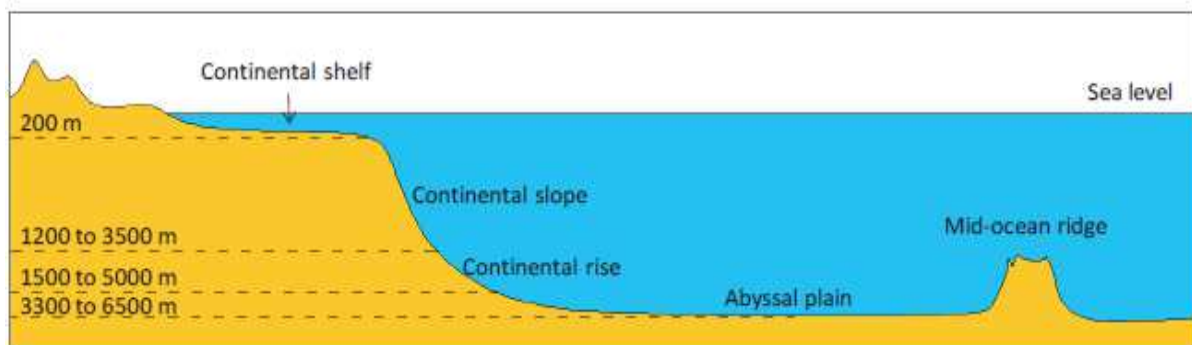


Figure 2.1: Sketch of main features of sea bed

Source: Available from (W Flentje, S E Lee, A Virnovskaia, S Wang, S Zabeen, 2012)

Other seabed features of interest include seamounts, which are underwater mountains formed by volcanic hot spot activity, and mid-ocean ridges, where new seafloor is created as tectonic plates move apart. The seafloor rock is generally covered in sediment, the thickness of which varies greatly. In general the sediment layer is thinnest on the mid ocean ridges and becomes thicker with distance from the ridges.

2.2.2 Seabed exploitation and exploration

The terms "Seabed exploitation" and "Seabed exploration" can be defined according to the definitions provided by the International Seabed Authority (ISA) for seabed mining.

Seabed exploitation means the recovery for commercial purposes of a deposit such as an ore, from the seabed and the extraction of minerals therefrom, including the construction and

operation of mining, processing and transportation systems for the production and marketing of metals.

Exploration means searching for deposits on the seabed, the analysis of such deposits, the testing of collecting systems and equipment, processing facilities and transportation systems, and the carrying out of studies of the environmental, technical, economic, commercial and other appropriate factors that must be taken into account in exploitation.

2.3 Resources Available On the Seabed

Oceans cover vast areas, around 80% of the earth's surface. In the past few decades the knowledge of deep seabed resources has increased significantly, and some believe that deep sea will become a 21st century strategic development base for a variety of natural resources which may include a deep-sea mining industry, deep-sea biotechnology industry, deep-sea technology and equipment manufacturing and other industrial categories. The main types of mineral resources that the seabed is rich in, are:

- Polymetallic massive sulphides
- Polymetallic manganese nodules
- Cobalt-rich manganese crusts,

2.4 Polymetallic Sulphides (SMS deposits)

2.4.1 Formation and Distribution

Seafloor Massive Sulphide deposits form on the ocean floor and contain appreciable concentrations of copper, zinc, gold, silver and other trace metals. They are the modern-day equivalents of ancient 'land-based' Volcanogenic Massive Sulphide ("VMS") deposits such as Kidd Creek in Canada. VMS deposits are a major source of the world's copper, zinc, lead, gold and silver.

SMS deposits form on the seafloor in water depths of up to ~4000 m. They form in areas where new ocean crust is forming, such as seafloor spreading centres. Seawater is drawn down through fractures in the oceanic crust, towards a hot buried magma chamber at depth (molten rock body). The heated seawater transforms into a hot acidic hydrothermal fluid and convection causes the fluid to rise up again towards the seafloor. The hot acidic hydrothermal fluid leaches metals from the surrounding rocks during transport, and may also interact with other hot fluids rising from the magma chamber. When these hot acidic fluids carrying

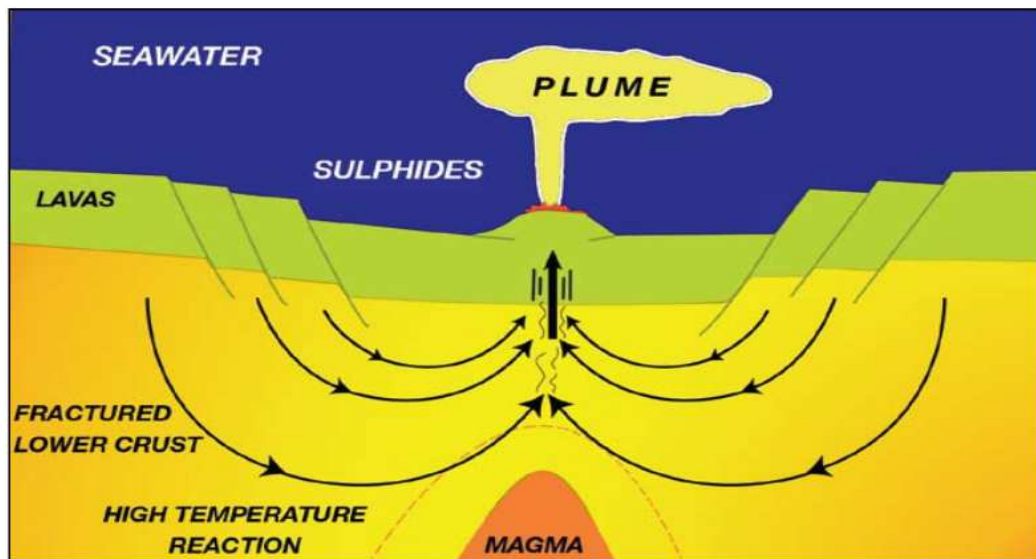


Figure 2.2: Formation of Seafloor Sulphides.

Source: <http://www.isa.org.jm/sites/default/files/files/documents/eng8.pdf>

dissolved metals and sulphur reach the seafloor (up to 400°C), they encounter cold ambient seawater (typically 2°C at 1500 m water depth). The sudden change in conditions causes metals and sulphur to precipitate out of solution as metal-rich sulphide, forming an accumulation of sulphide material on the seafloor. The formation of SMS deposits are illustrated as shown in Figure 2.2. SMS deposits commonly carry high concentrations of copper (chalcopyrite) and zinc (sphalerite) in addition to gold and silver. (Nautilus Minerals, 2014)



Figure 2.3: Hydrothermal Vents (www.botos.com)

Most hydrothermal chimneys (as shown in Fig 2.3) and SMS deposits have been located in mid-ocean at the East Pacific Rise, the Southeast Pacific Rise and the Northeast Pacific Rise. Several deposits are also known at the Mid-Atlantic Ridge but only one has so far been located at the ridge system of the Indian Ocean. The paucity of known sulphide deposits at the Mid-Atlantic Ridge and the Central Indian Ridge is explained by the fact that exploration in these areas has been limited. Only some 5 percent of the 60,000 kilometres of oceanic ridges worldwide have been surveyed in any detail.

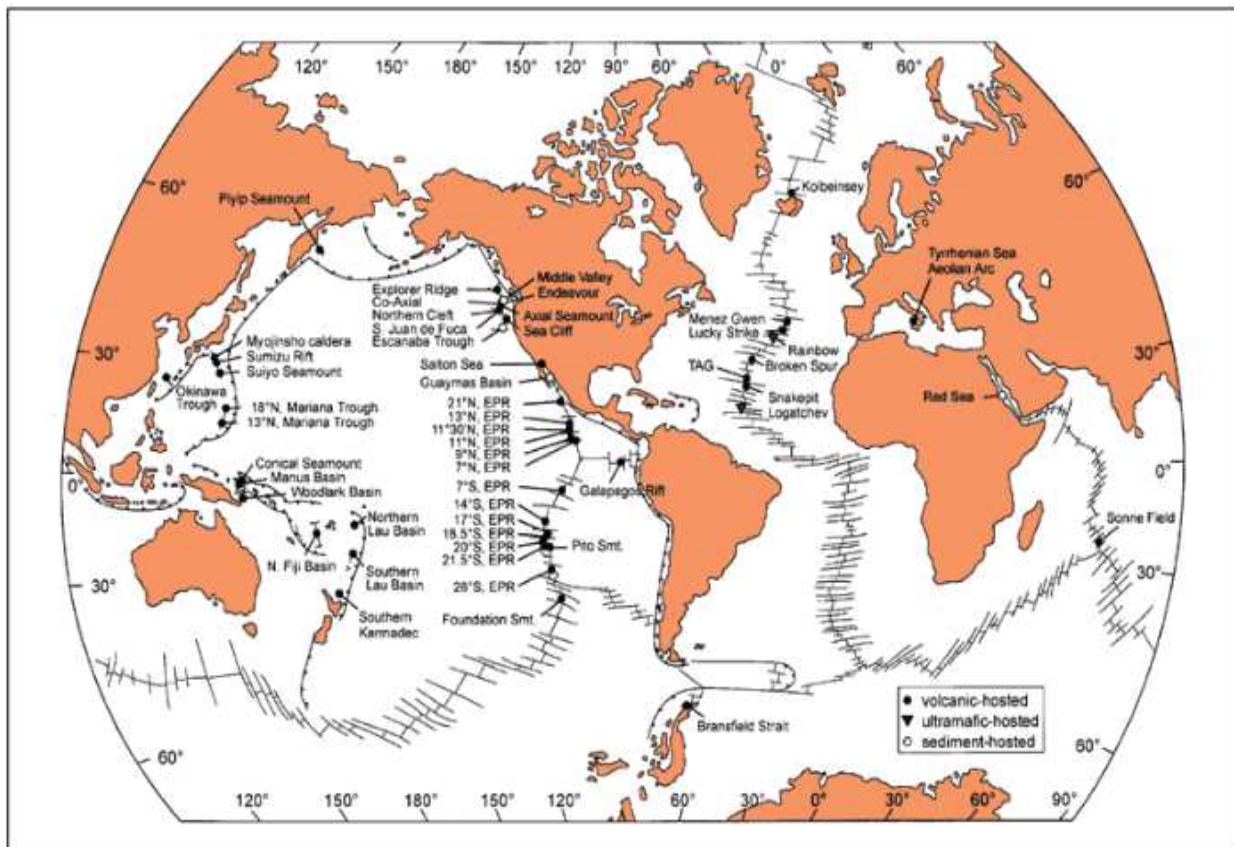


Figure 2.4: Location of Hydrothermal Systems and SMS deposits at the modern seafloor

Source: <http://www.isa.org.jm/sites/default/files/files/documents/eng8.pdf>

In the mid-1980s, additional sulphide deposits were discovered in the south western Pacific, at ocean margins where basins and ridges occur on the seafloor between the continent and volcanic island arcs. In these so-called back-arc spreading centres, magma rises close to the surface at convergent plate margins where one tectonic plate slips beneath another in a process called subduction. These discoveries led to extensive exploration of the marginal basins and the arc and back-arc systems of the western and south western Pacific, resulting in the discovery of further deposits in the Lau Basin and North Fiji Basin east of Australia, and the Okinawa Trough southwest of Japan. In 1991, extensive sulphide deposits were found to

be associated with felsic volcanism the most explosive type of volcanic activity, producing the heaviest ash flows in places such as the Manus Basin, north of New Caledonia. Hydrothermal deposits have also been located in the nearby Woodlark Basin, where seafloor spreading propagates into the continental crust east of Papua New Guinea. Today, more than 100 sites of hydrothermal mineralization are known as shown in Figure 2.4, including at least 25 sites with high-temperature black-smoker venting. (ISA 2014)

2.4.2 Metal Contents in Massive Sulphides

Comparison of nearly 1,300 chemical analyses of seafloor sulphides reveals that deposits in different volcanic and tectonic settings have different concentrations of metals. Relative to samples from sediment-starved mid-ocean ridges, massive sulphides formed in basaltic to andesitic environments of back-arc spreading centres (573 samples) are characterized by high average concentrations of zinc (17%), lead (0.4%) and barium (13%), but little iron. Polymetallic sulphides at back-arc rifts in continental crust (40 samples) also have low iron content but are commonly rich in zinc (20%) and lead (12%), and have high concentrations of silver (1.1%, or 2,304 grams/t). In general, the bulk composition of seafloor sulphide deposits in various tectonic settings is a consequence of the nature of the volcanic source rocks from which the metals are leached.

High concentrations of gold have recently been found in sulphide samples from back-arc spreading centres, whereas the average gold content for deposits at mid-ocean ridges is only 1.2 g/t (1,259 samples). Sulphides from the Lau back-arc basin have gold content of up to 29 g/t with an average of 2.8 g/t (103 samples). In the Okinawa Trough, gold-rich sulphide deposits with up to 14 g/t of gold (average 3.1 g/t, 40 samples) occur in a back-arc rift within continental crust. Preliminary analyses of sulphides in the Eastern Manus Basin reveal 15 g/t with a maximum of 55 g/t gold (26 samples). High gold content up to 21 g/t has been found in barite chimneys in the Woodlark Basin. The most gold-rich seafloor deposit found to date is located at Conical Seamount in the territorial waters of Papua New Guinea, close to Lihir Island. Maximum gold concentrations in samples collected from the summit plateau of this seamount (2.8 km basal diameter at 1,600 m water depth, summit at 1,050 m) range up to 230 g/t with an average of 26 g/t (40 samples), which is about 10 times the average value for economically-mineable gold deposits on land. (ISA 2014)

2.4.3 Economic and Societal Relevance of Massive Sulphides

The hydrothermal vent processes create high depositions of copper, lead, zinc, gold and silver. Detailed characteristics for each element and its societal relevance will be described in the following paragraphs.

Copper is a ductile metal with very high thermal and electrical conductivity. The major portion of copper produced in the world is used by the electronic industry; most of the remainder is combined with other metals to form alloys. Copper is among the most important industrial metals and has been used in power cables, data cables, electrical equipment, automobile radiators, cooling and refrigeration tubing, heat exchangers, artillery shell casings, small arms ammunition, water pipes and jewellery. Copper is a fairly common element, with great reserves in the Earth's crust. However, only a tiny fraction of these reserves is economically viable, given present-day prices and technologies. Various estimates of existing copper reserves available for mining vary from 25 years to 60 years, depending on core assumptions such as the growth rate. The price of copper has historically been unstable and quintupled from June 1999 to May 2006 as shown in Figure 2.5.



Figure 2.5: Mineral Price Development of Gold, Copper, Zinc and Silver (1990-2012)

Source: (L Egorov, H Elost, N L Kudla, S Shan, K K Yang 2012)

Gold has been widely used throughout the world as a vehicle for monetary exchange, investment and jewellery. It has a high malleability, ductility and resistance to corrosion and “EMSHIP” Erasmus Mundus Master Course, period of study July 2014 – February 2015

most other chemical reactions. There is little true consumption of gold in an economic sense. Most of the gold used in manufactured goods, jewellery and works of art is eventually recovered and recycled.

Zinc is a transition metal of a light grey. It is the fourth "common" of the metals, after iron, aluminium and copper. One of the major applications for zinc is corrosion-resistance. Other applications are in batteries and alloys, such as brass. A variety of zinc compounds are commonly used in the organic laboratory. Zinc is an essential mineral of biologic and public health importance. Zinc deficiency affects about two billion people in the developing world and is associated with many diseases.

Silver is a soft, white, lustrous transition metal. It has the highest electrical and thermal conductivity. Silver is used to manufacture high-value objects such as medals, trophies, cups, cards and various decorative. It is also widely used in dentistry for dental fillings, nuclear industry for control rods, and electronics industry for conductive material.

Given the high commercial mining potential and increasing mineral prices, many mining companies, organisations and countries are engaging in the exploration and exploitation of seafloor massive sulphide deposits. (L Egorov, H Elost, N L Kudla, S Shan, K K Yang 2012)

2.4.4 Environment and Ecosystem

The hydrothermal vents associated with massive sulphide deposits provide the habitat for a variety of animal life previously unknown to science. Unlike all other life forms on earth, which depend directly or independently on sunlight and photosynthesis for their energy, the vent community thrives in a lightless, hot water bath suffused with hydrogen sulfide, a chemical lethal to most other animals. In this environment dwell worms two metres long, living in tubes of their own making, without a digestive system, deriving their energy from micro-organisms that oxidize methane and sulphides. Some 500 previously unknown animal species have been discovered around these biologically diverse vent areas.

The uniqueness and fragility of this geographically fragmented ecosystem, and the value it holds for fundamental biological studies of metabolism, evolution and adaptation, will have to be taken into account in planning for mineral exploration and exploitation. Studies have shown the resilience of existing populations in dealing with the rapid environmental changes of a volcanically active area. This resilience may be due to the presence of a "mother

population” capable of recolonizing a disturbed area. If this base population is destroyed by mining, however, the result could be the extinction of rare species. (ISA, 2014)

2.5 Polymetallic Nodules

2.5.1 Formation, Chemical Position and Occurrence

Polymetallic nodules (Figure 2.6), also known as manganese nodules, were discovered at the end of the 19th century in the Kara Sea, in the Arctic Ocean off Siberia (1868). During H.M.S. Challenger’s (1872–76) scientific expeditions, they were found to occur in most oceans of the world. According to the ISA description (ISA 2008a), “polymetallic nodules are rock concretions formed of concentric layers of iron and manganese hydroxides around a core. The core may be microscopically small and is sometimes completely transformed into manganese minerals by crystallization. When visible to the naked eye, it can be a small test (shell) of microfossil (radiolarian or foraminifer), a phosphatized tooth of shark, basalt debris or even fragments of earlier nodules. The thickness and regularity of the concentric layers are determined by the successive stages of growth. On some nodules they are discontinuous, with noticeable differences between the two sides. Nodules vary in size from tiny particles visible only under a microscope to large pellets more than 20 centimetres across.



Figure 2.6: Sample and Seabed Images of Manganese Nodules

Source: The Federal Institute for Geosciences and Natural Resources (2012)

However, most nodules are between 5 and 10 cm in diameter, about the size of potatoes. Their surface is generally smooth, sometimes rough, mammillae or otherwise irregular. The bottom, buried in sediment, is generally rougher than the top”. Several theories have been proposed to explain the formation of nodules, including the hydrogenous, diagenetic, hydrothermal, halmyrolitic, and biogenic processes. Although the scientific community has not uniformly agreed, the following two theories are more popular:

Hydrogenous Process, which involves concretions that are formed by slow precipitation of the metallic components from seawater. This is thought to produce nodules with similar iron and manganese content and a relatively high grade of nickel, copper and cobalt.

Diagenetic Process, where the manganese is remobilised in the sediment column and precipitated at the sediment and water interface. Such nodules are rich in manganese but poor in iron and in nickel, copper and cobalt. The chemical composition of these nodules varies according to the location, size and characteristics of the core. The general composition of polymetallic nodules from different sources is provided in Table 2.1.

Origin	Chemical Composition (mass%)						References
	Mn	Fe	Ni	Co	Cu	Zn ^a	
Pacific Ocean	16.8 ^b	12.5	0.6	0.2	0.4	-	Heimendahl et al.(1976)
	24.5 ^c	11.5	0.7	1.15	0.25	-	Heimendahl et al.(1976)
	23.5	15.1	0.8	0.2	0.5	-	Han and Fuerstenau (1975,1976a,b) ^d
	31.3	5.62	1.61	0.14	1.75	-	Hsiaohong et al.(1992), Hsiaohong (1996)
	13.1	15.8	0.59	0.38	0.11	-	Ninae et al.(1996)
	27.1	4.12	1.23	0.13	1.21	0.12	Vu et al. (2005)
South-West Pacific Basin	16.6	22.8	0.35	0.44	0.21	-	Sen (2010)
Samoan Basin	17.3	19.6	0.23	0.23	0.17	-	Sen (2010)
Peru Basin	33.1	7.1	1.4	0.09	0.69	-	Sen (2010)
Indian Ocean	10	11.4	0.26	0.14	0.23	-	Kamungo and Jena (1988a,b),Kamungo and Das(1988),Kamungo (1999a,b)
	18.3	7.4	0.9	0.13	0.7	0.08	Jana (1993)
	20.1	6.29	0.99	0.1	0.1	0.13	Acharya et al.(1999)
	24	10	1.1	0.14	1.2	-	Kumari and Natarajan (2002a,b)
South Sea	27.7	8.92	1.62	0.02	0.1	0.08	Shen et al. (2007)

^a Zinc content was not reported by some authors.
^b Depth 4.9km
^c Depth 1.27km
^d Also contains molybdenum

Table 2.1: The chemical composition of polymetallic nodules from various source as reviewed by Senanayake (2011)

The nodules lie on the sea-bottom sediment, generally half buried. Some nodules are completely covered by sediment and, in some areas; nodules have been collected even though they are invisible on photographs. They vary greatly in abundance. In some places they cover more than 70 percent of the bottom, the nodules touching one another. However it is considered that, to be of economic interest, the abundance must exceed 10 kilograms per square metre, with an average of 15 kg/m² over areas of several tenths of a square kilometre. They can occur at any depth, but largest concentrations with sea floor sites covered by up to 70% were discovered in the abyssal zone between 4,000 and 6,000m. Nodules of economic interest have been found predominantly in three areas of the north central Pacific Ocean, the Peru Basin in the southeast Pacific and the centre of the Indian Ocean. Most promising

deposits in terms of nodule concentration and chemical composition are supposed to be in the Clipperton Fracture Zone and average abundance of polymetallic nodules are shown in Figure 2.7.

The total amount of polymetallic nodules lying on the sea floor was estimated at more than 1.5 trillion tonnes by John Mero in 1965. The estimate was reduced to 500 billion tonnes by A.A. Archer in 1981. However, not all nodule fields are eligible for mining. Several attempts were made to calculate the probable resources for future development. These approaches started by determining the number of mine sites that the world's oceans could accommodate. (ISA, 2014)

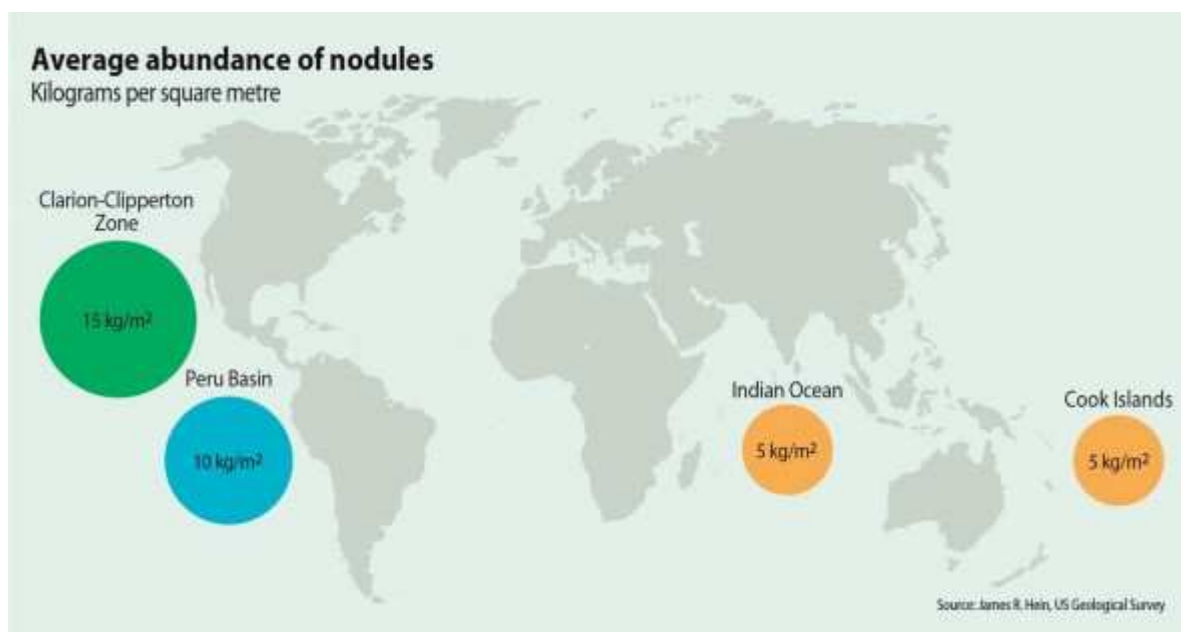


Figure 2.7: Average Abundance of Manganese Nodules

Source: James R.Hein, US Geological Survey

2.5.2 Economic and Societal Relevance

Since the 1960s various studies have addressed the economic feasibility of manganese nodule exploitation. Earlier studies concluded the break-even concentration of nodules per m² is 10 kg of nodules with a nickel and copper ratio of around 3% (Menard & Frazer, 1978). However, the feasibility is largely dependent on market price developments. Metal and mineral prices are highly volatile and sensitive both to market demands and supplies (see Figure 2.8 and Figure 2.9). Moreover, technological developments, the political environment and other factors may affect the prices. The figures below present prices of manganese, cobalt, copper and nickel for publically available timescales.

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The manganese nodules are rich in manganese, nickel, copper, cobalt and rare earth elements. Manganese (Mn) is essential to iron and steel production by virtue of its sulfur-fixing, deoxidizing, and alloying properties. Steelmaking, including its iron making component, accounts for most global manganese demand, around 90% of the total. Manganese ferroalloys, consisting of various grades of ferromanganese and silico manganese, are used to provide most of this key ingredient to steelmaking. Products for construction, machinery, and transportation are leading end uses of manganese. Manganese also is a key component of certain widely used aluminium alloys and, in oxide form, dry cell batteries. As ore, additional quantities of manganese are used for such nonmetallurgical purposes as plant fertilizers, animal feed, and colorants for brick.

Cobalt (Co) is a metal used in numerous diverse commercial, industrial, and military applications, many of which are strategic and critical. On a global basis, the leading use of cobalt is in rechargeable battery electrodes. Super alloys, which are used to make parts for gas turbine engines, are another major use for cobalt. Cobalt is also used to make airbags in automobiles; catalysts for the petroleum and chemical industries; cemented carbides (also called hard metals) and diamond tools; corrosion and wear-resistant alloys; drying agents for paints, varnishes, and inks; dyes and pigments; ground coats for porcelain enamels; high-speed steels; magnetic recording media; magnets; and steel-belted radial tires.



Figure 2.8: Mineral Price Development of Nickel and Copper (1989-2012)

Source: (L Egorov, H Elost, N L Kudla, S Shan, K K Yang 2012)

Nickel (Ni) is used in many specific and recognizable industrial and consumer products, including stainless steel, alnico magnets, coinage, rechargeable batteries, electric guitar strings, microphone capsules, and special alloys. It is also used for plating and as a green tint in glass. Nickel is an alloy metal, and its chief use is in the nickel steels and nickel cast irons, of which there are many varieties. It is also widely used in many other alloys, such as nickel brasses and bronzes, and alloys with copper, chromium, aluminium, lead, cobalt, silver, and gold. (L Egorov, H Elost, N L Kudla, S Shan, K K Yang, 2012)



Figure 2.9: Mineral Price Development of Manganese and Cobalt (2005-2012)

Source: (L Egorov, H Elost, N L Kudla, S Shan, K K Yang 2012)

2.5.3 Environment

Substantial amount of research has been carried out to characterise the biological environment in the areas of potential polymetallic nodules mining in the Pacific Ocean. (Tilot, 2006) studied distribution of the megafauna at the NIXO 45 site, which lies within Western French mining claim area in CCZ at 4,950 m depth. The megafauna is defined as organisms >1-4 cm that are visible in photographs of the ocean floor, and constitutes 17-50% of benthic abyssal biomass. The total density of the megafauna was estimated to 498 ind/ha. The author reports also that in several other studies the total density of the megafauna in several areas in CCZ is estimated to line in the range from 300 ind/ha and up to 4000 ind/ha, depending on the location, measurement method and primary production of the water column above the zone.

In the NIXO 45 site suspension feeders are more abundant than detritus feeders, carnivores and scavengers. Figure 2.10 shows the most abundant types of megafauna in the NIXO 45 site, and shows that the megafauna in this site is dominated by cnidarians, echinoderms and sponges. Cnidaria consist principally of actinids and octocoralliarids while echinoderms are represented mostly by holothurians and crinoids. The macrobentos types shown in Figure 2.10 are also representative for the CCZ area as a whole.

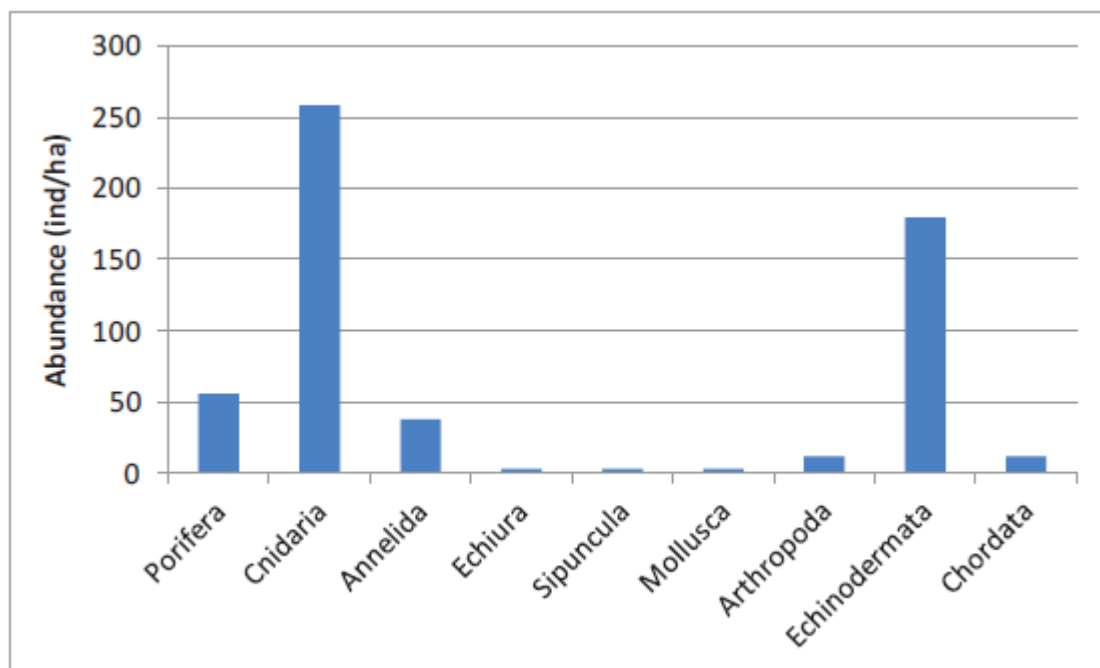


Figure 2.10: Abundance within each phylum at the NIXO 45 site within Western French mining claim area in CCZ (Tilot, 2006)

(Tilot, 2006) report also that abundance and composition of megafauna varied with different nodule-facies existing on the site. The greatest abundance of fauna was found on the facies with large scattered nodules (10 % area nodule coverage, close to 1200 ind/ha).

In the ISA Technical Study No. 3 (ISA, 2008a) the authors focused on polychaets, nematodes and foraminifera to study biodiversity, species ranges and gene flow in the abyssal Pacific Nodule Province. The reasons of focusing on these three animal types were:

- Polychaete worms dominate the abyssal macro fauna (animals between 0.3 to 30 mm in smallest dimension), constituting 60-75% of macrofaunal abundance and species richness.

- The nematode worms make up the bulk of the meiofauna (animals between 0.03 to 0.3 mm in smallest dimension) and may be the most abundant and species-rich, multi-cellular animals in deep-sea sediments.
- Foraminifera (amoeboid animals ranging in size from ~0.03 mm to 10s of centimetres) are the most abundant protozoans in deep-sea sediments, and substantially influence seafloor habitat structure and energy flow in the Pacific nodule province.

The main findings of the above study indicate that unexpectedly high and still poorly sampled levels of species diversity for all three sediment-dwelling animal types. Further, the result indicated that the abyss harbours a specially adapted fauna, distinct from the fauna of the continental margins. Also, the results provided significant evidence that community structure of the foraminifera and polychaetes differ substantially on scales of 1,000 to 3,000 across CCZ. (W Flentje, S E Lee, A Virnovskaia, S Wang, S Zabeen, 2012)

2.6 Ferromanganese Crusts

2.6.1 Occurrence, Formation and Geological Distribution

Oxidized deposits of cobalt-rich ferromanganese crust (Figure 2.11) are found throughout the global oceans on the flanks and summits of seamounts (submarine mountains), ridges and plateaux, where seafloor currents have swept the ocean floor clear of sediment for millions of years. These seamounts can be huge, some as large as mountain ranges on the continents. Only a few of the estimated 30,000 seamounts that occur in the Pacific, where the richest deposits are found, have been mapped and sampled in detail. The Atlantic and Indian oceans contain far fewer seamounts but have been far less sampled.

The minerals in crusts have precipitated out of the cold ambient seawater onto the rock surface, likely with the aid of bacterial activity. The crusts form pavements up to 25 centimetres thick and cover an area of many square kilometres. According to one estimate, about 6.35 million square kilometres, or 1.7 per cent of the ocean floor, is covered by cobalt-rich crusts, translating to some 1 billion tonnes of cobalt. Crusts do not form in areas where sediment covers the rock surface. They are found at water depths of about 400-4,000 metres, in contrast to the 4,000-5,500 metres at which manganese nodules occur. The thickest crusts, richest in cobalt, occur on outer-rim terraces and on broad saddles on the summits of seamounts, at depths of 800-2,500 metres.

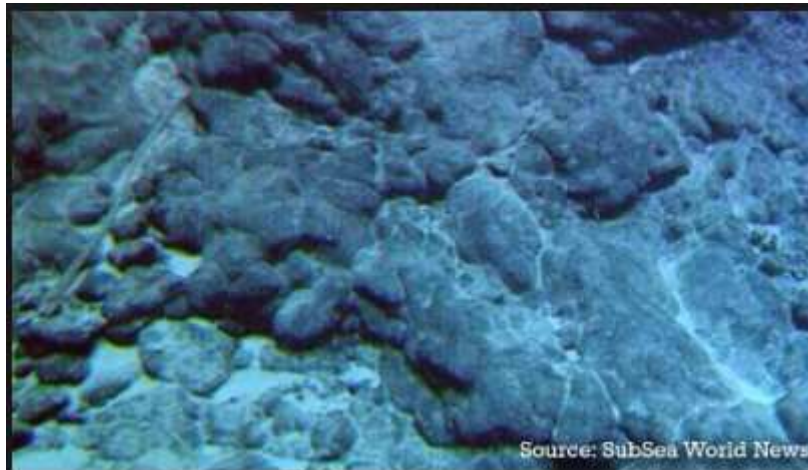


Figure 2.11: Seamount crusts.

Source www.deepseaminingoutofourdepth.org

Crusts generally grow at the rate of one molecular layer every one to three months, or 1-6 millimetres per million years, one of the slowest natural processes on earth. Consequently, it can take up to 60 million years to form a thick crust. Some crusts show evidence of two formative periods over the past 20 million years, with an interruption in ferromanganese accretion during the late Miocene epoch 8 to 9 million years ago, when a layer of phosphorite was deposited. This separation between older and younger materials can be a clue in identifying more ancient and thus richer deposits. The occurrence of richer deposits at depths where the water contains minimum oxygen has led investigators to attribute part of the cobalt enrichment to the low oxygen content of the seawater.

Based on grade, tonnage and oceanographic conditions, the central equatorial Pacific region offers the best potential for crust mining, particularly the exclusive economic zones around Johnston Island and Hawaii (United States), the Marshall Islands, the Federated States of Micronesia and international waters of the mid-Pacific. Moreover, crusts from shallow waters contain the greatest concentration of minerals, an important factor for exploitation. Exclusive economic zones are ocean areas extending 200 miles offshore from coastal baselines, within which coastal States have exclusive rights over resources as shown in Figure 2.12.

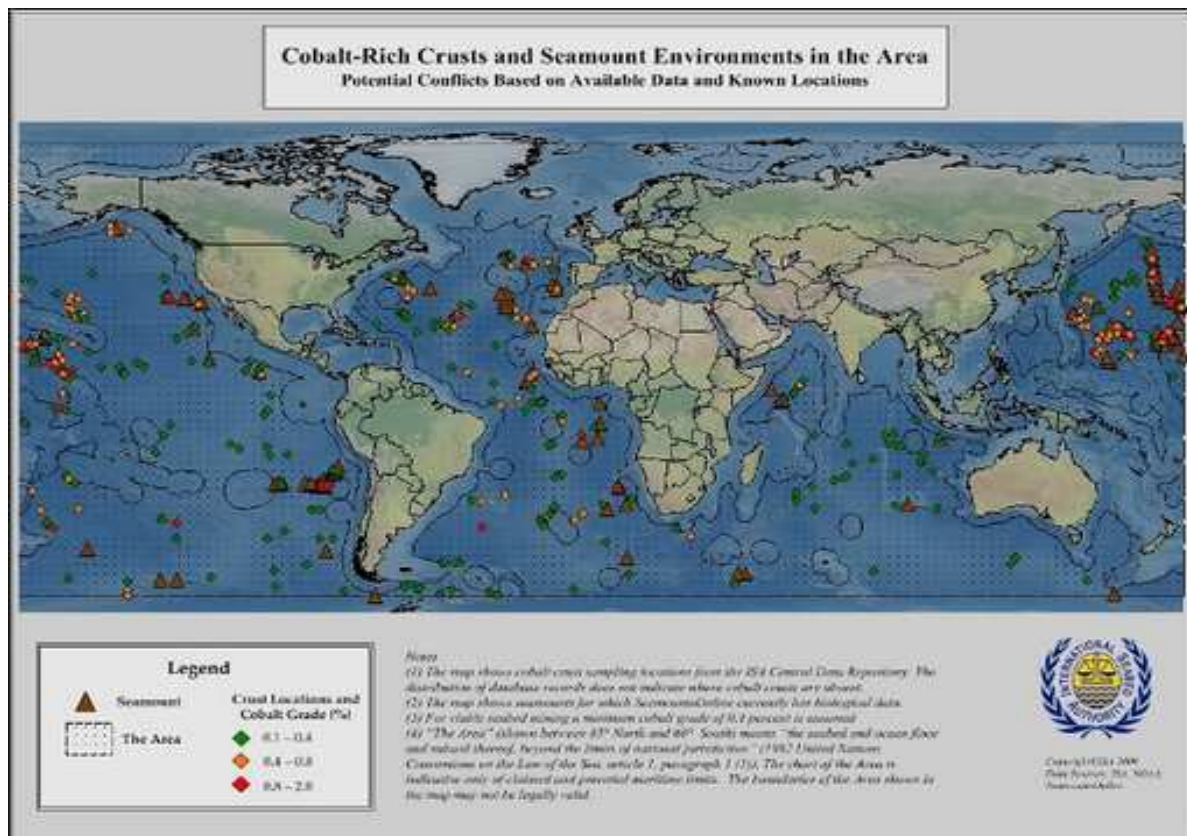


Figure 2.12: Geological distribution of Cobalt Crusts around the world (ISA)

2.6.2 Economic factor

Besides the high cobalt content compared to abyssal manganese nodules, exploitation of crusts is viewed as advantageous because high-quality crusts occur within the exclusive economic zones of island nations, in shallower waters closer to shore facilities. Recognition in the late 1970s of the economic potential of crusts was enhanced by the fact that the price of cobalt skyrocketed in 1978 as the result of civil strife in the mining areas of Zaire (now the Democratic Republic of the Congo), then the world's largest producer of cobalt. By 2005, Democratic Republic of Congo, Zambia and Canada together accounted for more than half of world mine production of about 53,500 tonnes.

Historically the price of cobalt has tended to be volatile: during the 1979 disturbances in Shaba Province of the former Zaire, the price quadrupled within a matter of weeks. At that time Zaire provided almost half of world supply. Output is now much less geographically concentrated, but demand tends to be price-inelastic in the short to medium term. After reaching peak price in 1995, the price of cobalt slumped steadily and came down to 1990 levels in 2002-03.

Value of metals in one metric tonne of cobalt-rich crust			
	Mean price of metal (2007 \$US/kg)	Mean Content in Crusts (ppm)	Value per Metric Ton of Ore (\$US)
Cobalt	54.56	6,899.00	376.41
Titanium	14.66	120,350.00	176.36
Cerium	88.00	1,605.00	141.20
Zirconium	150.00	618.00	92.70
Nickel	26.72	4,125 .00	110.22
Platinum	54,481.00	0.50	27.24
Molybdenum	56.76	445.00	25.26
Tellurium	242.00	60.00	14.52
Copper	6.90	896.00	6.18
Total	--	--	\$970.09

Kg is kilogramme; ppm is parts per million, which equals grams per tonne.

Table.2.2: Value of metals in one metric tonne of cobalt-rich crust.

Source: www.isa.org (ISA, 2014)

However, over the past four years there has been a sharp increase in cobalt prices, which stand now at around 54.5 \$/kg. If demand continues to increase, or if a supply problem is perceived, the price may increase further over a relatively short period. Since 2001 there has been steady increase in demand for both copper and cobalt metal which is evident from the increased production. In 2001, the world cobalt metal production was 38,000 tonnes where as in 2005 it was 53,500 tonnes. Demand for one or more of the many metals concentrated in crusts, in addition to that of cobalt, may ultimately be the driving force for seabed mining.

Despite the economic and technological uncertainties, at least three companies have expressed interest in crust mining. Several evolving circumstances may change the economic environment and promote mining in the oceans - for example, land-use priorities, fresh-water issues and environmental concerns in areas of land-based mines. There is a growing recognition that cobalt-rich crusts are an important potential resource. Accordingly, it is necessary to fill the information gap concerning various aspects of crust mining through research, exploration and technological development. (ISA, 2014)

3 LEGAL ENVIROMENT

3.1 Introduction

The legal framework for deep-sea mining derives from multiple levels of law. The foundation of the framework is provided by international law, the body of law that regulates the rights and duties of States and other actors, such as international organisations, recognised by international law. Seabed exploitation refers to seabed in national and international waters. Against the background of the seabed definition within this report (see Chapter 2), this section presents relevant legal authorities and regulations.

3.2 United Nations Convention on the Law of the Sea

The starting point for examining international law relating to deep-sea mining is the law of the sea, the branch of international law that is concerned with all uses and resources of the sea. The cornerstone of the law of the sea is the United Nations Convention on the Law of the Sea ('UNCLOS') and its two implementing agreements: the Part XI Implementation Agreement and the UN Fish Stocks Agreement. UNCLOS was finally adopted in 1982, after a lengthy and difficult negotiation process, and entered into force in November 1994. At present there are 166 parties to UNCLOS including the EU and its Member States. The overarching objective of UNCLOS is to establish a universally accepted, just and equitable legal order for the oceans that lessens the risk of international conflict and enhances peace and stability in the international community. The development of UNCLOS required a balancing exercise between the competing interests and claims of States in their various capacities including coastal States and land-locked States flag States and port States, and industrialized and developing States.

The issue of deep-sea mining was particularly controversial in this respect and is also one of the reasons why UNCLOS was finally adopted by a vote and is even one of the reasons why the USA has still to accede to it. Indeed the controversy over Part XI of UNCLOS, which is concerned with deep-sea mining, was such that the adoption of an additional implementing agreement, in the form of the Part XI Mining Agreement, was subsequently found necessary to modify UNCLOS in order to facilitate its entry into force.

Part of the balance eventually achieved by UNCLOS was through the system of maritime zones that it provides for, including those that pertain to coastal. These zones determine the

spatial competence and jurisdiction of States, and thus which specific legal regime applies to deep-sea mining, are considered next. Figure 3.1 gives an overview of the zones and definitions detailed in the following. Relevant to the research at hand are the territorial seas, contiguous zone, exclusive economic zones and the continental shelf as well as the high sea legislations.

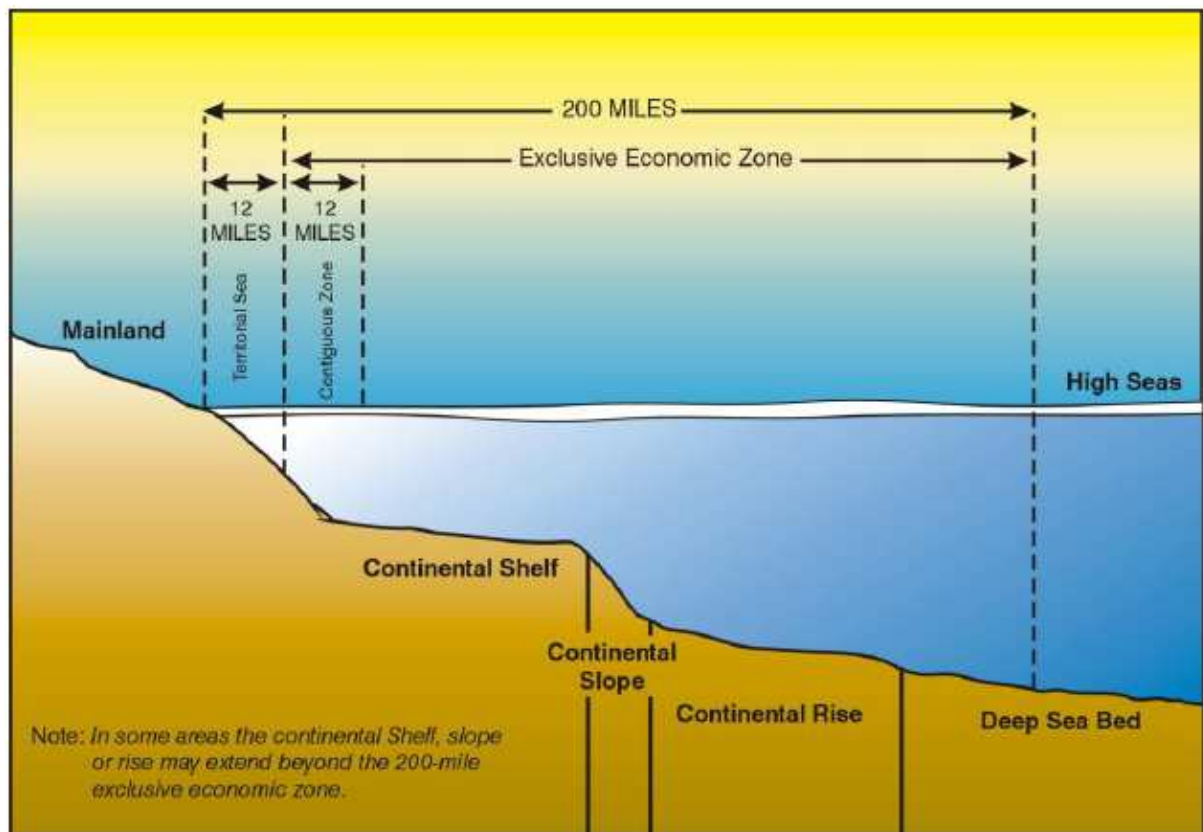


Figure 3.1: Maritime zones under UNCLOS

Source: Available from online document (ECORYS, 2014)

3.2.1 Territorial Waters and Contiguous Zone

Territorial waters (Art. 3 ff) reach out to 12 nautical miles from the low-water mark or so called baseline. The coastal state is allowed to define laws and regulate the exploitation of its resources within these waters. Foreign vessels are given rights to “innocent” passage, whereas fisheries, environmental jurisdiction and commercial activities are subject to state policies. The contiguous zone (Art. 33) may extend the territorial waters line to another 12 nautical miles. Within this zone states can enforce policies on customs, taxes, migration and the environment.

3.2.2 Archipelagic Waters

For a group of islands, the baseline is drawn between the outermost points of the territories. The waters in-between these points are defined as archipelagic waters and are in the sovereignty of the state but allow “innocent” passage.

3.2.3 Exclusive Economic Zones (EEZs)

EEZs define the waters 200 nautical miles from the baseline. Within its EEZ, coastal states have the sovereignty rights to the economic exploitation and exploration of its EEZ, such as the production of energy, as well as deep-sea mining and exercise jurisdiction. Foreign nations and vessels have the freedom of navigation and over flight. Land-locked or so called geographically disadvantaged nations have the right to participate in the revenues of exploited living resources of the EEZ's of coastal states in the same region. Figure 3.2 indicates the global allocation of EEZ's.

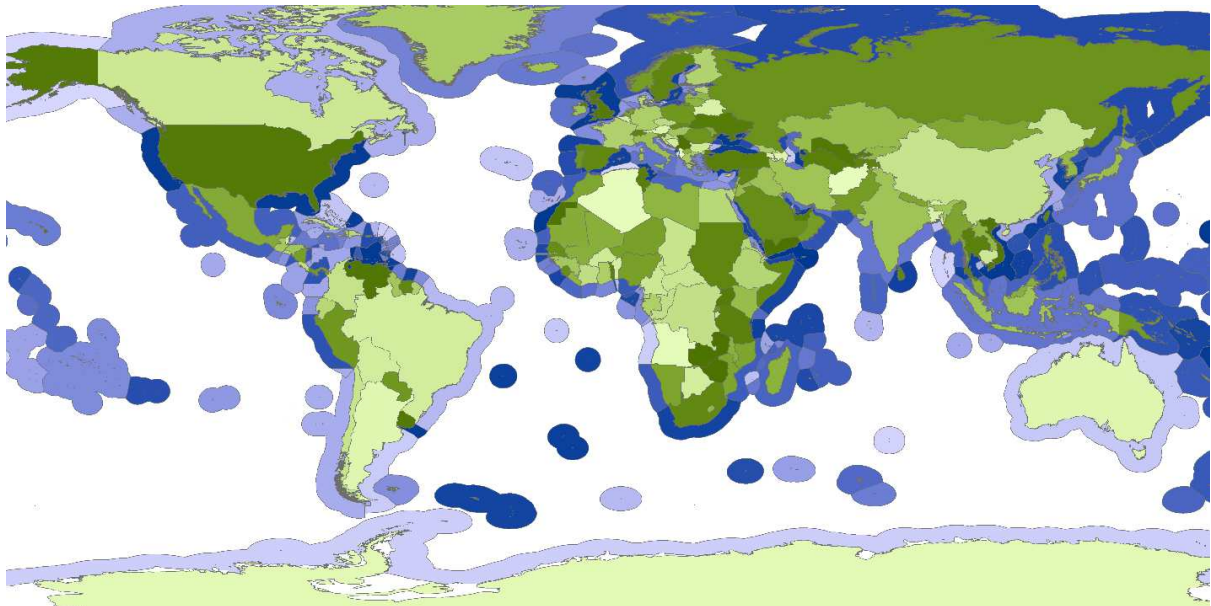


Figure 3.2: Exclusive Economic Zones (EEZs)

Source: Based on Maritime Boundaries Geodatabase, version 6.1,

<http://www.vliz.be/vmdcdata/marbound>

3.2.4 Continental Shelf

The continental shelf (Art. 76) was given a legal definition as the stretch of the seabed adjacent to the shores of a particular country to which it belongs. The continental shelf is defined as the natural prolongation of the land territory to the continental margin's outer edge, or 200 nautical miles from the coastal state's baseline, whichever is greater. It may never

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exceed 350 nautical miles from the baseline; or it may never exceed 100 nautical miles beyond the 2,500 meter.

Coastal states have exclusive rights to resources located within the continental shelf. Coastal states have the exclusive right to harvest minerals and non-living materials in the subsoil of its continental shelf and also have exclusive control over living resources "attached" to the continental shelf, but not to creatures living in the water column beyond the exclusive economic zone.

3.2.5 The Area and High Seas

Beyond the outer edge of the continental shelf lies the Area, defined by UNCLOS as the 'seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction', and which is the subject of Part XI of UNCLOS. No State may claim sovereignty or sovereign rights over any part of the Area or its resources. Instead, all rights in the 'resources' of the Area are 'vested in mankind as a whole' on whose behalf the International Seabed Authority (ISA), established pursuant to UNCLOS, is to act. Further provisions on the functioning of ISA are set out in the Part XI Implementation Agreement and this will be considered in more detail below.

The water column and the surface waters of the sea directly above the Area (and above any part of the continental shelf that extends beyond 200 nm from the baseline) are the high seas which include all parts of the sea that do not form part of the EEZ, territorial sea or other maritime zones of coastal States. The high seas are the subject of Part VII of UNCLOS. The provisions of Part VII therefore apply to the airspace, surface waters and water column beyond the outer limit of the EEZ and the seabed and subsoil of that same area. In other words, the UNCLOS regime for the high seas overlaps with its regime for the Area and, as noted, may overlap with the regime of the continental shelf (to the extent applicable). All States enjoy the freedoms of the high seas, which include the freedoms of over-flight, fishing and scientific research. Moreover no state may seek to subject any part of the high seas to its sovereignty. This principle ensures the conservation of resources for future generations and regulates exploration and exploitation by the international community.

3.3 International Seabed Authority (ISA)

The International Seabed Authority is an intergovernmental body based in Kingston, Jamaica, that was established to organize and control all mineral-related activities in the international seabed area beyond the limits of national jurisdiction, an area underlying most of the world's oceans. Currently there are 166 members of the Authority (165 States and the European Union). The Authority was established under the 1982 United Nations Convention on the Law of the Sea and came into force in 1994 as a fully operational international organization. The headquarters are located in Kingston, Jamaica. The ISA has a 35-member staff led by Secretary-General Nii Allotey Odunton of Ghana.

The budget of ISA is based on the United Nations (UN) scale of assessments modified to take account of the fact that ISA has fewer members than the UN. The principal organs of ISA foreseen in Part XI of UNCLOS are the Assembly, the Council and the Secretariat as well as the Enterprise as illustrated in Figure 3.3. The Council is also assisted by a Legal and Technical Commission and an Economic Planning Commission.

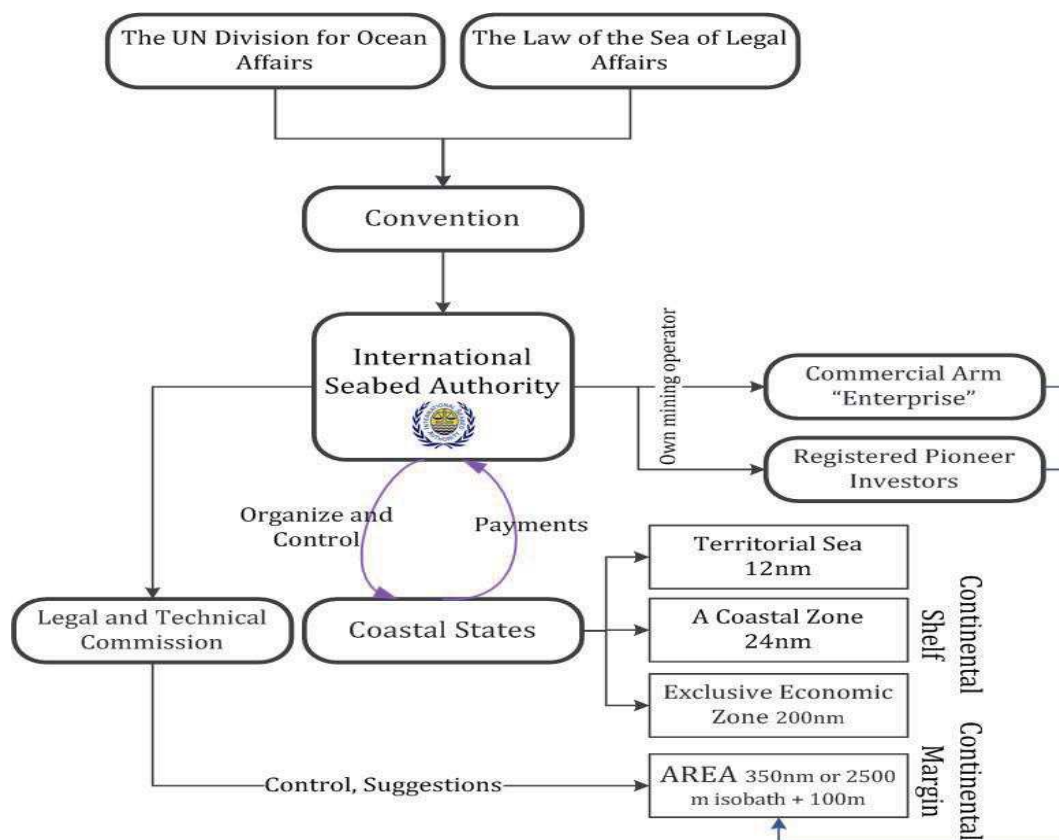


Figure 3.3: International Seabed Authority Framework, available from (J Parada, X Feng, E Hauerhof, R Suzuki, U Abubakar , 2012.)

3.3.1 The Assembly

The Assembly, which comprises one representative from each ISA member, is the supreme organ of ISA responsible for establishing the general policies of the organization. Meetings of the Assembly, which must take place at the seat of ISA in Kingston, Jamaica unless the Assembly decides otherwise, are usually held once a year over a four-day period each July.

As a general rule, decision making in all of the organs of ISA should be by consensus, although if consensus is not possible each member of the Assembly has one vote. Practically all decisions of the Assembly have been taken by consensus. Although the Assembly is considered to be the supreme organ of ISA, it is responsible for electing the members of the Council and the Secretary-General and approving the budget, with regard to a wide range of issues in terms of rule and policy-making. The Assembly may only consider and accept the recommendations of the Council or alternatively reject them and return them to the Council for reconsideration. In other words the Assembly does not have the power to modify such recommendations. To date, because of the consensual manner in which ISA operates, no Council recommendation has yet been rejected.

3.3.2 The Council

The Council is the executive organ of ISA which establishes the specific policies to be followed by the organisation as well as approving applications for exploration/exploitation rights. It consists of 36 members of the Authority elected by the Assembly on the basis of specific criteria laid down in paragraph 15 of the Annex to the Part XI Implementation Agreement so as to provide a balanced composition.

The criteria for Council membership are somewhat complex. In brief the rules provide for the division of the Council into a series of groups. Group A is made up of major consumers of commodities produced from the categories of minerals to be derived from the Area. The current members are: China, Italy, Japan and the Russian Federation. Group B is made of the four ISA members among the eight State Parties that have made the largest direct or indirect investments relating to activities in the Area. The current members are France, Germany, India and the Republic of Korea. Group C comprises four ISA members that are major net exporters of the categories of minerals to be found in the Area. The current members are Australia, Chile, Canada and South Africa. Group D is made up of six ISA members from among developing States representing different special interests such as States with large

populations, landlocked or geographically disadvantaged States and island States. Finally Group E has 18 members elected in accordance with the principle of ensuring an equitable geographical distribution of seats in the Council on the basis of the following geographical regions: Africa, Asia, Eastern Europe, Latin America & the Caribbean and Western Europe and others.

As with the Assembly, decisions of the Council are in principle to be taken by consensus. If, however, a vote becomes necessary each group will be treated as a chamber and depending on the subject matter a majority in each chamber may be required. In other words the voting system is extremely complex and fortunately, as decisions have also been taken on the basis of consensus, it has yet to be tested in practice. Because the Assembly is restricted to accepting or rejecting in full the recommendations of the Council the latter is in practice in an extremely powerful position within ISA.

The Council also now meets once a year, usually for a six-day period immediately before the meeting of the Assembly.

3.3.3 Legal and Technical Commission and the Finance Committee

Article 163 of UNCLOS provides that the Council is to have two organs, namely the Legal and Technical Commission and the Economic Planning Commission. For the time being, however, in accordance with Section 1(4) of the Annex to the Part XI Implementation Agreement the functions of the latter commission are discharged by the Legal and Technical Commission (LTC).

The LTC comprises 25 suitably qualified members elected for a five year term by the Council to undertake a range of tasks including reviewing applications for plans of work for activities in the Area, supervising exploration or mining activities, assessing the environmental impact of such activities and advising the ISA Assembly and Council. The LTC usually meets twice a year, in February and in July immediately before the meetings of the Council and the Assembly.

Mention can also be made of the Finance Committee provided for by Section 9 of the Annex to the Part XI Implementation Agreement, the members of which are elected by the Assembly for a term of five years. The basic task of the Finance Committee is to make recommendations to the Council on a range of financial issues. The Council is required to take account of such recommendations but is not bound by them.

3.3.4 The Secretariat

The ISA Secretariat, which comprises a Secretary-General elected for a four-year term by the Assembly, and ‘such staff as the Authority may require’, is located in Kingston, Jamaica. There are currently around 40 technical and non-technical staff.

3.3.5 The Enterprise

As noted above, one of the objectives of the Part XI Implementation Agreement was to reduce the size of the institutions foreseen under Part XI of UNCLOS including the Enterprise. As originally envisaged in UNCLOS, the Enterprise was to have sufficient legal and operational capacity to play a significant and active role in deep-sea mining on behalf of the international community. The industrialised countries were in particular concerned that in this form the Enterprise would have been bureaucratic and unwieldy. The Part XI Implementation Agreement substantially modified the provisions on the Enterprise and provides that the ISA Secretariat is to perform the tasks of the Enterprise on an interim basis. In reality the Enterprise exists on paper only.

In 2012 an application was made by the Canadian deep-sea mining company Nautilus Minerals Inc. to activate the Enterprise. Under the Part XI Implementation Agreement the only way the Enterprise can now exist is through a joint venture. Under the scheme for deep-sea mining activity in the Area, which will be considered in more detail below, a reserve area must be set aside in respect of each block. Activities in such areas are reserved to developing countries or the Enterprise. In the end the Council turned down Nautilus’ application due in part to the fact that a developing country, Singapore, had also applied for the same reserve area. It remains to be seen if the Enterprise will ever be formally established.

3.4 The regulatory regime for deep sea mining

Seabed resources may be found in the EEZ or continental shelf zone, or in the Area, and the law that applies depends on the location. Resources found within a country’s EEZ must be exploited in accordance with the laws of that country. National legislation is often written so as to be similar to international laws. However, as seabed mining is a relatively new industry, many countries lack relevant laws. When a country doesn’t have sufficient law governing seabed development, the country may choose to enforce the relevant international law or a neighbouring country’s law. This depends on the contract between the country and the

enterprise, and international organizations watch the contract contents with interest as shown in Figure 3.4. However, the international organizations cannot enforce any laws in this case.

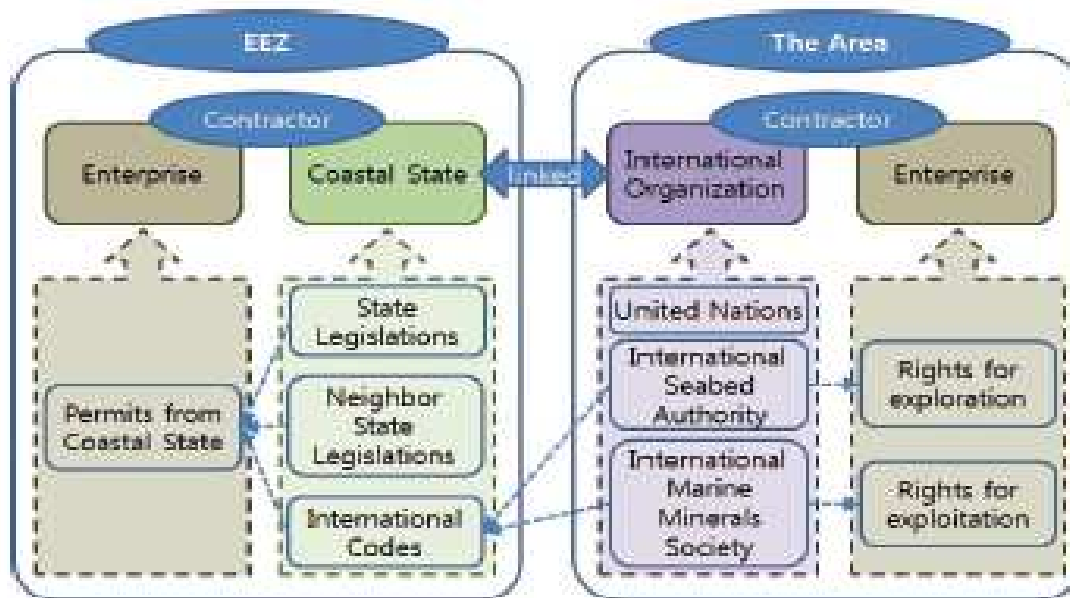


Figure 3.4: Legal relationships between coastal states, international organizations and Enterprises. (M B Bashir, S H Kim, E Kiosidou, H Wolgamott, W Zhang, 2012)

The regulatory regime for deep-sea mining in the Area is set out principally in Annex III of UNCLOS, which is entitled ‘Basic conditions of prospecting, exploration and exploitation’, as modified by the Part XI Implementation Agreement. In outline, exploration and exploitation activities may only be carried out in areas specified in detailed and approved plans of work by suitably qualified applicants in terms of financial and technical capabilities and on the basis of authorizations issued by ISA. Moreover such activities may only be undertaken by the Enterprise or by State Parties or by state enterprises or legal or natural persons that are sponsored by a State Party. The notion of ‘sponsorship’ is unique to Part XI and will be considered in more detail below. The regime addresses the three steps mentioned in the title of Annex III namely prospecting, exploration and exploitation.

The regulatory regime is supplemented by a series of rules, regulations and procedures adopted by ISA that together make up the ‘Mining Code’. These include the following instruments:

- Decision of the Assembly of the International Seabed Authority regarding the amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area (ISBA/19/A/9) (the ‘Nodules Regulations’);
- Decision of the Assembly of the International Seabed Authority relating to the regulations on prospecting and exploration for polymetallic sulphides in the Area (ISBA/16/A/12/Rev.1) (‘the Sulphides Regulations’);
- Decision of the Assembly of the International Seabed Authority relating to the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area (ISBA/18/A/11) (the ‘Crusts Regulations’); and
- Decision of the Assembly of the International Seabed Authority concerning overhead charges for the administration and supervision of exploration (ISBA/19/A/12).

A number of formal recommendations have also been adopted. The key point to emphasize about the regulations adopted to date is that they are only concerned with exploration. Regulations on exploitation and royalties have yet to be adopted. In other words although much work has been accomplished to date, the legal framework for deep-sea mining in the Area is not yet complete.

3.4.1 Prospecting

Prospecting is the subject of article 2 of Annex III of UNCLOS. Article 2(1) (b) requires a proposed prospector to: (a) provide a written undertaking to ISA to comply with the requirements of UNCLOS; and (b) to notify ISA of the approximate area or areas in which prospecting will take place. Additional provisions on prospecting are contained in the Nodules Regulations, the Sulphides Regulations and the Crusts Regulations. The regime for prospecting is slightly curious in that it does not actually confer any rights on the prospector in terms of exclusivity or the acquisition of mining rights. In other words there is basically no difference between prospecting and marine scientific research. Consequently it is probably not surprising that to date only one country has made a notification under article 2.

3.4.2 Exploration

Exploration activities may only be carried out in areas specified in detailed and approved plans of work by suitably qualified applicants in terms of financial and technical capabilities and on the basis of authorizations issued by ISA. The main legal provisions on exploration are

contained in article 153 and Annex III of UNCLOS, as amended by the Part XI Implementation Agreement, and in the Nodules Regulations, the Sulphides Regulations and the Crusts Regulations depending on the type of resource in question.

The three sets of regulations are essentially in the same form. The Nodules Regulations were adopted first in order to ‘grandfather’ the rights of the pioneer investors as required by the Part XI Implementation Agreement.

The regulations are rather detailed and are set out in ten parts. Part I, ‘Introduction’ includes a number of definitions. Similar definitions are found in the other regulations. Part II is concerned with Prospecting. Part III describes the content of applications to ISA for the approval of plans of work. Each application is to be made in the standard form prescribed in Annex II to the regulations accompanied by a certificate of sponsorship as necessary, information about the financial and technical capabilities of the applicant, information about previous contracts with ISA, written undertakings to comply with the applicable legal regime, a description of the area to which the application relates, sufficient to enable the LTC to designate a ‘reserved area’ and information necessary for the approval of the plan of work. Moreover each application is to be accompanied by an application fee, currently USD 500,000.

Part IV of the regulations is concerned with contracts for exploration: once a plan of work is approved a contract between ISA and the applicant is concluded in the form set out in Annex III of the regulations and containing the standard clauses set out in Annex IV, which include an express recognition of the security of tenure of the contractor which may only be suspended, terminated or revised in accordance with the contract.

Each contractor has the exclusive right to explore an area subject to a plan of work for specified resources and a preference and priority for exploitation in that area or those resources. Each contract also specifies the maximum size of the area allocated to the contractor. This varies depending on the type of resource. Thus the total area for nodules is 150,000 km² while for sulphides it is 10,000 km² divided into 100 blocks of 10 km² within an overall constraint area of 300,000 km². As regards Crusts, each ‘cobalt crust block’ may not exceed 20 km² in size (it may be square or rectangular) and there may be a maximum of 150 blocks, making a total exploration area of 3,000 km², which must be arranged in clusters of 5 contiguous blocks within a constraint area of 550 x 550 km. Each contract lasts for 15 years, after which the contractor must apply for a plan of work for exploitation unless the

contractor has already obtained an extension. Extensions for a period of five years are approved by the Council on the recommendation of the LTC.

Part V addresses the protection and preservation of the marine environment. ISA is required on the basis of recommendations from the LTC, to establish and periodically review rules, regulations and procedures to ensure the effective protection of the marine environment, to which end both ISA and sponsoring States must apply the precautionary principle. The LTC must also develop and implement procedures for determining on the basis of the best available scientific and technical information whether proposed activities would have serious harmful impacts on vulnerable marine ecosystems and to ensure that measures are taken to prevent such impacts or to refuse to authorise them. Contractors are required to take the necessary measures to prevent, reduce and control pollution and other hazards to the marine environment resulting from their activities in the Area and to apply a precautionary approach and best environmental practices.

Part VI of the regulations is concerned with the issue of confidentiality. In particular there is a presumption that data and information transferred to ISA pursuant to the regulations or a contract and designated as confidential by the contractor will be so treated subject to certain exemptions such as public availability from other sources.

The remaining parts of the regulations are relatively short. Part VII is concerned with general procedures, such as the service and delivery of notices under the contract and the adoption by the LTC of technical or administrative recommendations for the guidance of contractors, Part VIII is concerned with the settlement of disputes, Part IX is concerned with the finds of resources other than those which are the subject of the contract and Part X calls for the periodic review of the regulations. (ECORYS, 2014)

3.4.3 Exploitation

Work has begun on the development of the exploitation regulations that will form the exploitation code. ISA has recently completed a major stakeholder survey and the issue was discussed by the LTC at its most recent meeting in February 2014.

The development of the new regulations will inevitably be a very complex and challenging task that will need to address the applicable financial and environmental regimes. In terms of the financial arrangements key issues that will need to be addressed include the approach to royalties payable to ISA, the method of calculating such royalties and the relationship with

national taxation regimes. A certain degree of guidance is provided by section 8(1) of the Annex to the Part XI Implementation Agreement, which sets out a series of guiding principles. Apart from stipulating that the system of payments must be fair both to the contractor and to ISA (and that they must provide adequate means to determine that the contractor has complied with the system) the paragraph: indicates that the rates of payment should be within the range of those prevailing in respect of land-based mining to prevent competitive distortions; specifies that the system should not be complicated or impose major administrative costs (to this end the options of a royalty scheme or combined royalty and profit sharing system are canvassed); provides for the payment of annual fixed fees; calls for the periodic review of the system of payments; and provides that disputes shall be resolved in accordance with UNCLOS.

As regards matters of principle it is anticipated that the environmental framework will be easier to agree in that it will clearly require environmental impact assessment and environmental monitoring mechanisms. Environmental considerations certainly appear to be at the forefront of ISA's work. There will also be procedural issues to address as well as matters relating to the financial qualifications of applicants, guarantees and performance bonds. The Code for Environmental Management developed by the International Marine Minerals Society may provide a useful starting point for discussions in this respect.

There is some time pressure here given that the first exploration contracts will end in 2016: the Part XI Implementation Agreement specifies that the Council must thereafter consider and provisionally approve an application for a plan of work for exploitation even if the rules, regulations and procedures for exploitation are not in place. (ECORYS, 2014)

4 INTERNATIONAL RESEARCH ACTIVITIES

4.1 Introduction

As a result of the rising global need for raw materials and the declining quality of the land based mining deposits, exploiting new sources of raw materials is gaining importance for securing the long-term supply of natural resources and most industrialized countries interest to do research activities for exploration and exploitation in deep sea. This section aims to assess all the research activities of international companies which held exploration licenses from International Seabed Authority and especially for Germany. At the same time, some classification societies are interesting to involve in deep sea mining market and their preparation plans are to be approached in this chapter.

4.2 Exploration Licenses around the World

The International Seabed Authority has entered into 15-year contracts for exploration for polymetallic nodules and polymetallic sulphides in the deep seabed with fifteen contractors pursuant to resolution II of the Third UN Conference on the Law of the Sea. Twelve of these contracts are for exploration for polymetallic nodules in the Clarion Clipperton Fracture Zone with two contracts for exploration for polymetallic sulphides in the South West Indian Ridge and the Mid Atlantic Ridge and one contract for exploration for cobalt-rich crusts in the Western Pacific Ocean. (Table 4.1)

The conclusions of contracts allow these contractors to explore specified parts of the deep oceans outside national jurisdiction. Under the Regulations, each contractor has the exclusive right to explore an initial area of up to 150,000 square kilometres. Over the first eight years of the contract, half of this area is to be relinquished. Each contractor is required to propose a programme for the training of nationals of developing States. The training programme, as agreed with the Authority, is incorporated into the contract. Each contractor is also required to submit an annual report on its programme of activities. Prior to the commencement of its programme of activities under the contract, each contractor is also required to submit to the Secretary-General a contingency plan to respond effectively to incidents arising from its activities in the exploration area.

Type of mineral deposit	Sponsoring State	General location of the exploration area under contract	Contractor	Date of entry into force of contract	Date of expiry of contract
Sea-floor polymetallic sulphides	France	Mid-Atlantic Ridge	Institut français de recherche pour l'exploitation de la mer	To be signed	
	Korea	Central Indian Ridge	Government of the Republic of Korea	To be signed	30.04.2029
		Mid-Atlantic Ridge	Government of the Russian Federation	29.10.2012	28.10.2027
	China	Southwest Indian Ridge	China Ocean Mineral Resources Research and Development Association (COMRA)	18.11.2011	17.11.2026
Cobalt-rich ferromanganese crusts	China	Western Pacific Ocean	COMRA	29.04.2014	28.04.2029
	Japan	Western Pacific Ocean	Japan Oil, Gas and Metals National Corporation (JOGMEC)	27.01.2014	26.01.2029
Polymetallic (manganese) nodules	Kiribati	Clarion-Clipperton Fracture Zone (CCZ)	Marawa Research and Exploration Ltd.	To be signed	
	United Kingdom of Great Britain and Northern Ireland	CCZ	UK Seabed Resources Ltd.	08.02.2013	07.02.2028
	Belgium	CCZ	G-TEC Sea Mineral Resources NV	14.01.2013	13.01.2028
	Tonga	CCZ	Tonga Offshore Mining Limited	11.01.2012	10.01.2027
	Nauru	CCZ	Nauru Ocean Resources Inc.	22.07.2011	21.07.2026
	Germany	CCZ	Federal Institute for Geosciences and Natural Resources of Germany	19.07.2006	18.07.2021
		Indian Ocean	Government of India	25.03.2002	24.03.2017
	Japan	CCZ	Deep Ocean Resources Development Co. Ltd.	20.06.2001	19.06.2016
	France	CCZ	Institut français de recherche pour l'exploitation de la mer	20.06.2001	19.06.2016
	China	CCZ	COMRA	22.05.2001	21.05.2016
		CCZ	Government of the Republic of Korea	27.04.2001	26.04.2016
	Bulgaria, Cuba, Czech Republic, Poland, Russian Federation and Slovakia	CCZ	Interoceanmetal Joint Organization	29.03.2001	28.03.2016
	Russian Federation	CCZ	Yuzhmoregeologiya	29.03.2001	28.03.2016

Table 4.1: Exploration licenses issued from International Seabed Authority.

Source: http://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=112

4.3 Germany

Germany as an industrial nation is highly dependent on the import of mineral or metal resources. Sources which have not been considered until now are the marine mineral resources, which in recent times are enjoying more and more increasing interests and which might provide in future a considerable contribution to the supply security on metal resources. In terms of economic usability and the long-term safeguarding of access to metallic raw materials, the incidence of manganese nodules, cobalt-rich manganese crusts, seafloor massive sulphides and phosphorite nodules is of great interest.

Germany has held an exploration license for manganese nodules in the Pacific Ocean since 2006. An application for a second exploration license for seafloor massive sulphides in the Indian Ocean was made to ISA in 2013. With the aid of the German government's National Masterplan Maritimes Technologies (NMMT), policy-makers and society have become more aware of deep-sea mining in recent years, and the issue has been highlighted at various events.

The objective of environmentally friendly deep-sea mining must be furthered. To this end, the related federal ministries, along with interested companies and research institutes and the Federal Institute for Geosciences and Natural Resources (BGR), are required to prepare and implement an environmentally friendly technology demonstration project which can also take place in the European context and which has been coordinated with the ISA, taking into consideration the entire process chain.

This would enable Germany to pioneer high standards for environmentally friendly deep-sea mining. To date, German companies have only played a relatively minor role on the market for marine mineral resources, which is developing dynamically globally. All the major mining companies as potential end clients are located outside of Germany.

Innovative solutions in the key fields of drilling technology, conveying technology and underwater engineering are available. Synergies can be achieved by using related technologies from the fields of mining engineering, drilling and tunnel-driving engineering, pump technology as well as automatic control engineering. German companies and institutions offer tried-and-tested exploration technologies and services. Furthermore, Germany has efficient, innovative shipyards and maritime suppliers in the field of special shipbuilding. Technological challenges pertaining to the future commercialization of the extraction of marine mineral resources are: increasing economic efficiency, optimizing environmental compatibility, the supply of energy, the development of intelligent systems for largely autonomous production processes and chemical metallurgical processing.

4.3.1 Deep Sea Mining Alliance (DSMA)

Backed up by the NMMT of the German government and corresponding activities the idea and the advantage of deep sea mining gained more and more interests and supporters. Based on this development the Deep Sea Mining Alliance (DSMA) association was founded in April 2014. Major goals of the association are the preparation of commercial, technological and scientific projects on deep-sea mining as well as a better coordination of national and international activities on an environmentally friendly and sustainable exploration and exploitation of marine mineral resources. As a joint platform of the industry, the main objectives of the DSMA are:

- To push ahead with the development of deep-sea mining projects both in Germany and internationally

- Support of innovation and R&D projects
- Close cooperation with leading research institutes, taking into consideration all environmentally relevant aspects
- Creation of a "strategy roadmap" with the preliminary target being the performance of a "pilot mining test".

The DSMA will cover the entire deep-sea mining value chain from a single source and will support deep-sea mining innovations based on R&D and JIP projects. The newly founded association will be open for international members. In the meantime the DSMA comprises more than 20 members mainly from the industry. A number of further membership applications - including also international applicants - are announced. Mr Leonhard Weixler from Bauer Maschinen was elected as President of the DSMA. Prof Peter E. Halbach, Free University of Berlin, was elected as Chairman of the advisory board. The members of DSMA and their respective focuses are described below in Table 4.2.

Company/Institution - Contact Person -	Focuses
BAUER Maschinen GmbH - Leonhard Weixler -	Drilling equipment for offshore foundations and subsea exploration, sea bed drill rigs
Dr. Warner Brückmann - Dr. Warner Brückmann -	Scientific consulting for marine mineral resources
Continental / ContiTech / Oil and Marine Eddelbüttel + Schneider GmbH - Tamo Voelkner -	Special rubber riser systems for offshore mining
Develogic GmbH - Ivonne Kussmann -	Signal processing solutions for underwater communication systems
DFKI - German Research Center for Artificial Intelligence - Jens Mey -	Development and realisation of artificial intelligence methods in underwater systems and robotics
DNV GL SE - Karsten Hagenah -	Classification society
EvoLogics GmbH - Dr. Rudolf Bannasch -	Solutions for multiple underwater communication, positioning, navigation and monitoring applications
Fraunhofer - Prof. Thomas Rauschenbach -	Maritime systems, underwater robotics
Free University Berlin - Prof. Peter Halbach -	Raw material geology and marine geochemistry for marine mineral resources
Harren & Partner Ship Management - Heiko Felderhoff -	Ship management in the sectors of heavy-lift, offshore oil & gas-offshore and the wind energy

HYDROMOD Service GmbH - Johannes Post -	Management, consulting in deepsea mining, hydro-geophysical field measurements, oceanographic modelling, environmental monitoring; Environmental Impact Studies, MetOcean-Studies
IMS Ingenieurgesellschaft mbH - Dr. Alexander Mitzlaff -	Civil engineering, offshore technology, engineering and installation, environmental engineering
Keppel Offshore & Marine Technology Centre (KOMtech) - Ms. Wang, Rong -	R&D and product development for offshore and deep-sea technologies
Prof. Hermann-Rudolf Kudrass - Prof. Hermann-Rudolf Kudrass -	Scientific consulting for marine mineral resources
Lloyd's Register - Uwe Bollwinkel -	Classification society
MBT GmbH - Torsten Turla -	Sales and service for oceanographic, geophysical and hydrographic equipment
MC Marketing Consulting - Michael Jarowinsky -	Management and technology consulting for deep-sea mining
MHWirth - Dr. Steffen Knodt -	Drilling rig systems for the offshore oil & gas industry, several concept studies for deepsea mining
RWTH, AKR, Aachen - Martin Koepcke - - Dr. Ludger Rattmann -	Processing concepts and solutions for marine mineral resources
Siem Offshore Contractors GmbH - Lars Muck -	Service contractor for the offshore oil and gas/renewable energy industry
Technical University Clausthal - Jonas Weber -	Processing concepts and solutions for marine mineral resources
Wärtsilä - Henning von Wedel -	Power solutions for marine and energy markets, ship design

Table 4.2: Members of DSMA and their focuses

Source: www.deepsea-mining-alliance.com

4.3.2 Exploration Activities in the German Area

Germany has been a member of the International Seabed Authority since its foundation in 1994. Germany has been engaged substantively in research activities in the Area. In 2006 the German Federal Institute for Geosciences and Natural Resources entered a contract for exploration for polymetallic nodules in the Clarion-Clipperton Fracture Zone with the ISA. In December 2013, the Federal Institute applied for the approval of a plan of work for exploration for polymetallic sulphides in the Indian Ocean. The aim of exploring this deposit prior to industrial use is the long-term security of supply in Germany with the raw materials mentioned above.

The German license area covers 75,000 km², spread over two sites with 17,000 km² in the central area of 58,000 km² and the east of the so-called manganese nodule belt. Centrally

located between Hawaii and Mexico deep-water area with water depths of 4000-6000 m is densely covered with polymetallic nodules, also called manganese nodules. The tubers are mostly 3 and 8 cm in size. In addition to an average of 25 percent contain manganese also around 3 percent copper, nickel and cobalt. Above all, these three latter value metals form an important source of raw materials for the future. Other trace metals that are found in the tubers in interesting concentrations are molybdenum, lithium and neodymium.

Contractual agreements with the IP stipulate that each contractor collects environmental reference data already during the 15-year exploration phase. Based on these data, the impact of possible future mining activities will be assessed and evaluated before the intervention in the deep sea habitat. In addition to the collection of biological data, extensive studies of the oceanographic conditions and sediment properties are required (Eg. flow speeds and directions; particle concentrations in the water column; shear strength, composition and grain size distribution of the sediments, seafloor topography).

In order to assess the impact of a possible future manganese nodule mining on the soil fauna must first be identified on the basis of the above data undisturbed areas (Preservation reference zones), which can then be compared with disturbed areas (Impact reference zones). For monitoring the impact of the reference areas must equal in terms of their habitat (species composition, population density) and tuber density and sediment properties. Because the areal distribution of manganese nodules is not uniform, large unspoiled areas would remain between the economically attractive areas. The re-colonization of disturbed areas could then take place on these adjacent, non-degraded fields.

A central element in deciding on a future mining will be the obligation to submit an environmental impact study (Environmental Impact Assessment). In such a study, the results of 'pre-pilot mining tests' and the related comparison of environmental studies before and received after the test. Such measures should use in principle both sustainable as also ensure effective protection of the deep sea at all times.

In the years 2008 and 2009 were two exploration trips instead of the US research vessel Kilo Moana. The main objective was the detailed topographical survey of the sea floor in the entire license area for the creation of a digital terrain model. In addition, samples were taken to the spatial variations in the loading density with manganese nodules and their metal content to be determined. In one funded by the BMBF expedition with the German research vessel Sonne in spring 2010, extensive studies have been carried out about the history of the tubers.

Another important part of this BMBF-project is the study of biodiversity in the license area. Partner in this three-year research project are the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven (AWI), the Leibniz Institute of Marine Sciences in Kiel (IFM-GEOMAR), the German Centre for Marine Biodiversity (DZMB) in Wilhelmshaven, the Centre for Marine Environmental Sciences at the University of Bremen (Marum) and the Max Planck Institute for Marine Microbiology (see below). In the spring of 2012, the German-French expedition BIONOD took place on the French research vessel L'Atalante. The focus of this collaboration, a comprehensive comparison is the diversity and distribution of soil fauna in the two national license areas for exploration of poly metallic nodules.

The previously analysed samples show a high abundance and diversity of soil fauna. The Inventory of Species richness and density of soil organisms contributes to the large-scale acquisition of the habitats in manganese nodule belt. On the basis of these data, the IMF wants to mine reserves of 400 x 400 km including a total of approximately 30% of the area of the manganese nodule belt. These areas are intended to preserve the unique ecosystems of the deep sea ensure manganese nodule belt and allow for recolonization of harvested areas after a possible future mining.



Figure 4.1 Nodule Collecting Model developed by Aker (BGR, 2014)

The extreme environmental conditions in the salt water of the deep sea with pressures to 600 bar and temperatures of 2 ° C require a highly resistant technology to reduce manganese nodules. Although no production started after years to be expected, BGR use the time for the

development of a contemporary and possible eco-friendly concept for possible future recovery from the deep sea. A building block for such pumping technology is a self-propelled collector, it was conceived in 2010 at the order of BGR by the Aker Wirth GmbH. Currently, and BGR is working with the RWTH Aachen and the Jacobs University in Bremen on a concept for processing and metal recovery of manganese nodules. (BGR, 2014)

4.4 EU Funded Consortiums

4.4.1 MIDAS Project

The MIDAS project - Managing Impacts of Deep-sea Resource exploitation - is a new, multidisciplinary research programme that will investigate the environmental impacts of extracting mineral and energy resources from the deep-sea environment. This includes the exploitation of materials such as polymetallic sulphides, manganese nodules, cobalt-rich ferromanganese crusts, methane hydrates and the potential mining of rare earth elements. MIDAS is funded under the European Commission's Framework 7 programme and started on 1 November 2013 for a period of 3 years.

The MIDAS partnership represents a unique combination of scientists, industry, social scientists, legal experts, NGOs and SMEs from across Europe. MIDAS will carry out research into the nature and scales of the potential impacts of mining, including

- The physical destruction of the seabed by mining, creation of mine tailings and the potential for catastrophic slope failures from methane hydrate exploitation;
- The potential effects of particle-laden plumes in the water column, and
- The possible toxic chemicals that might be released by the mining process and their effect on deep-sea ecosystems.

Key biological unknowns, such as the connectivity between populations, impacts of the loss of biological diversity on ecosystem functioning, and how quickly the ecosystems will recover will be addressed.

MIDAS will work closely with regulatory organisations such as International Seabed Authority to develop the guidance framework for exploitation of seabed resources. The results from MIDAS will also serve to inform EU Member State regulatory obligations (e.g the Marine Strategy Framework Directive), not least by seeking to provide critical thresholds needed to establish the precautionary principle for securing a viable and sustainable seabed mining operating framework. The key aim of the project is to ensure that policy makers and

stakeholders have access to the best available scientific, technical and socio-economic knowledge regarding seabed mining.

The main expected outcomes of MIDAS are:

- Identification of the scale of possible impacts, and their duration, on deep-sea ecosystems associated with different types of resource extraction activities;
- Development of workable solutions and best practice codes for environmentally sustainable and socially acceptable commercial activities;
- Development of robust and cost-effective techniques for monitoring the impacts of mineral exploitation and the subsequent recovery of ecosystems;
- Work with policy makers in the European and international arenas to enshrine best practice in international and national regulations and overarching legal frameworks.

The MIDAS partnership are across Europe and listed in below Figure 4.2.

THE MIDAS CONSORTIUM

The MIDAS partnership represents a unique combination of scientists, industry representatives, social scientists, technologists, legal experts and SMEs from across Europe. Our partners are:

Seascope Consultants Ltd, UK	University of Bremen, Germany
Natural Environment Research Council, UK	University of Tromsø, Norway
GEOMAR, Germany	Wycliffe Management, Poland
Ifremer, France	Median SPC, Spain
University of Southampton, UK	University of Bergen, Norway
Instituto do Mar, Azores	Gianni Consultancy, the Netherlands
Alfred Wegener Institute, Germany	University of Algarve, Portugal
International Research Institute Stavanger, Norway	Deep Seas Environmental Solutions Ltd, UK
Senckenberg Institute, Germany	Universite Pierre et Marie Curie, France
University of Gent, Belgium	Coronis Computing SL, Spain
Norwegian Geotechnical Institute, Norway	IHC Mining, the Netherlands
NIOZ, the Netherlands	Fugro Geos, UK
Natural History Museum, UK	Environmental Resources Management, UK
CoNISMa, Italy	Dredging International, Belgium
Scottish Association for Marine Science, UK	BGR, Germany
University of Barcelona, Spain	P.P. Shirshov Institute of Oceanology, Russia

Figure 4.2: Partnership of MIDAS Project

Source: www.eu-midas.net

4.4.2 Blue Mining Project

The Blue Mining project will interact with other initiatives, current and past research projects. These are European Commission funded initiatives, like FP7 MIDAS (The MIDAS project addresses fundamental environmental issues relating to the exploitation of deep-sea mineral and energy resources) and ERA-MIN (Era-Min – Network on the Industrial Handling of Raw Materials for European Industries). Next to this the Blue Mining project will interact with the EC Study: “Study to investigate state of knowledge of Deep Sea Mining”.

The overall objective of Blue Mining is to provide breakthrough solutions for a sustainable deep-sea mining value chain. The project aims to develop the technical capabilities for accurate and cost-effective discovery, assessment and extraction of deep-sea mineral deposits from water depths up to 6,000m, as this is the required range where valuable seafloor mineral resources are found. Controlling these three capabilities is the key to accessing raw materials, decreasing EU dependency on imported resources, and strengthening Europe’s mining sector and its technology providers.

Blue Mining has adopted the land base mining project development approach as the backbone for economic, overall technical environmental and legal evaluation. For the scientific and technical approach, Blue Mining has adopted the “Technology Readiness Level (TRL)” methodology. TRL is a measure used to assess the maturity of evolving technologies (devices, materials, components, software, work processes, *etc.*) during its development and in some cases during early operations. The TRLs for the exploration of eSMS and SMnN are raised by research into self-potential surveys, controlled source electromagnetic surveys, optical mapping and geochemical grid sampling. Furthermore, seismic imaging, sub-seafloor drilling and sonar mapping – together with inversion of this data – will be used for faster and more reliable resource assessment.

The research into the exploitation of a deep-sea mine focuses on bringing the TRL of the vertical transport system (VTS) to a system demonstration level (in a relevant environment).

A design methodology for the VTS will be devised, including investigation into wear, and models for the slurry flow and riser dynamics. Blue Mining will also create its own design for the VTS. This will be integrated into a concept design of a full deep-sea mining operation, including ship-to-ship transfer of ore.

The UK-based National Oceanography Centre is involved in “MIDAS and BLUE MINING” projects and others in support of deep-sea exploration, geological and ecosystem modelling.

4.4.3 Conference and Events

Offshore & Deep Sea Mining conference is held on 6-7 November 2014 in London and many expert speakers from different companies such as ISA, and ABS are discussing about establishing economic feasibility, developing regulatory policy and capitalising on commercial opportunities. This event is aimed to companies seeking to explore opportunities in the deep sea mining industry and the following topics are discussed.

- Discuss utilising existing technology for deep sea mining and explore diversification opportunities for companies involved in offshore oil and gas, dredging and land-based mining
- Assess the commercial potential, examine the business case and get to grips with the economic fundamentals of deep sea mining
- Receive direct operational feedback from offshore and deep sea mining projects already in progress around the globe
- Hear from key regulators including the International Seabed Authority and the European Commission
- Scrutinize technical challenges and knowledge gaps, and identify R&D and innovation hot-spots
- Analyse the international mining support vessel market and discuss designing and equipping of purpose-built vessels

Furthermore, another conference called “Deep Sea Mining Summit 2015” will be held its third annual event in Aberdeen, UK on 9th February 2015. It will bring together a large array of solution providers, upcoming deep sea miners, members from the scientific community, and those within allied industries wanting to learn more about the opportunities within this emerging marketplace. Following the huge success of the previous Deep Sea Mining Summit, this year’s objective is to build on and identify new and innovative technology developments, technical know-how’s, and to focus on the real challenges which face a new breed of deep sea miners and industry providers. Case studies and real results will address the issues.

4.5 Benchmarking of Other Class Societies

In order to sustain the economic growth and increased demand for metals in the face of a dwindling supply on land, mining companies are highly interested to explore the seafloor for mineral resources. The mining companies (both contractors and equipment suppliers) positioning themselves in the seabed mining market will have the opportunity to benefit. At the same time, classification societies will have same opportunity to work for contractors and suppliers in certification of mining tools, consulting project definition for exploration, assessing the potential environmental impacts and providing technical solutions. Most classification societies such as ABS, DNV and Lloyd's Register established sets of rules and regulations for marine offshore industry and some have been involved in deep water field developments. In this section, benchmarking activities of some classification societies for deep sea mining are reviewed.

4.5.1 DNV GL

DNV GL is the member of Deep Sea Mining Alliance Association which is founded by the National Masterplan Maritime Technologies of the German government in April 2014. Major goals of the association are the preparation of commercial, technological and scientific projects on deep sea mining as well as a better coordination of national and international activities on an environmentally friendly and sustainable exploration and exploitation of marine mineral resources.

EU based consortium, Blue Atlantis will establish the world's only deep-sea mining test facility, covering RTD, mining tests, standards development and market access support. The consortium has 45 partners from 8 European countries along the entire value chain. DNV GL is one of the partners and envisions a commitment to perform classification, certification, and advisory services in the form of management system verification, environmental assessments, feasibility studies, approval in principle of underwater vehicles and mining tool concepts prior to detail design, support vessel integration, safety analysis, development of the mining standard, and training services with respect to the following work packages with other partners;

- Environmental monitoring and assessment
- Exploration activities for SMS in the EEZ of the Azores
- Mining Equipment Development

- Evaluation of the R&D projects
- Preparation of the mining support and production vessel
- Standards and risk
- Education and Training Programmes

Furthermore, DNV GL will join the Deep Sea Mining Summit 2015 as speaker and will discuss the following key points under the topic called ‘A risk-based approach to handle environmental aspects in deep sea mining’.

- Assessing the environmental impacts caused by deep sea mining activities.
- Guidelines for contractors for the assessment of possible environmental impacts arising from exploration.
- Developing a method based on identifying possible hazards and assessing their probability and consequences.
- A risk-based assessment of deep sea mining projects based on existing guidelines.

Moreover, DNV will be partially involved in certification of the Launch and Recovery System (LARS) of the first production support vessel which will be chartered by Nautilus Minerals Inc. The following DNV rules and regulations shall be complied.

- DNV Standard for Certifications of Lifting Appliances No. 2.22, October 2011 (The Launch and Recovery System for SPTs with all associated equipment and fittings are supplied with DNV certification and shall require load testing on board in accordance with same).
- DNV stands for Lifting Appliances (The 200t Subsea crane, 100t Ship to Ship Crane, 2 x20t Knuckle boom on deck cranes, lifting gear for ships maintenance, lifting gear for SPE maintenance are to be supplied with DNV certification and shall require load testing on board in accordance with same)
- DNV, AISC standard for structural Steel Buildings (The Dewatering plant shall be supplied in compliance with these standards with design verification, inspection and certification by a reputed third party approved by the CHARTERER).
- API Offshore Structure Standards (The Derrick with all associated equipment and fitting and substructure, the gantry and riser system shall be supplied in compliance with these standards with the design, inspection and certification by a reputed third party approved by the CHARTERER).

4.5.2 ABS

ABS is one of the world's leading classification societies in marine and offshore facilities and has developed a suite of classification rules and guides, with enhanced standards and associated notations for the classification of drilling systems in deep water. Based on the combination of FPSO and drilling system regulations, ABS steps into the deep sea mining industry as registered classification society for the first mining support vessel which is designed by Dubai based company Marine Assets Corporation (MAC) and will be built in Fujian Mawei Shipyard in China. The vessel will be chartered to Nautilus for a minimum period of five years, with options to either extend the charter or purchase the vessel at the end of the five-year period. The vessel will first serve as the operational base for the joint venture to be formed by Nautilus and the Independent State of Papua New Guinea's nominee, Eda Kopa (Solwara) Limited, a wholly owned subsidiary of Petromin PNG Holdings Limited.

When completed, the vessel will measure 227 meters in length and 40 meters in width with accommodation for up to 180 people and generate approximately 31MW of power. All of the below deck mining equipment will be installed in the vessel during the build process to minimize the equipment integration to be completed following delivery of the vessel. The vessel is expected to be delivered by the end of 2017.

ABS has also been engaged by Trans-Tasman Resources limited for certification of the Mining Vessel and trans-shipment Vessel which will be used in iron ore extraction in EEZ area. The vessel will be designed in accordance with the rules and regulations of ABS as a special purpose mining vessel for site-specific mining activities according to ABS classification rules and regulations with the Flag State for this vessel being New Zealand.

Moreover, ABS technology director, Mr. Sudheer Chaud will lead the discussion about classification of deep sea mining vessels at deep sea mining summit 2015 which will be held in UK on February 2015.

5 ENVIRONMENTAL IMPACTS AND MITIGATIONS

5.1 Introduction

This chapter defines the potential environmental impacts and examines some of the uncertainties surrounding the mining resources. It begins with a brief review of experiments conducted to examine deep-sea mining impacts from nodule mining experiments. Then it evaluates potential impacts and offshore issues arising from deep-sea mining of SMS if explored. Each category is followed with a brief discussion of mitigation approaches that have been submitted or are being pursued by the companies involved.

5.2 General Environmental Impact of Deep Seabed Mining

The environmental impact from deep sea mining can be divided into three main environmental problem areas (Markussen, 1994).

1. **Impact on the seabed:** As the cutter and/or collector unit gathers ore it will destroy the top layer of the seabed causing major disturbance and disruption to the flora and fauna in the mining tracks. In addition, a particle plume will be created by the cutter head or the propulsion system of the collector unit which will stir up sediments. As a result in sediment rich areas organisms in and around the tracks will be partially or entirely buried. In the areas where sediment coverage is low (such as recently created ocean floor around active hydrothermal vent systems, where mining for seabed hydrothermal sulphides may potentially become important) there is a likely potential of smothering, clogging and contamination of vent communities by drifting particles. For organisms found in the mining tracks a mortality rate of 95-100% may be expected.

2. **Discharge of waste water from the mining ship:** The ore collected and crushed on the seabed will be brought to the surface as slurry containing both crushed ore and water. When the slurry reaches the surface there will be a partial discharge of waste water containing particles and trace metals. Depending on the discharge location of the waste water the discharge may interfere with light penetration and reduce photosynthesis in the surface layers. Furthermore, the waste water may be considerably colder than surface water.

3. **Onshore processing:** Onshore processing produces waste water, tailings and slag. Here roughly the same problems will be encountered as in land-based mining operations, although

the ore composition and resultant waste from seabed mining may differ from that of land-based mines.

There are other types of environmental impact from deep sea mining, such as the possibility of accidental discharge of oil or ore during transport, noise/vibrations on the seafloor and aerosols at the surface.

Noise - Underwater radiated noise propagates far from a source (e.g. around 600km distance from the mining site at Solwara 1 project). Both surface and seabed equipment can generate noise in seabed mining operations.

Underwater radiated noise from floating vessels has an effect on marine species. A seabed mineral mining ship usually stays in the same area, and makes noise continuously. The density of marine life is higher near the surface, and creatures in these zones are exposed to noise from the vessel.

Deep seabed equipment is another significant noise source. The sound from a deep seabed source tends to be transmitted upwards, because the temperature at the deep seabed is usually lower than upper layers of sea water. Considering the distance that noise may propagate, it is apparent that noise from seabed mineral mining machines and processing equipment may affect creatures living in all zones of the sea.

Light Emissions -Light disruption should also be addressed. Increased light levels may affect the biotic communities inhabiting these depths, since the abyssal environments lack light and all the characteristics of these organisms are adapted to these conditions, e.g. organisms relying on bioluminescence. Any seabed mining operation is likely to have sources of light where human operator control is required. This is likely to be in places like ROVs, mining excavators, etc. Prior to full-scale operations, lighting studies are necessary, in order to test different light spectra, and examine which spectrum attracts the fewest organisms.

Heat -Another potential issue is temperature rise, caused during excavation, pumping and extraction processes. All of these are potential sources of heat; the dredged material is transferred through pipeline, where friction and flow generate heat; chemical leaching is exothermic and mechanical excavation may generate more heat. Tailing discharging, which takes place after the separation process, will probably raise the water temperature locally. A second possible disposal shall be neutralized, acidic liquids expelled from the previous chemical processes. It is expected that these wastes will also be of higher temperature than the surrounding environment. However, the ambient ocean temperature is around 20C, which

means that the interaction between cold ocean and waste will lead to waste temperature reduction eventually.

There is still a concern, though, since the heating effects on the benthic communities are not clearly known, yet. Since the dredging machine plays an important role in the whole procedure, a possible discharging delay (due to equipment malfunction or other possible cause) could probably lead to higher waste temperature, causing potentially greater environmental harm. However, in some cases it is recommended that there is a possibility for cooling/refrigerating during the processing, so that the amount of thermal pollution from the effluent discharging on the seabed is reduced (Steiner 2009).

These impacts are usually not identified among the major environmental problem areas of deep sea mining in the literature reviewed (Markussen, 1994, ISA, 2008b, ISA, 2011).

5.3 Environment Impacts and Management Plan of Nodules Mining

5.3.1 Environment Impacts

Over the last decade a number of studies were carried out to investigate the biological environment of potential mining areas of polymetallic nodules in CCZ and the impact mining activities would have on the environment of this area (ISA, 2011), (ISA, 2008b) and references therein). Based on the performed studies ISA summarizes the environmental impact of polymetallic nodule mining in CCZ as follows (ISA, 2008b):

Abyssal nodule mining will affect large areas of the sea floor owing to direct mining disturbance (estimated scales of 300-600 km² per year) and redeposition from sediment plumes (over scales of 10-100 km from the mining site). The redeposition range of 10-100 km mainly is due to near-bottom plumes created by tailings from the mining head during nodule extraction from the sea floor. Plumes in the water column derived from sediments attached to nodules during lifting from the seabed will contain orders of magnitude less sediment mass than near-bottom plumes, but may drift for years and disperse for several hundred to over 1000 km, depending on release depth. However, based on the estimated mass flux of lifted sediments and the estimated space scales over which these particles will be deposited after dispersing more than 100 km, resultant deposition rates will be much less than ambient net sediment accumulation rates in the region. Thus the benthic ecological impacts of a water column plume after dispersing more than 100 km are expected to be negligible.

Each mining claim area consists of 75,000 km² of sea floor. Over the 15-year timescale of an individual mining operation it could be mined virtually anywhere within the claim area, so for conservation management the entire claim area must be considered to be potentially directly impacted.

Benthic ecosystem recovery from mining impacts will be very slow, requiring decades or more for the soft sediment fauna and thousands to millions years for the biota specialising on polymetallic nodules.

Over the timescales of benthic ecosystems recovery (millennia), all current mining claim areas will potentially be exploited. The slow ecosystem recovery rates at the abyssal sea floor will cause the environmental impacts of mining to be widespread and simultaneous across CCZ. To ensure protection for the marine environment from harmful effects of mining operations in CCZ, ISA has established several rules and regulations (ISA, 2000), (ISA, 2002) and (ISA, 2011). Some of the main aspects of the regulations for protection and preservation of the marine environment during exploration and exploitation of polymetallic nodules in the CCZ that may affect contractor activities in the area are summarized below.

Site specific environmental baseline studies

Every exploration contract for polymetallic nodules shall require the contractor to gather environmental baseline data and to establish environmental baselines against which to assess the likely effects of its programme of activities. When applying for approval of a plan of work for exploration a description of a programme for oceanographic and environmental baseline studies must be provided. Contractors will provide their environmental data from the CCZ on an annual basis to the ISA. The guidelines for the required environmental baseline studies are provided (ISA, 2002).

Site specific impact reference zones and preservation of reference zones

According to the governing regulations (ISA, 2000) and (ISA, 2011) if the Contractor applies for exploitation rights it shall propose areas to be set aside and used exclusively as impact reference zones and preservation reference zones. "Impact reference zones" means areas to be used for assessing the effect of each contractor's activities in the Area on the marine environment and which are representative of the environmental characteristics of the Area. "Preservation reference zones" means areas in which no mining shall occur to ensure representative and stable biota of the seabed in order to assess any changes in the flora and fauna of the marine environment. Impact reference zones should be designated to be within

the seabed claim area actually mined. Preservation reference zones should be designated to include some occurrence of polymetallic nodules in order to be as ecologically similar as possible to the impact zone and to be removed from potential mining impact.

5.3.2 Environmental Management Plan for the Clarion-Clipperton Zone

On the 26th of July 2012 the Council of the International Seabed Authority adopted a decision to establish an environmental management plan for the Clarion-Clipperton Zone. The environmental management plan for the Clarion-Clipperton Zone establishes nine areas of environmental interest to protect the biodiversity and ecosystem structure and functioning of the zone from the impact of mining of polymetallic nodules in the area, as shown in Figure 2.4. The nine areas of environmental interest span 400×400 km each. The placement of areas of particular environmental interest avoided overlap with licence areas, as well as reserved areas where possible. By establishing the nine areas of environmental interest the environmental management plan aims at protecting 30 to 50% of the total CCZ management area. The environmental management is implemented for an initial three year period which includes the designation of a network of areas of particular interest.

The plan will be applied in a flexible manner to allow improvement as more scientific technical and environmental baseline data are available. The decision states also that for a period of five years from the date of the decision or until further review by the Legal and Technical Commission or the Council no application for approval of a plan of work for exploration or exploitation should be granted in the areas of particular environmental interest. The plan was formulated based on results from extensive scientific studies on biodiversity in the polymetallic nodule ecosystem in the Pacific Nodule Province (ISA, 2008a, Tilot, 2006) and data and assumptions from workshops held in 2007 and 2010. Faunal communities vary across CCZ, with north-south and east-west gradients in productivity, depth and other environmental variables. In order to protect the full range of habitats and biodiversity across the CCZ, destructive seafloor activities must be excluded in particular areas distributed across those gradients. The areas of particular environmental interest were chosen so that they contain large areas with self-sustaining populations and a broad range of habitat variability. Moreover, those areas should not be affected directly by physical activity or indirectly by mining effects such as plumes, although the degree of impacts raised by potential deep sea mining is still unknown. Based on a consideration of environmental and impact data briefly

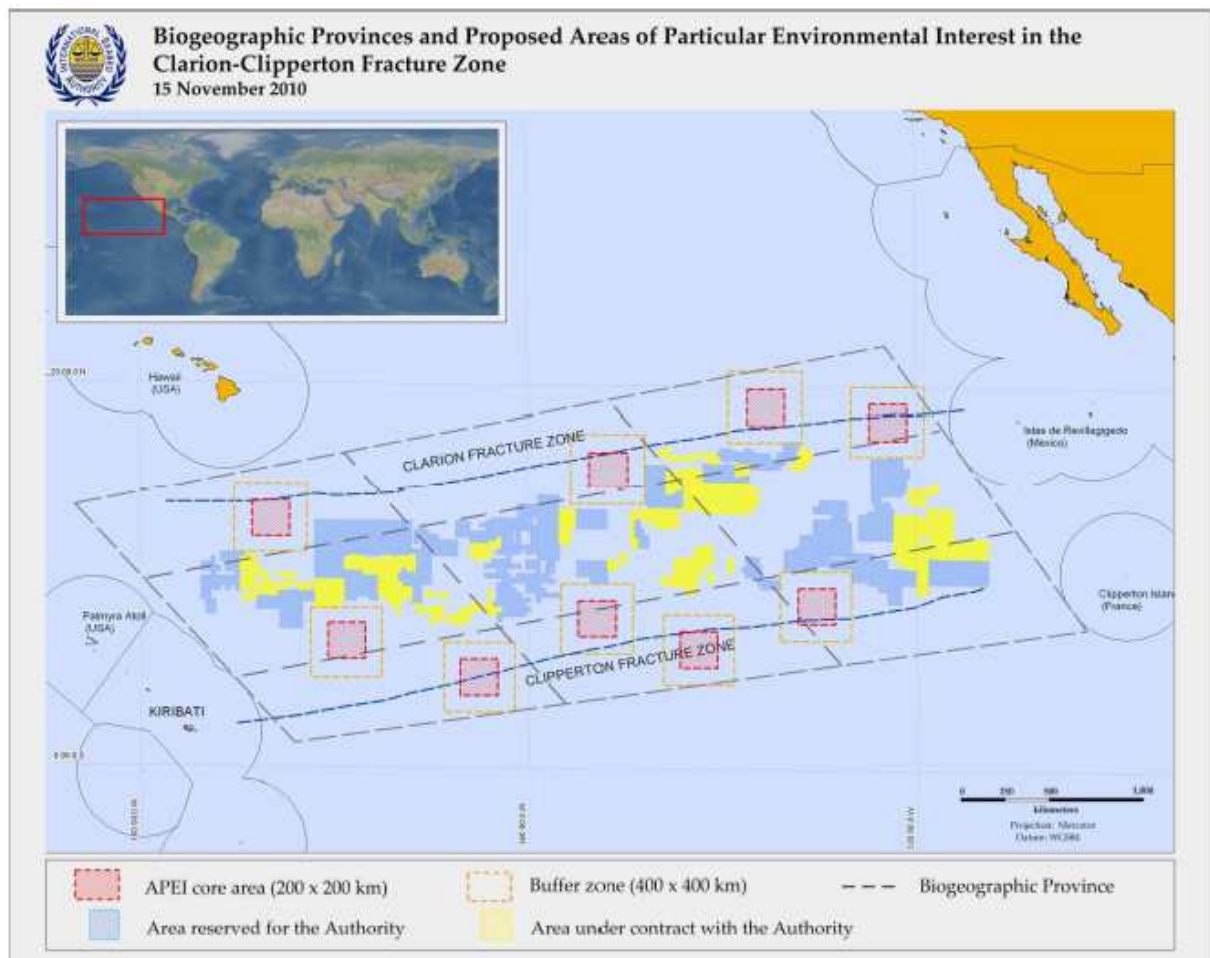


Figure 5.1: Location of the areas of particular environmental interest, indicating the nine biogeographic sub regions, the core of each area of particular environmental interest and the buffer zones. (ISA, 2008)

summarized above it was determined that a section of each area of particular environmental interest should be protected. Each section should be at least 200 km in length and width, i.e. large enough to maintain minimum viable population sizes for species potentially restricted to a sub region of the CCZ and to capture the full range of habitat variability and biodiversity within each sub region. In addition each section of particular environmental interest should be surrounded by a buffer zone 100 km in width to ensure that it is not affected by mining plumes from any activities immediately adjacent to an area of particular environmental interest. Thus the dimensions of each full area of particular environmental interest, including the 200 × 200 km section surrounded by 100 km buffer zone, should be 400 × 400 km, as shown in Figure 5.1.

5.4 Issues, Mitigations and Residual Impacts of SMS mining in Solwara Project

5.4.1 Offshore Issues

Impacts on the seafloor and its biological communities will arise from a number of sources, as represented in Figure 5.2. The Seafloor Production Tools (SPT) will directly remove seafloor substrate, including active and inactive areas, causing loss of habitat and associated animals. Disturbance to the seafloor and sedimentation will result from mining and from the removal and relocation of the surface layers of unconsolidated sediment (and some competent waste material) to the outer margins of Solwara 1 (Figure 5.3). Water containing elevated concentrations of metals and some retained sediments from the dewatering of ore will be discharged 25 to 50 m above the seafloor.

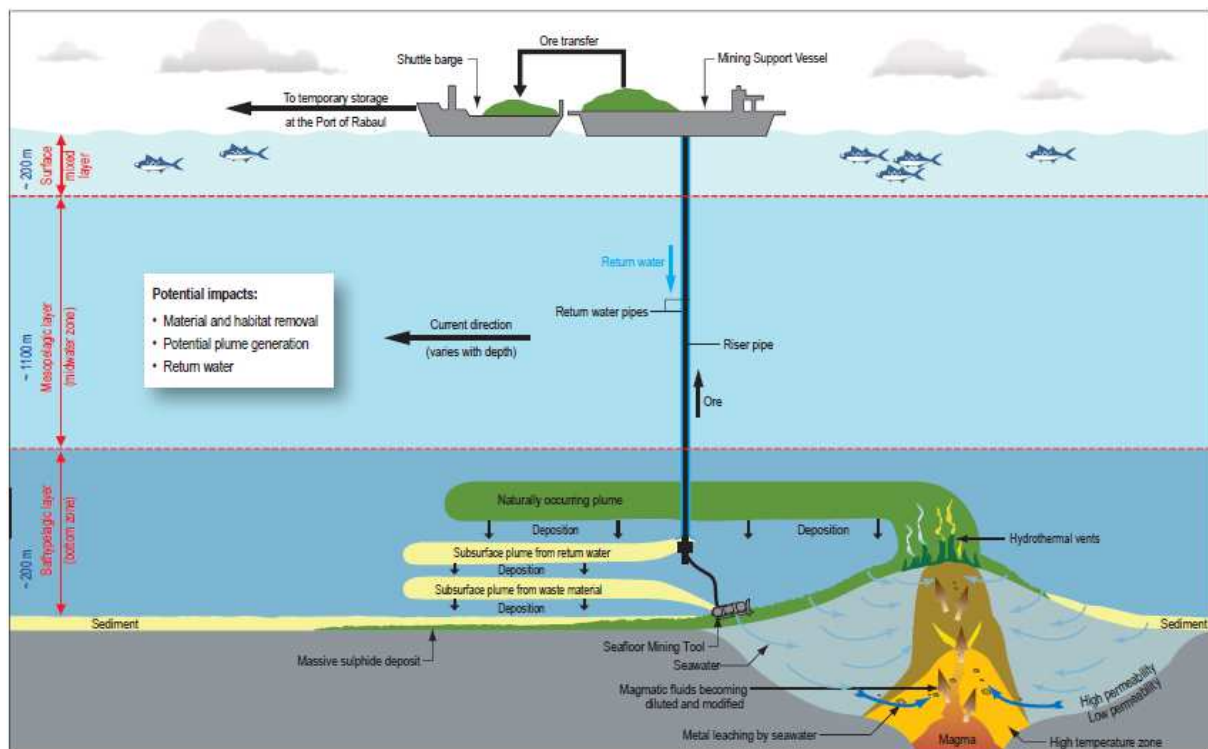


Figure.5.2: Potential Impacts from Offshore Mining Operations

Source: Environmental Impact Statement (Nautilus Minerals, 2008)

Once dewatered, barges will transfer ore to the Port of Rabaul, where it will be unloaded for temporary storage prior to export. The most significant source of underwater noise is predicted to be from cavitation noise produced by the thrusters on the Production Support Vessel (PSV), although this will not be substantially different from the underwater noise from the vessels involved in exploration and research. If unplanned events were to occur, additional issues could arise from loss of material from abnormal conditions, ranging from minor leaks

of hydraulic fluids, pump and rise pipeline failures, spillage of ore during transfer, to ship. (EIS, 2008)

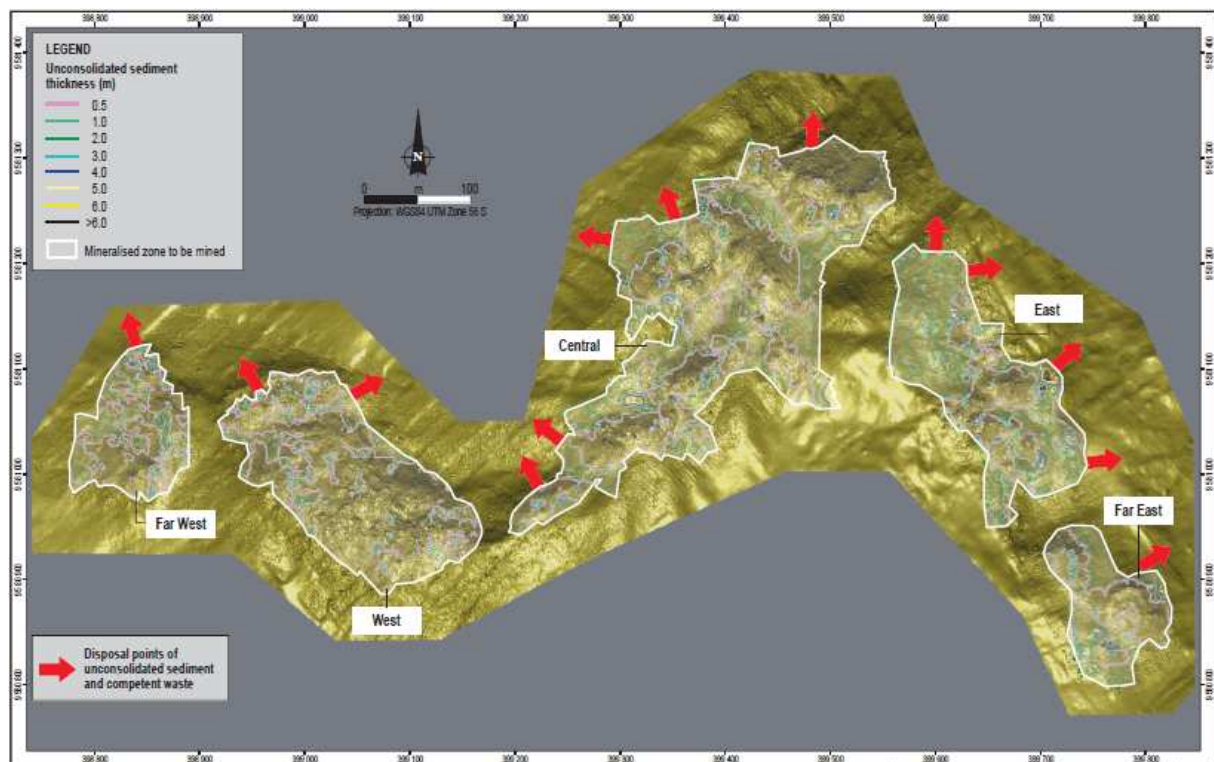


Figure 5.3: Unconsolidated sediment at Solwara 1

Source: Environmental Impact Statement (Nautilus Minerals, 2008)

5.4.2 Mitigation – Natural

There are many mitigation approaches open to Nautilus, including design of the mine plan based around enhancing natural aspects of the prevailing environment and minimising impacts. Mining cannot remove or exhaust the natural venting energy source at Solwara 1, which will continue until the underlying geothermal energy source naturally dissipates. The active venting field will remain, chimney structures will reform and the underlying hydrothermal energy basis will still exist for the potential re-establishment of vent-dependent and associated communities.

The time sequence for the recovery of fauna is not known precisely but it is expected, from observations during research surveys, that within a few years, the major faunal elements will have re-established. It is also evident that animals living in such a highly mineralised area are tolerant to the naturally elevated levels of metals in ambient water and sediments compared with those from mid water or shallower and less naturally contaminated environments.

Disturbance of the seafloor and the return of water and some entrained sediment to its area of origin is unlikely to affect the resident benthic animals as it might do to the shallow water test “EMSHIP” Erasmus Mundus Master Course, period of study July 2014 – February 2015

organisms. Even so, the assessment of potential impacts from water and sediments (e.g., from dewatering) are based on calculations of dilution factors to meet ANZECC/ARMCANZ (2000) water quality guidelines for dissolved metals.

The presence of natural plumes over the Project area and periodic volcanic deposition originating from North Su (approximately 1 km southeast of Solwara 1), and other sources indicates the dynamic natural processes at play. Within this setting, localised sediment disturbance and dewatering discharges are expected to be minor.

There are also physical limitations to the areas in which the SPT can operate, for example, there are limitations to the hydraulic systems at water temperatures above 35°C. Temperature sensors on the SPT will detect ambient temperatures so that it can withdraw from the area in the event of detection of excess temperature. The extent of the area unable to be mined for reasons of temperature is not fully known but it is expected that the SPT would be able to operate up to 1 m from any hot vent. (EIS, 2008)

5.4.3 Mitigation – Seafloor Biodiversity Protection

The operational mitigation strategies described below are aimed to reduce the impacts to the seafloor environment to levels as low as can be achieved. These have been developed in consultation with the research scientists who conducted the research and impact assessment work. The main objectives are the protection of biodiversity and maintenance of nearby communities of animals to enhance the rate of recovery post-mining. The three ways proposed to maximise recovery success are the protection (from current mining) of a nearby reference area at South Su, the retention of temporary unmined refuge areas within Solwara 1, and the enhancement of recolonization by translocation of animal communities from areas about to be mined to areas where mining is complete.

While it may be difficult to determine which of these methods is most effective, demonstration of recovery and ecological sustainability is the immediate priority of the Project. (EIS, 2008)

Unmined Control Area at South Su

South Su is proposed to remain as an unmined control area about 2 km up current from Solwara 1 until the completion of mining and confirmation that the rehabilitation techniques are effective at Solwara 1. It is expected to provide a source of recruitment to mined areas and provides a control location to set up transects to monitor natural variations in vent activity and

communities over time. Biological comparisons of the two areas have shown that the active sites at both Solwara 1 and South Su share the same biomass-dominant species and generally similar indices of diversity and community structures. Where there are significant differences, South Su generally has higher abundances of secondary species and higher dominance of some groups. Some recruitment may also come from North Su, where mining is not currently planned. However, because of the continuous active conditions and sediment-occluded visibility at North Su at the times of surveys, it has not been possible to characterise its vent communities to the same extent as at Solwara 1 and South Su. (EIS, 2008)

Temporary Refuge Areas within Solwara 1

Not all of the resource can be mined simultaneously. Mining will be sequenced according to the mine plan that currently proposes that mining of the mineralised East and Far East Zones will be the last in the development of the Solwara 1. Therefore, these areas will function as undisturbed sources of parent fauna and supply of larvae within Solwara 1 for the greatest amount of time. However, it is difficult to prescribe which areas will be the last to be mined, or the size of any areas potentially set aside as refuge areas, while allowing for flexibility in the mine plan during the progress of mining.

This is referred to as a ‘temporary refuge area’, and it is based on the expectation that recovery will be sufficiently well-progressed to meet specified criteria that monitoring can demonstrate that the major community elements (i.e., the three biomass-dominant species) have re-established at active chimneys in the earliest mined-out area, to enable the refuge areas to be mined. However, mining at the refuge areas will not commence until these recovery criteria have been met. (EIS, 2008)

Transplant of Animals

The loss of animals in the path of the SPT is partially avoidable and it is proposed that the ROV remove large clumps of rock substrate with its biology intact and relocate them initially to unmined areas for preservation and ultimately to venting areas where mining is complete. These clumps will be targeted to maximise the biomass-dominant species and any other associated attached or sessile fauna. Monitoring will be undertaken to confirm the success of this strategy. The extent to which this will be done is a matter of practicality and will be undertaken opportunistically and during routine monitoring. (EIS, 2008)

Artificial Substrate

Colonies of bamboo coral (*Keratoisis* sp.) are characteristic of hard substrates in mainly inactive areas away from the vent ecosystems and it is expected that recovery of these, and their associated fauna after disturbance, will be slower (compared with animals of active areas). In order to enhance this process, hard settlement surfaces (e.g., concrete plates) will be located in appropriate areas. Using the ROV, representative stands of *Keratoisis* will also be removed from the path of mining (where multiple stands are within easy access of the ROV), and repositioned in structures such as crates, where they might reform attached colonies. The survival and growth of such transplants will be monitored, with continued relocation if successful. (EIS, 2008)

Disposal of Unconsolidated Sediment and Competent Waste Material

The Solwara 1 deposit is variably covered by an unconsolidated sediment layer composed of fine silt and clay as well as containing some competent waste material within the designed mine area that is below the mine cut-off grade. It is proposed to remove the unconsolidated sediment (approximately 130,000 t) before mining commences in each area by side casting to the outer areas of Solwara 1 mound as outlined in Figure 5.3. The competent waste material (approximately 115,000 t) will also be relocated to the same area. Side casting has less impact on this material than transporting the material to the surface and returning it to the seafloor, as there will be no temperature or oxygenation changes. (EIS, 2008)

5.4.4 Mitigation – Protection of Coral Reefs and Fisheries

Dewatering Plume

The avoidance of impacts on coral reefs, fish and large marine animals such as whales, dolphins and turtles from discharge of water and entrained sediments from the dewatering process on the PSV will be achieved by:

- Discharging at depths between 25 to 50 m above the seafloor to confine all impacts to the bottom zones from where the water/sediment originated. Benthic animals are most adapted to this material while surface and mid-water species will not be exposed.
- Retaining all particles above (nominally) 8mm in size, which is expected to significantly reduce the quantities of sediment lost in the dewater discharge. The proportion of particles below this size is estimated to be less than 5% of the total suspended solids.
- Limiting the exposure time to surface temperatures and oxygenation to 12 minutes, thereby

reducing potential for geochemical changes. Temperatures are not expected to exceed 13.5oC (Note that it is expected to take some start-up time and initial trials to achieve these equilibrium conditions of handling time and discharge temperatures). Additionally, the pipes used to transport the return water to the seafloor will allow for cooling of the return waters. (EIS, 2008)

Surface Activities: PSV and Ore Transfer

An exclusion zone of 500 m will apply around the PSV at all times to avoid risks of collisions. This is a minor area of fishing exclusion for mainly commercial tuna fishing, but the Project area is not one from which catch return statistics indicate there would be any significant impact. Normal maritime navigational and communications procedures will apply for all shipping in the area to maintain safe distances. Being so far offshore, the recorded frequency of inshore vessels such as canoes and small vessels occurring at Solwara 1 is low. The main source of underwater noise from the Project is the operation of the thrusters on the PSV. Modelling suggests these levels attenuate rapidly within the first 2 km and could only be sufficient to cause whales to deviate in direction if they approach within 1 to 2 km of the source, although some attraction or avoidance behaviour may occur beyond this distance until animals become accustomed to the operations. Sounds are insufficient to cause physiological harm and as a stationary source, risks of collisions or sudden exposure to loud sounds are low. Tug and barge movements will also be very slow (6 to 8 knots) and easily avoidable by large marine animals and other vessels. (EIS, 2008)

Hazard Management

The risks of major losses of equipment or spills of ore or fuel oils (during operational and abnormal conditions) will be extremely low with the implementation of best practise vessel and equipment maintenance procedures, navigational procedures, safety plans, environmental management plans, and emergency response plans. (EIS, 2008)

5.4.5 Residual Impacts

The residual impacts that are predicted after the implementation of the aforementioned mitigation measures are described as follows.

Venting

In areas where the SPT has completed mining, venting of fluids will continue at new or pre-existing locations. New chimney structures will start to reform within hours to days

(depending on temperature and chemistry of venting fluids), as the vent fluids mix with the seawater causing metal sulphides to precipitate. Diffuse venting may also continue in any mined areas where soft sediments settle, although in the directly mined areas, the majority of the existing soft sediments will have been mined or removed. (EIS, 2008)

Biodiversity and Endemism

After an area is mined, recolonization around actively venting areas is expected to follow a succession that is initiated by the rapid (days to weeks) formation of microbial mats on the newly exposed surfaces, followed by the establishment of the characteristic vent-dependent, zone forming snail and barnacle species and their associated fauna respectively, as described at other ocean vent systems. The rate of recovery will depend on the relative success of the following main mitigation measures:

- Active relocation of clumps of biomass-dominant animals to suitable unmined or mined-out areas.
- Migration of adults or settlement of larvae produced by those adults from the unmined areas or temporary refuge areas within Solwara 1.
- Settlement of larvae produced from the unaffected communities of the South Su control area.

With these measures, it is expected that, after a transition period of a few years post mining, populations characteristic of active sulphide mounds will return and reorganise to a condition (biomass and diversity) that resembles the pre-mining state, with overall effects being reversible and moderate.

In the inactive hard (sulphidic) surfaces and sediments, it may take more years to return to premining conditions, due to presumed slower growth rates. Actions to enhance recolonization of *Keratoisis* and its associated secondary species will be monitored to determine recovery rates.

The efforts of Nautilus to set aside refuge areas and to salvage and relocate animals are expected to lower substantially the risks of loss of biodiversity and endemism. At the inactive sedimentary areas, natural recolonization is expected to occur but will be slow, with no practical means of enhancement by relocation of benthic fauna. (EIS, 2008)

Disposal of Unconsolidated Sediment and Competent Waste Material

The coarser fraction of disposed material will rapidly settle immediately downslope of the disposal point and form mounds slightly over 500 mm deep. Lighter materials will travel

further from the disposal points, and the lightest components of the disposed materials will form plumes near the seafloor.

Plumes will rapidly settle on the seafloor no further than 1 km from the point of discharge around Solwara 1. The resultant footprint depth will be between 0.18 and 500 mm and cover an area just over 2.3 km². Some deposition will occur further afield, but at a thickness less than natural sedimentation rates.

The material being entrained is not expected to undergo significant geochemical change through reaction with seawater under the conditions that exist within the environment downstream of Solwara 1. Fauna in areas of settlement of SPT-induced sedimentation and unconsolidated sediment may be smothered; however, there is very low biomass in the areas that are being considered for sediment placement. Interstitial microbial animals are likely to survive the processes of relocation and resuspension/settlement of sediments by the SMT in newly settled area. Expected impacts are therefore mainly to filter feeding organisms outside the area of mining. (EIS, 2008)

Suction and Loss of Organisms at the SPT

The water pumped from the SPT to the vessel will potentially contain some entrained organisms such as planktonic larvae or small fish that would not be able to survive the rise to surface. The net movement of water over Solwara 1 (to a height of 20 m above the seafloor) measured over 12 months is in the order of 8,800 ML/day. The volume of water sucked in by the SMT during mining is estimated at 24 ML/day, which represents less than 0.3% of the potential larval entrained water around the mound. (EIS, 2008)

Plumes from Dewatering Discharge

Results of elutriate tests indicate that, at the point of discharge, concentrations of some metals contained in water released to the environment will be above ANZECC/ARMCANZ (2000) guidelines for 95% protection. A 600-fold dilution will be required before guidelines for metals are met. Hydrodynamic modelling indicates that the required number of dilutions will be achieved 85 m from the point of discharge.

Plumes of suspended sediment formed from material entrained in the return water discharge will require a 5,000-fold discharge to meet ANZECC/ARMCANZ (2000) guidelines for 95% protection levels for total suspended solids. On average (i.e., for 183 days per year), plumes will not extend more than 900 m beyond the point of discharge (and cover an area of 0.81 km²) before meeting the target TSS concentration protection levels.

Additionally, plumes will not rise above 1,300 m water depth and will not affect North Su or South Su, instead they will generally occur above Solwara 1 and to the northwest. Suspended sediment will flocculate and settle on the seafloor approximately 5 to 10 km to the west and northwest of Solwara 1. Maximum depositional thicknesses will not exceed 0.1 mm and rates of settling are less than existing deep-sea sedimentation rates as measured at Solwara 1 and South Su.

Within the context of the ambient seafloor geology and the fallout from the particulate plumes originating from North Su, and to a lesser extent South Su and Solwara 1, the animals are likely to be adapted to naturally elevated metal concentrations and sedimentation. (EIS, 2008)

Surface Activities

The application of an exclusion zone and normal maritime navigation and communication procedures will limit the impact of the operations to the area of the site.

Characteristics of the PSV's thrusters have been used to model noise attenuation, which is rapid for the first 2 km, then slower beyond that distance in deep water (with an assumed reflective basaltic seafloor).

Levels are insufficient to cause any physiological harm. As with all vessels in open oceanic water, noise will be audible for considerable distances but all received levels are expected to be below 140 dB re 1 μ Pa within about 1,100 m from source. The PSV will be stationary, thereby reducing any significant risks of collisions or interference with whales. While some avoidance or attraction may occur, even as far as 15 km from the vessel, habituation is likely. Experience from analogous situations, wherein whale migrations off the east and west coasts of Australia and west coast of USA continue past offshore oil and gas infrastructures, suggests that any risks from the operation are considered to be very low. (EIS, 2008)

6 CASE STUDY ON SOLWARA 1 PROJECT

6.1 Introduction

Nautilus Minerals Inc. (“Nautilus”), the world’s first company to explore the ocean floor for polymetallic seafloor massive sulphide deposits, located in the Bismarck Sea, Papua New Guinea (PNG) where it is aiming to produce copper, gold and silver. In this chapter, case study on first mining project called Solwara 1 Project is reviewed and analysis on the progress of exploration results and its production development plan. Firstly, sea floor production system of Nautilus Minerals is introduced in the beginning of the chapter and followed by its project estimation of the capital and operation expenditure. Thereafter, the focus moves to review on the oceanic environment background of the project and the potential environmental impacts and mitigation strategies are discussed. Moreover, the current financial statement of Nautilus Minerals is evaluated and finally the legal and environmental rules of Solwara 1 project are reviewed.

6.2 Sea Floor Production System

6.2.1 Solwara 1 Project Mining System

Nautilus is focused on the Solwara 1 Project, which is located at 1600 metres water depth in the Bismarck Sea, Papua New Guinea. Solwara 1 is located approximately 30 kilometres from the nearest coast (New Ireland Province) and 50 kilometres north of the international Port of Rabaul. Using existing technologies from the offshore oil & gas, dredging and mining industries, Nautilus plans to extract high grade SMS systems on a commercial scale. Nautilus has been working over the past number of years on the building of the Seafloor Production System. The main components of offshore production systems of Nautilus Minerals are

- Seafloor production tools (SPTs)
- Riser and lifting system
- Production support vessel.

The whole sea floor production system is illustrated as in Figure 6.1, and more details are elaborated in this chapter.

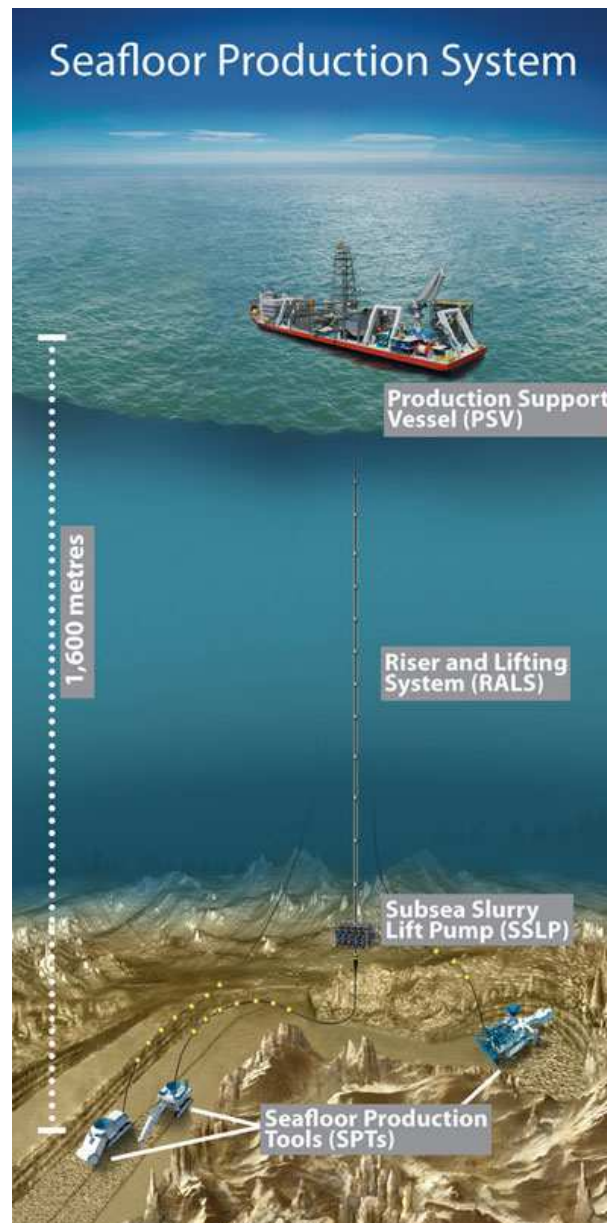


Figure 6.1: Nautilus Offshore Production System

Source: www.nautilusminerals.com

6.2.2 Seafloor Production Tools

Subsea vehicle designer and manufacturer, Soil Machine Dynamics Ltd (SMD) of Newcastle upon Tyne, UK, is awarded the contract to design and build the SPTs for Nautilus at the end of 2007, with three vehicles designed to operate in depths of up to 2,500m on SMS deposits. The contract included three subsea mining machines with weights up to 310t, vessel-based power and control systems, pilot consoles, umbilical systems and launch and recovery systems (LARS). Some world class companies have been involved in the design of the SPTs:

- The cutting drum of the Bulk Cutter ("BC") was designed and built by Sandvik (Austria), a world leader in hard-rock mechanized mining and rock cutting equipment. The designs are based on similar designs used on large continuous miner machines used in underground mining and construction.
- The track sets for all three SPTs have been designed and built by Caterpillar, based on an existing Caterpillar excavator track design. Modification to the track set for subsea operation and required cutting duty was completed by SMD in consultation with Caterpillar and Sandvik.
- The dredge pumps for all three SPTs have been supplied by DAMEN, one of the world's leading dredge equipment suppliers and are based on existing catalogue designs used in the dredging industry.
- The hydraulic equipment for all three SPTs is based on existing off-the-shelf Bosch Rexroth hydraulic equipment, with adaptations by SMD.
- The flexible hoses for all three SPTs have been designed and supplied by ContiTech AG (Germany), and are very similar to the rubber hoses used in the dredging industry.

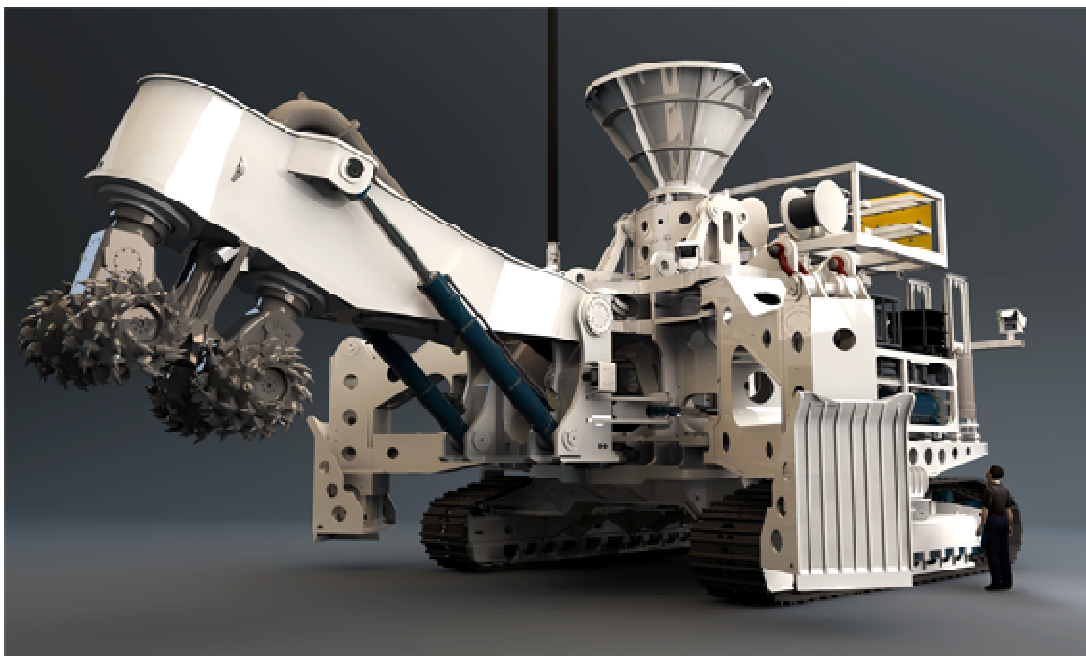


Figure 6.2: Auxiliary Cutter

Source: <http://www.smd.co.uk/products/submerged-mining/special-projects.htm>

Nautilus announced that assembly of the BC, which is the first of the SPTs, has been completed on April 10, 2014. The next step is to carry out commissioning and acceptance testing of the BC in parallel with assembling the other two production tools, the Auxiliary Cutter ("AC") and the Collecting Machine ("CM").

The excavation and collection has been split into three individual tasks which will each be carried out by a different vehicle. The AC is a preparatory machine that deals with rough terrain and creates benches for the other machines to work. It will operate on tracks with spud assistance and has a boom mounted cutting head for flexibility. The second machine, the BC, has higher cutting capacity but will be limited to working benches created by the AC. Both machines leave cut material on the seafloor for collection by the CM. The CM, also a large robotic vehicle, will collect the cut material (sand, gravel, silt) by drawing it in as seawater slurry with internal pumps and pushing it through a flexible pipe to the Riser and Lifting System.



Figure 6.3: Back side view of Bulk Cutter

Source: <http://www.smd.co.uk/products/submerged-mining/special-projects.htm>

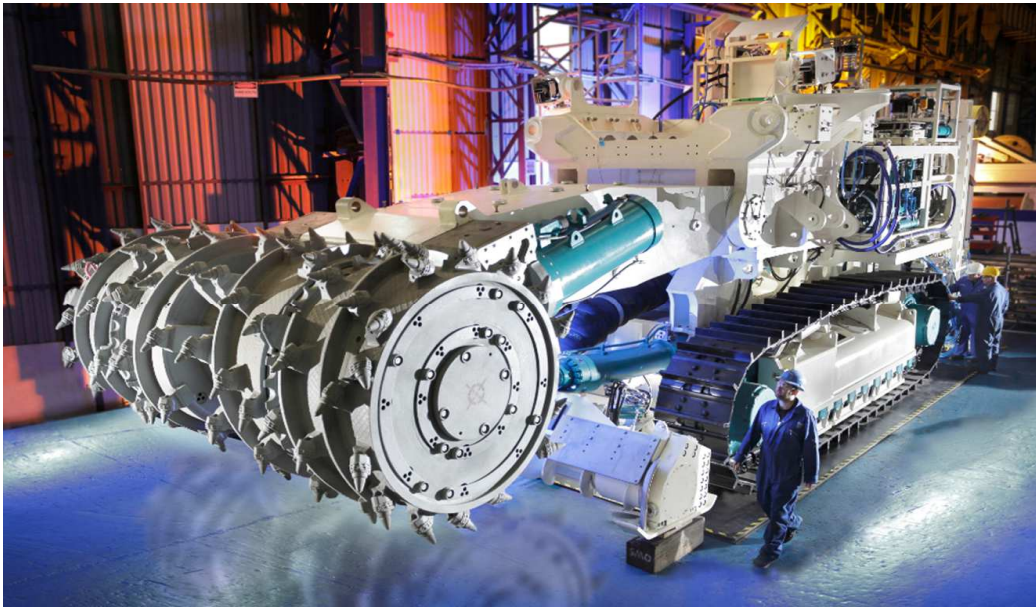


Figure 6.4 Complete assembly of Bulk Cutter at SMD

Source: <http://www.smd.co.uk/products/submerged-mining/special-projects.htm>



Figure 6.5: Collecting Machine

Source: <http://www.smd.co.uk/products/submerged-mining/special-projects.htm>

6.2.3 Riser and Lift System (RALS)

The purpose of the Riser and Lift System (RALS) is to lift the mineral ore particles mined from SMS deposits to the PSV, using a Subsea Lift Pump (SSLP) and a vertical riser system suspended from the PSV. The ore particles mined by the Subsea Mining Tools are collected using the CM and the seawater /ore slurry pumped into the positive displacement SSLP at the base of the riser, where it is pumped to the surface. Once at the surface, the slurry passes through a dewatering process. The solids are transferred to a transport barge for shipment to shore and the (filtered and cleaned) return water is topped up with additional seawater as required and pumped down to the SSLP, where it is used to drive the positive-displacement chambers of the SSLP prior to being discharged into the sea close to the depth at which it was originally collected.

Much of the RALS and components have been taken directly from the offshore oil and gas industry where these items are field proven in similar applications. The RALS can be broken down into the following major sub components:

- Riser Transfer Pipe (RTP).
- Subsea Lift Pump (SSLP).
- Main vertical slurry riser, connectors, flexes joint and accessories.
- Return water riser, connectors and accessories.
- Surface pressure seawater supply system (“mud” pumps).

The riser and lift system will conduct the following functions:

- Receive the ore slurry from the gathering machine and pump it vertically up riser system to the dewatering plant inlet on the deck of the floating support vessel.
- Send the return water to the seabed.

Nautilus Minerals announced in 2008 that it has awarded a US\$116 million target price contract to Technip USA Inc ("Technip") to provide engineering procurement and construction management ("EPCM") services for RALS. The Riser system is completed more than 50% and delivery will be second quarter of 2015.

Riser Transfer Pipe

The Riser Transfer Pipe is normally 150-200 m long with a flexible hose which nominal inner diameter is 280mm and it is used to connect the subsea slurry pump to the collecting machine. The mixed seawater/ore slurry is pumped through the riser transfer pipe from the seabed

collecting machine to the subsea slurry lift pump. The Riser Transfer Pipe configuration is analogous to dynamic subsea flow lines and risers that are extensively used in the offshore industry to connect subsea wellheads to Floating Production, Storage and Offloading (FPSO) facilities.

Subsea Lift Pump

The Subsea Lift Pump to be supplied by GE Hydril is suspended at the bottom of the riser and receives slurry from the collecting machine through the riser transfer pipe. The subsea lift pump subsequently pumps the slurry to the production support vessel. The pump assembly comprises two pump modules, each module containing five positive displacement pump chambers driven by pressurised return water delivered from the PSV to the pump via the riser assembly. The use of multiple pump chambers provides a consistent pressure / flow regime and also provides a high degree of redundancy. The use of multiple pump chambers provides a consistent pressure and also provides a high degree of redundancy. The subsea lift pump is expected to weigh approximately 129 tonnes in air and measure 5.2m x 6.4m x 3.7m high, see Figure 6.6.

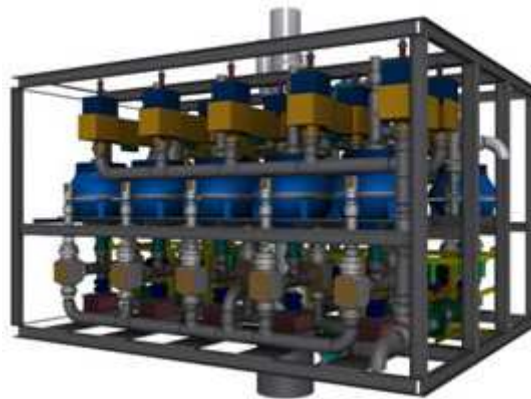


Figure 6.6: GE Hydril Pump, 120 ton 10 Chambered Positive displacement type pump

Source: www.nautilus.com

6.2.4 Production Support Vessel

The main function of Production Support Vessel is to support surface and subsea operations and will maintain its position over the seafloor mine site using dynamic positioning. Dewatering of slurry will operate on the deck of the production support vessel and solid ore will discharge to the transportation barge moored alongside. The used water is pumped back to the seafloor through riser and it also provides hydraulic power for the riser and lifting

system. The production support vessel will support continuous mining production operations simultaneously with:

- Offshore bunkering.
- Offshore transfer of provision supply.
- Offshore waste management / disposal.
- Fresh water making.
- Offshore crew change out.
- MEDIVAC transfer capability.
- Equipment and maintenance sparring transfer and storage.

The primary basis for crew change-out will be crew boat from Port. Helicopter facilities will be provided for emergency evacuation purposes.

Dubai-based marine solutions company Marine Assets Corporation (MAC), enters into ship building contract with Fujian Mawei Shipbuilding for the construction of the Nautilus Minerals seafloor production mining vessel. The vessel will be chartered to Nautilus for a minimum period of five years, with options to either extend the charter or purchase the vessel at the end of the five-year period. The vessel will first serve as the operational base for the joint venture to be formed by Nautilus and the Independent State of Papua New Guinea's nominee, Eda Kopa (Solwara) Limited, a wholly owned subsidiary of Petromin PNG Holdings Limited, to support the operations carried out by the joint venture to extract and to transport high grade copper and gold material from the mine site, in the Bismarck Sea of Papua New Guinea.

When completed, the vessel will measure 227 meters in length and 40 meters in width with accommodation for up to 180 people and generate approximately 31MW of power to run the ship systems, including DP, and the integrated seafloor production equipment. The vessel will be fitted out with two main cranes – One 200T subsea crane and the other a 100T ship to ship crane. The vessel will support topside modules including those required for product dewatering, product offloading, SPTs launch and recovery (“LARS”), vehicle control and maintenance, and product pumping from the seafloor. These topside modules include seafloor production tools and associated launch and recovery systems, dewatering plant, Derrick and riser and lift pump system, riser storage systems, ROV's, product materials handling systems and integrated central control system. All of the below deck mining equipment will be installed in the vessel during the build process to minimize the equipment integration to be

completed following delivery of the vessel. The vessel is expected to be delivered by the end of 2017. The vessel will have four cargo holds arranged amidships and of capacity to store about 45,000 tonnes of SMS ore (copper ore) at density varying between 2.2 to 3.5 tonnes/m³. The vessel will also have a completely enclosed cargo handling system which will transfer the ore processed on-board directly to any hold and from the holds to incoming Handy size bulk carriers of capacity carrying ranging from 25,000 to 45,000 tonnes deadweight.

Principal Particulars of Solwara 1 JV (See Fig 6.7)

Length overall (Mid hull)	: 227.0 m
Length B.P	: 210.0 m
Breadth Moulded	: 40.0 m
Depth Moulded	: 18.2 m
Draft moulded (design)	: 13.2 m
Draft moulded (scantling)	: 13.2 m
Crew members	: 180



Figure 6.7: Production Support Vessel

<http://www.nautilusminerals.com/i/photos/SOLWARA-img3.jpg>

Classification

Solwara 1 JV is registered as a Production Support Silo Vessel under the Flag of Singapore and is to be constructed, machinery installed and equipment and spare gear provided in

accordance with the rules and regulations of ABS referred to as Classification for unrestricted international voyages and to their special survey to hull and machinery with notation:

+1 A1E OFFSHORE SUPPORT VESSEL SPS, MLC-ACCOM, HAB++ (WB), HELIDK
(With Certificate of Compliance in respect of UKOOA CAP 437, NORSOK C-004
Standards), CPS, HDC (Exposed Main Deck, 10t/m²),
+AMS, + ACCU, DPS – 2 EHS – F, UWILD, NBLES

6.3 Cost Study

In 2010, Nautilus Minerals commissioned an independent definition and cost study for its proposed Bismarck Sea offshore production system. The findings of the cost study with respect to the production system were up to 2010 and the estimates are prepared using costs as of the third quarter of Calendar 2009. The summary below presents the findings released in the cost study at the time, and are not adjusted for subsequent movements in input prices, system design adjustments, and changes in operating parameters and assumptions, including any changes that might be made as a result of the updated resource estimate.

The cost study provided an overview of the proposed project, including cost estimates to extract mineralised material from the seafloor at the company's Solwara 1 site in the Bismarck Sea and deliver it to the Port of Rabaul, PNG. Estimation of capital expenditures (CAPEX) and operating expenditures (OPEX) for the offshore components are considered and the following items are excluded. (SRK Consulting, 2010):

- Ore unloading, stock piling and load-out onto transportation vessels at the Port of Rabaul
- Shipping from load out facility to concentrate processing plant
- Concentrator facility and/or charges
- Shipping from concentrator facility to smelter clients
- Expended (sunk) costs prior to 31 December 2009
- Escalation over project life
- PSV / transportation barge dry docking costs (for maintaining class obligations) during life of mine operations
- Site demobilisation costs

While estimating CAPEX, they considered the following elements;

- Seafloor Production Tools (SPTs)

- Auxiliary Cutter (AC)
- Bulk Mining Machine (BM)
- Gathering Machine (GM)
- Riser and Lift System (RALS)
- Production Support Vessel (PSV) with Dewatering Plant (DWP) and ore transfer facilities
- Shuttle barges for transfer of ore from vessel to onshore
- On-shore stock piling and load in/load out facility at Rabaul

The key conclusions of the cost study are as follows;

- Capital costs for the offshore production system were estimated to be US\$383 million (including 17.5% contingency).
- Average operating costs for extraction of material and delivery to the port of Rabaul were estimated to be US\$70 per tonne (including a 10% contingency) based on a production rate of 1.35 million tonnes per year.
- The cost study assumed production commencing at a rate of 1.2 million tonnes per year (dry equivalent) but with the capacity to ramp up to 1.8 million tonnes per year.
- The cost study estimated that construction of the offshore production system and commencement of production would take approximately 30 months from the date of Board approval.

The cost study was prepared by SRK (Australia) Pty Ltd in Perth and Nautilus Mineral aimed to revise it including CAPEX and OPEX in first quarter of 2015.

6.4 Location, Environment and Climate of Bismarck Sea

Solwara 1 is located 50 km North side of Rabaul in East New Britain and 1,600 m below the surface of the sea in the Bismarck Sea of Papua New Guinea. Rabaul is located on the Northeast coast of the island of New Britain and is the main port of East New Britain Province Solwara 1 is located.

Marine life varies with the water depth. At the Solwara 1 site the ocean may be divided into three broad zones (Golder Resource Report, March 2012).

- The ‘Surface Mixed Layer’ which is the upper water column between ~0-200m and contains mostly pelagic fish species including tuna, squid and sharks. Other animals known to exist in the area include dolphins, turtles and migrating whales.

“EMSHIP” Erasmus Mundus Master Course, period of study July 2014 – February 2015

- The ‘Mesopelagic Zone’ which is the mid water column between ~200-1,000m and where amongst others squid and occasional short visits by, for example, tuna in search of prey and migrating whales may occur.
- The ‘Bathypelagic Zone’ which is the bottom water column, deeper than ~1,000m where animals typical of active hydrothermal vent sites, such as gastropods, shrimp, crabs, barnacles occur.

The climate of the Bismarck Sea and surrounds is tropical, with high temperatures and high rainfall throughout the year. The location of Solwara 1 is approximately 4° south of the equator in a sheltered sea (except to the West where the fetch can be > 1000km) well outside of the tropical cyclone belt. There are two distinct monsoonal regimes, the Northwest Monsoon, which persists typically from about November to April (summer) and the Southeast Monsoon (Trade Winds), which persists typically from about May to October (winter). The months of April and October are transition months, when winds of either Monsoon (Northwest or Southeast) may persist.

6.5 Environmental Impact Statement

According to the Environment Act 2000, Solwara 1 Project is high level activity which requires that an Environmental Impact Statement (EIS) be submitted to the Department of Environment and Conservation (DEC). Coffey Natural Systems (Australia) was appointed by Nautilus Minerals to lead consultant for the Environment Impact Report and Environmental Impact Statement process.

In contrast to a typical land-based project, there are no direct landowner impacts, and the primary focus is on scientific issues. Its environmental footprint is mainly that of a single mining ship and precision mining machinery operating on an area proposed for mining of approximately 11.2Ha. One of the main environmental issues is the need to understand the biology of hydrothermal vent communities and the surrounding seafloor, and the potential impacts of mining on them.

It is suggested to discharge the water from dewatering close to its point of origin at depths between 25 to 50 m above the seafloor, and not at shallow or mid-water depths. This avoids any exposure or impacts on surface ecosystems. The processes of mining and dewatering will therefore not affect the pelagic tuna, tuna fisheries or near-shore coral reefs.

Potential impacts to surface pelagic animals are only from the presence of the surface vessels and their normal operations, including lighting, underwater noise and routine discharges (in compliance with relevant maritime acts and regulations). These impacts are generally similar to shipping and to the exploration surveys already completed.

In an effort to enhance scientific knowledge while meeting the needs of the EIA process, Nautilus Minerals engaged international scientific experts to design and conduct the following environmental studies for the Project:

- Macro fauna of hard seafloor areas (College of William and Mary, Duke University)
- Macro fauna and meiofauna of sediments (Scripps Institution of Oceanography)
- Abyssal meiofauna (Dr John Moverley and Coffey Natural Systems).
- Sediment geology (University of Toronto)
- Sediment geochemistry – elutriate and toxicity testing (CSIRO and Charles Darwin University)
- Biomass, biodiversity and bioaccumulation (Hydrobiology)
- Water quality (CSIRO and Coffey Natural Systems)
- Natural hazards (Rabaul Volcano Observatory)
- Oceanography (Coffey Natural Systems)
- Underwater acoustic modelling (Curtin University of Technology)
- Discharged water and sediment dispersion modelling (Asia-Pacific Applied Science Associates)

Additionally, Nautilus Minerals provided oceanographic and deep sea sampling platforms (ROVs) to conduct this work.

The main objectives of the Environmental Impact Statement were to understand the existing environment, the potential impacts due to mining and how to mitigate significant impacts. The Environment Impact Statement discusses the issues and impacts associated with the Project in a range of spatial contexts such as the mining areas at Solwara, barge corridor and crew transfer routes and the project facilities to be used during operations at the Port of Rabaul.

Key sections of the Environmental Impact Statement include:

- Executive summary and overview of proposal;
- Purpose of the development;
- Viability of the project;

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- Overview of the policy, legal and administrative framework;
- Stakeholder consultation;
- Description of the proposed development activity;
- Development timetable;
- Physical, biological and social characteristics of the receiving environment;
- Socioeconomic environment;
- Potential impacts of the project and mitigation and management measures;
- Accidental events and natural hazards;
- Waste minimisation, cleaner production and energy balance;
- Environmental management, monitoring and reporting; and
- Other statutory decisions.

6.5.1 Potential Impacts

Although the impacts to the seafloor, its hydrothermal chimneys and associated vent fauna have been identified as the main defining environmental issue for this Project there may be impacts throughout all three zones. The process of impact assessment was approached through internal risk assessment of issues at each step of the process. The results of this provided the initial assessment of potential hazards, impacts, mitigation strategies and severity of residual effects. This was further developed at a workshop held in San Diego, USA in April 2008, where input was provided by an international team of scientists on appropriate mitigation measures aimed at protecting biodiversity of the Solwara 1 site. Several aspects may give rise to specific environmental impacts (see Figure 6.8). These include

- Water use and discharge;
- Water quality;
- Noise and vibrations on the seafloor and at the surface;
- Sedimentation and dewatering;
- Acid mine drainage; and
- Emissions to air.

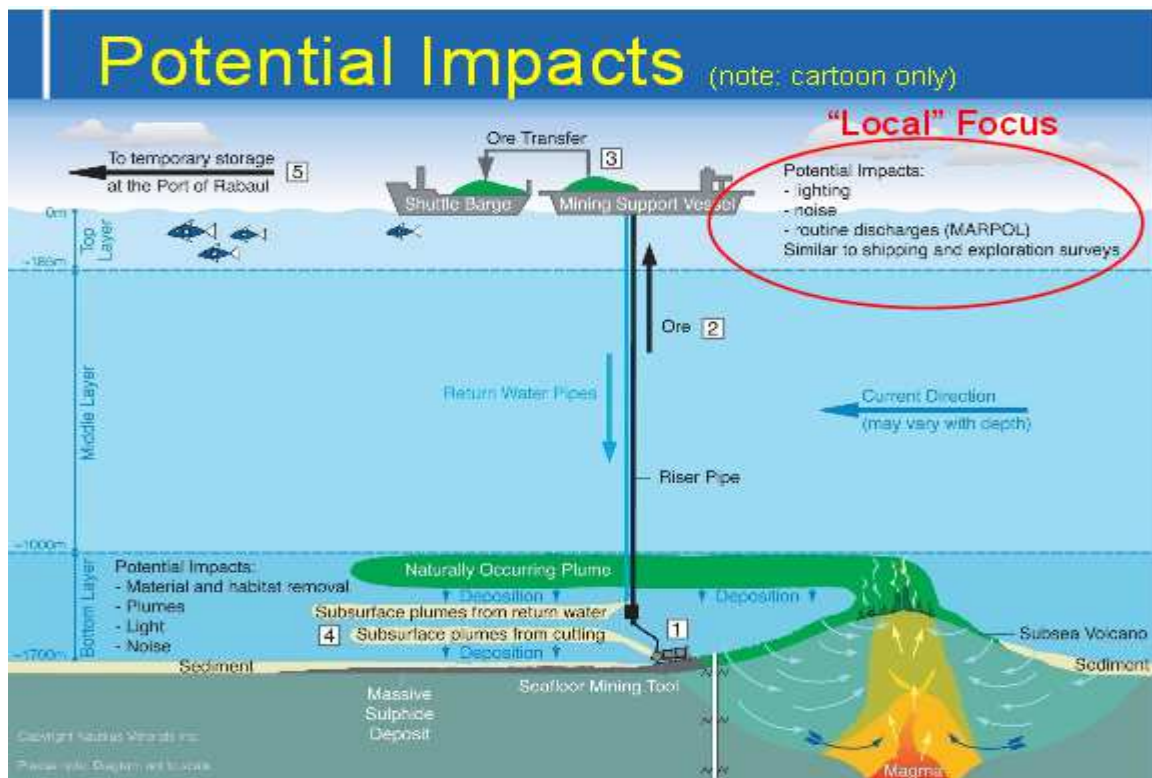


Figure 6.8: Potential Impacts from Solwara 1 Project

Source: Nautilus Minerals (EIS, 2008)

Water use and discharge - Potable water on the production support vessel will be obtained using two 35 kL/day reverse osmosis desalination plants resulting in brine production of up to 82 kL/day. This brine will be discharged to the sea. The brine salinity will typically be double the salinity of the sea water, but is not expected to have any material impact. However pre-treatment requirements for the desalination plants such as chlorination, brominating, dechlorination, coagulation and filtration may lead to waste streams that may require treatment prior to discharge. A further waste stream associated with desalination through reverse osmosis include filter backwash water with elevated salinity and retained solids.

Water quality - Impacts on water quality may occur due to accidental hydraulic fluid leaks, fuel spills during transfers at the site of the PSV, spills during transfer to barges and bulk ore carriers and in extreme cases due to accidental collisions resulting in loss of vessels. Unexpected equipment malfunctions could result in the loss of material in the Riser and Lifting System (“RALS”). The maximum amount of rock in the riser pipe at any one time is approximately 11 m³, which could be lost to the seafloor. Any of these occurrences could cause localised impact to water quality near the seafloor or in surface waters, along with associated smothering of animals on the seafloor.

Noise - Transmission of noise from operating machinery through the water is an important consideration due to the presence of marine turtles and whales, both of which are protected by international conventions. It was identified that the most likely source of noise which may cause disturbance is from the vessel power generation, dynamic positioning system (“DPS”) thrusters or SPT. Modelling indicated that noise levels will drop rapidly within the first 2 km, and more slowly thereafter. These sounds may be audible (e.g., to whales) at up to 600 km but at long ranges, the sounds will not be greatly above that of background ocean noise depending on sea surface conditions.

The maximum distances for specific received level thresholds being exceeded show that it would not be until an animal approached closer than 1.1 km from the source that the levels would be greater than 140 dB. Harmful effect to whales is unlikely as literature suggests behavioural avoidance at levels generally between 130 to 140 dB. Masking of marine animal calls may occur if the mining vessel noise interrupts or prevents the listener from detecting the communicative signal. The operational noise associated with DPS of the mining vessel is continuous over a wide frequency bandwidth. Animals may suffer signal-masking effects at similar ranges up to approximately 15 km.

Sedimentation and dewatering - Prior to mining pre-stripping of unconsolidated surface sediment will be required. It is anticipated that approximately 130,000 t of unconsolidated sediment and 115,000 t of competent waste rock will be moved within the mining zones. The unconsolidated sediment will be disposed of, and competent waste material side cast, at a number of locations adjacent to the mining area. While suspended sediment plumes may be created, no significant geochemical changes are expected to occur as the unconsolidated sediment and competent waste material will remain near the seafloor and not be exposed to any increases in temperature or oxidation. Where practicable, relocation of low-grade material is to be conducted in such a way so as to minimise sediment re-suspension and plume generation. As such the intention is to discharge such material horizontally along the seafloor rather than into the water column to minimise plume formation and enhance the rate at which material settles to the seafloor.

The waste water plumes from dewatering will be discharged such that it will not have an unacceptable impact in the water column shallower than 1300 mBSL. Discharge plumes of the slurry waste water are therefore not expected to impact fish and other animals in the mid (~200 to 1000 mBSL) and upper (0 to 200 mBSL) water column. It is intended to keep

exposure time to cold and un-oxygenated seawater recovered from the seafloor to surface to a minimum so as to not lead to an unacceptable change in oxygen or temperature levels when pumped back to the seafloor. Discharges from dewatering are not expected to have any adverse toxicity effects to seafloor ecosystems and will have negligible overall effects.

Acid mine drainage - Onshore storage and material handling at the Port of Rabaul will be designed to minimise acid generation and deal with acid rock drainage. Where such generation and drainage cannot be eliminated, then a drains treatment facility will be added to prevent any acidic water draining into the ocean.

Emissions to air - Air emissions will consist of combustion emissions from the vessel DPS thrusters, vessel power supply and the mining, transfer and processing power supply. Air emissions of most concern are carbon dioxide, carbon monoxide, nitrous oxides and sulphur dioxide. It is expected that there will be no dust emissions from processing or transport activities due to the moisture content of the processed massive sulphide. Emissions to air from this Project should not have a direct impact on marine life.

6.5.2 Impact Mitigations

In order to minimise adverse environmental and socioeconomic impacts identified, Nautilus Minerals proposes the following management and mitigation measures:

- The application of sound engineering design, deployment and operational practices for the seafloor production tools so as to minimise disturbance to the seafloor and the suspension of sediments.
- The adoption of a dewatering management strategy that will involve discharge at depths from which the material originated, thereby avoiding impacts to the water column.
- The retention of an unmined area at South Su and temporary reserve areas in Solwara 1 to aid in the recolonization of the mined areas and conservation of biodiversity. Relocation of animals to already disturbed areas is to be considered as is placement of artificial substrates to enhance recolonization.
- The adoption of lighting and noise strategies that will address surface and subsea operational and safety requirements and minimise the potential for the attraction of, and interaction with, marine animals.

- The adoption of a waste management strategy that will address the management of sewage, chemical and hazardous materials to minimise the potential for contamination of the water column.
- The adoption of appropriate water management strategies at the Port of Rabaul that will involve the containment and, possibly, treatment of surface runoff to ANZECC/ARMCANZ (2000) standards to avoid any impacts of acid drainage prior to any discharge to the shallow Simpson Harbour waters.
- Where practicable, the application of policies for the employment and training of the workforce that will maximise benefits to the local communities and minimise adverse social effects.
- The development of emergency response plans to mitigate the effects of natural disasters and unplanned events

6.5.3 Environment Management System

Nautilus Minerals states that it intends to manage the Project under the governance of an environmental management system which is to be developed in accordance with the international EMS standard, ISO 14001:2004 as adapted for use in Australia and New Zealand as AS/NZS ISO 14001:2004. This standard will provide Nautilus Minerals with the elements to implement, achieve, review and maintain the Company's environment policy.

Details of the Project's proposed environmental monitoring program, including descriptions of the components to be monitored, frequency of monitoring and purpose, will be included in the detailed EMP's which are still to be submitted to the Papua New Guinea regulatory authorities and will take into account any relevant conditions of approval set in the Environmental Permit.

The Project will provide the Papua New Guinea regulatory authorities with compliance reports as stipulated in environment, water abstraction and waste discharge permits. Regulatory authority and internal assessments of EMP implementation will occur, with the schedule for such assessments and reporting to be determined in consultation with the Department of Environment and Conservation.

Much of the proposed monitoring of the deep seafloor is anticipated to extend into more general scientific research, for which Nautilus Minerals will encourage publication through the normal scientific peer review process.

Incidents that occur as a result of an emergency, accident or malfunction or that cause or threaten serious adverse environmental impacts or are likely to adversely impinge on relations with local communities will be immediately reported to Project senior management in addition to the relevant Papua New Guinea regulatory authorities.

6.6 Legal and Environmental Regulations for the Solwara 1 Project

Prior to commencing either onshore construction activities or seafloor mining operations inside the exclusive economic zone of PNG, the Solwara 1 Project has to be granted a Mining Lease and an Environmental Permit in accordance with the PNG *Mining Act 1992* and the *Environment Act 2000*, respectively. The application process requires the submission of a Mining Development Proposal and approval of an Environmental Permit. Nautilus has in the first instance used local PNG legislation and requirements as reference standards; however where local requirements were inadequate or non-existent, Equator Principles and other internationally recognised standards and guidelines were used. Nautilus also took cognisance of international conventions and maritime law requirements.

The Mining Act 1992 is presently the principal policy and regulatory document governing the mining industry in PNG. The Mining Act 1992 vests ownership of all minerals in or below the surface of land with the national government, and governs the exploration, development, processing and transport of minerals. The Mining Act allows exploration activities and mining of minerals to be undertaken on the seafloor within PNG territorial waters. The Solwara 1 deposit falls into this category.

The Environment Act 2000 defines the activities which require an Environmental Impact Assessment (EIA) process prior to the approval of an Environmental Permit. It sets out three levels of activities, ranging from Level 1 to Level 3 activities, where Level 3 activities are defined as those that may result in serious environmental harm. It also sets out the EIA process to be followed, which commences with the registration with the Department of Environment and Conservation (DEC) of the intent to carry out preparatory work for an activity. After review DEC serves a notice, for Level 3 activities, to undertake an EIA process. The first step in this process is to prepare and submit an Environmental Inception Report (EIR) under Section 52 of the Environment Act 2000. Once the EIR is approved the proponent commences with the preparation of an Environmental Impact Statement (EIS).

ENVIRONMENT REGULATORY FRAMEWORK

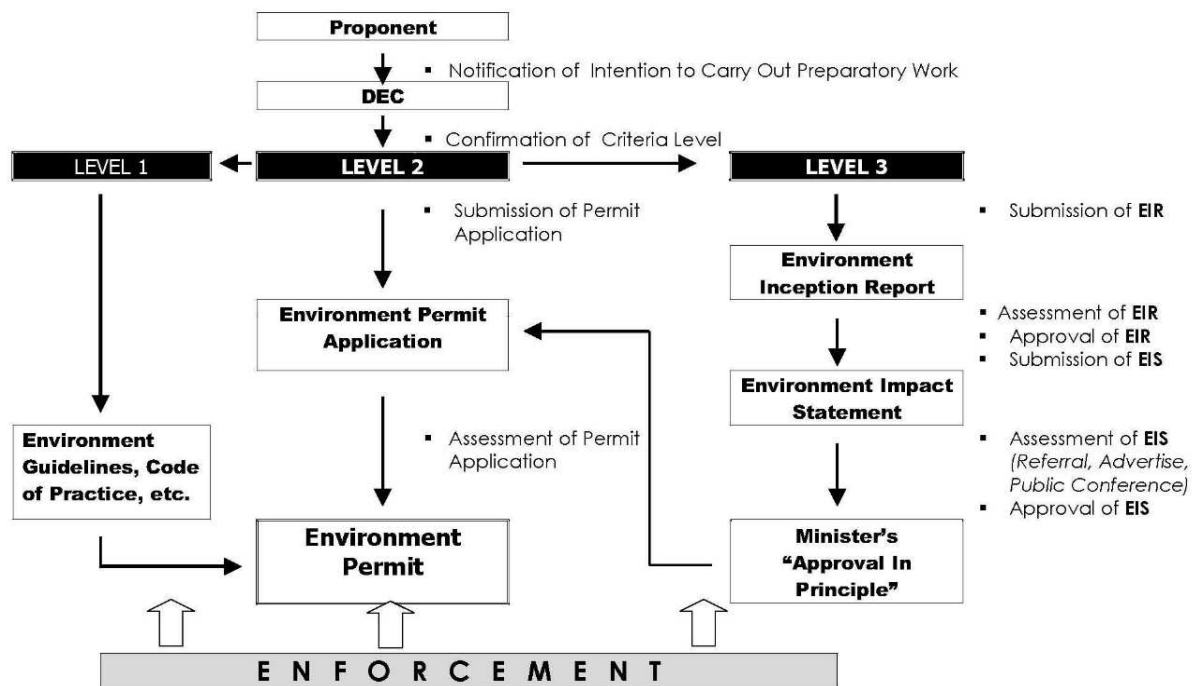


Figure 6.9: Environment Regulatory Framework

Source: Smith (2010)

The Environmental Impact Statement (Nautilus Minerals Inc., 2008) was submitted to the PNG government in September 2008. The main objectives of the EIS were to understand the existing environment, potential impacts due to mining and how to mitigate significant impacts. The EIS discusses the issues and impacts associated with the project in a range of spatial contexts such as the mining areas at Solwara 1, barge corridor and crew transfer routes and the project facilities to be used during operations at the Port of Rabaul and emergency response plans for accidental events and natural hazards. To ensure transparency, collaborating researchers are free to publish their findings.

Nautilus Minerals also conducts a public consultation process, which involves extensive interactions with stakeholder groups. Consultation with communities in New Ireland, East New Britain, and other provinces, NGOs and the international scientific community has included formal meetings, presentations and workshops. Mining Warden’s Hearings were carried out for a total of nine provinces and there has been ongoing regular consultation with PNG government departments. Information dissemination and feedback acquisition had also

occurred through the Nautilus website and attendance at a number of international conferences, workshops, and meetings.

The Environmental Permit for the Solwara 1 Project was granted on 29 December 2009 from the Department of Environment and Conservation (DEC) of PNG for a term of 25 years, expiring in 2035. The next steps for Nautilus are to prepare the draft project Environmental Management Plan (EMP) for submission and approval by the DEC 3 months prior to project commissioning in the early 2017.

The Environmental Management Plan for the Solwara 1 Project will address the management, monitoring and reporting requirements for the various phases of the Project, e.g. baseline, operations and decommissioning, accounting for the commitments made in this EIS and the conditions of approval stipulated by the state. The latter includes validation of predicted impacts and identification of unforeseen effects and needs for additional management measures.

In the case of Solwara 1 project, waste from ships will be managed in accordance with the MARPOL 73/78 Convention and the Protection of the Sea (Prevention of Pollution from Ships) Act 1983 which states that no disposal of food wastes or untreated sanitary wastes shall take place within 12 nautical miles of land. The marine support vessel is more than 12 nautical miles from land and food scraps and sewage will be macerated and treated to MARPOL standards. In the case of no regulation is in place, the government/organization and mining contractor have to work together to create new regulation for the specific situations. Emergency response plans have to be developed to mitigate the effects of natural disasters and unplanned events. (L Egorov, H Elost, N L Kudla, S Shan, K K Yang, 2012)

7 COMPARISON WITH OFFSHORE OIL AND GAS INDUSTRY

7.1 Introduction

This chapter aims to approach the offshore oil and gas industry in respect of technologies, safety and legislation in order to draw lessons for developing the deep sea mining industry. Some offshore oil and gas companies get contract to design and manufacture robotic machine tools for subsea operations and involved in developing technologies for deep sea mining. So, their subsea mining products and technologies are introduced in this section. Thereafter, existing Lloyd's Register Rules and Regulation for Offshore industry are examined and made analysis in different sections such as design, construction, survey, environment and technology. Finally, the results are concluded that what can be used and what is missing in current rules and regulations to develop for deep sea mining industry.

7.2 Similarities from Offshore Oil and Gas Industry

Deep sea mining presents exciting new opportunities to advance the welfare of mankind and sustain global development. However, just like at the position of oil and gas industry in the 1960's, it is still in its nascent stage and unprecedented in deep waters. Currently, deep water technologies in the oil & gas industry are established for water depths of 3,000 m to 3,500 m, with a much deeper drilling depth. Deep Sea Mining Industry could be different from Oil and Gas industry in exploring different materials but same water depth and similar challenges. So, it is good idea to draw lessons from the offshore oil and gas industry which has a long history of evolving its safety and environmental rules. We should recognize the various technical and commercial barriers to overcome in order to make deep sea mining in reality.

7.2.1 Safety and Environmental Rules

As a nascent industry, safety should be made a top priority. Safety practices and standards should be set and observed at all levels. Workers and professionals need to be nurtured through various training and development initiatives to ensure that they have the knowledge and skills to provide quality services and carry out their work safely. As a reference, the oil and gas industry improves its safety performance through leadership, communication and cooperation. Transparent reporting of safety performance and learning from accidents and incidents is achieved through information sharing at many industry safety forums. The

industry recognizes the importance of engaging the workforce and trade unions through offshore safety committees.

The ISO 14001 environmental management standards by the International Standard Organization are a widely accepted framework for environmental management, through self-reporting and external validation. The ISA should leverage such well-established tools to propagate industry best practices. Other references could include those established by classification societies such as ABS, DNV, and Lloyd's Register. Such classification systems will enhance the safety of life and property at sea by ensuring high technical standards of design, manufacture, construction and maintenance.

7.2.2 Riser Systems

Since deep sea mining technology is still in an early stage, wide parts of engineering systems are or may be transferred from the oil and gas as well as dredging industries. This refers particularly to the risers and lifting system which is the key component in sea floor production as stated in chapter 6. In this section, riser system used in offshore oil and gas industry are discussed as follows.

Marine risers are structure systems that connect the subsea fields to the production floating unit. The main purpose of the riser system is to transfer the mineral ore particles mined from sea bed to the floating vessel. The mineral ores collected by the seabed mining tool are then pumped as a seawater/ore slurry into the positive displacement subsea lift pump at the base of the riser, where it is pumped to the floating vessel. A failure in the riser will result in stoppage of mineral ore production and can also lead to pollution and spillage as well as very high economic and political consequences. Therefore, the riser is considered as a vital element for seabed mining platforms.

The selection of a riser system type depends on the metocean data and the water depth. Several types of risers are available extending from the flexible risers, SCR, and free-standing hybrid risers to the top-tensioned rigid risers. There are primarily two main types of risers: rigid risers and flexible risers. The most popular marine riser used in deep water is the Steel Catenary Riser (see Figure 7.1) which presents major merits over conventional flexible or freestanding hybrid risers.

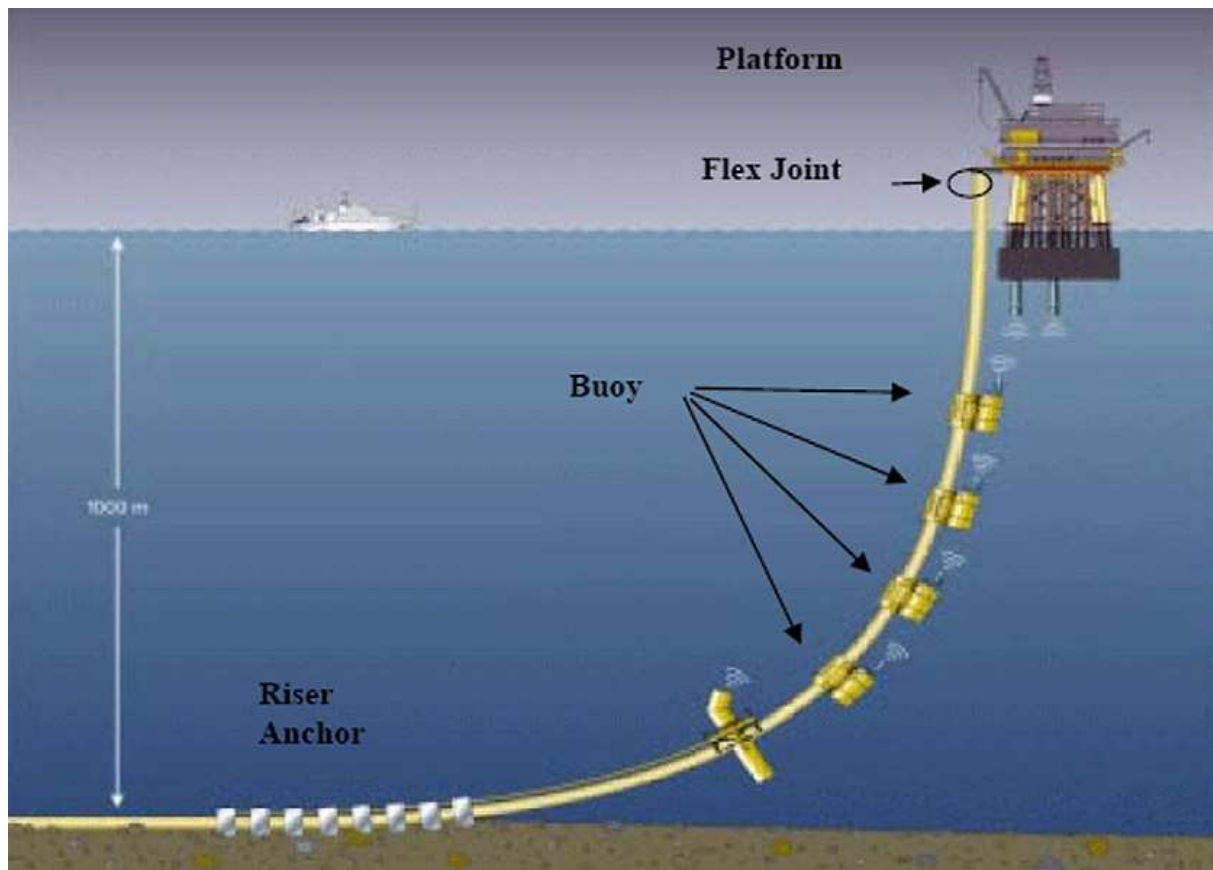


Figure 7.1: Steel Catenary Riser Systems

Source: www.oilandgastechologies.wordexpress.com

7.2.3 Production Support Vessel

The production support vessel is similar to vessels that service the large markets of offshore (subsea) construction, drilling and production for the offshore oil and gas industry. The main technical requirements for a suitable PSV are:

Adequate deck space – Vessel deck dimensions and deck layout shall be capable of integrating and accommodating the following while satisfying the relevant stability and design criteria.

All the seafloor production equipment and its integration including the various elements of SPE and including launch and recovery and operating systems, RALS, 3-off WROVs, DWP, ore self-loading, self-unloading and offloading facilities, Ore storage, export vessel and supply vessel and crew transfer vessel, Handling and mooring arrangements and equipment, workshops, laboratories, stores, control vans, hydraulic power packs, electrical equipment, maintenance crane and lifting equipment, service tools, work platforms and associated items of equipment in SPE integration Specifications.

“EMSHIP” Erasmus Mundus Master Course, period of study July 2014 – February 2015

Accommodation – Total complement of vessels will be around 180 men including 150 seabed production crew and 30 ship crews. So the vessel should meet the requirements of comfort class notation.

Dynamic positioning reliability – The vessel is to be fitted out for the seafloor resource production support, silage and other related duties. In this capacity, the vessel will be stationed over the allocated area and support SPE such ROVs, specialised SPTs, riser and lifting systems.

Adequate electrical power – The vessel should have adequate installed power to run the ship systems, including DP, and the integrated seafloor production equipment.

Cargo Space – The vessel should have cargo holds arranged mid-ship and of capacity to store several tonnes of ore at varying density. The vessel should have a completely enclosed cargo handling system which will transfer ore processed on board directly to any hold and from the holds to incoming Handy size bulk carriers. (See Fig 7.2)

Most classification societies have set rules and regulations for construction and survey guidelines of offshore supply vessels so it would be first step to develop the rules for offshore mining support vessels to involve in deep sea mining market.



Figure 7.2: Production Support Vessel's Operation with Ore Carrier.

Source: Nautilus Minerals

7.3 Subsea Mining Companies and Their Products

The technology for deep-sea mining is not something of the future but it is largely existing. A deep-sea mining operation consists of a mining support platform or vessel; a launch and recovery system; a crawler with a mining head, centrifugal pump and vertical transport system; and electrical, control, instrumentation and visualization systems. Companies such as Lockheed Martin, Soil Machine Dynamics, IHC Mining and Bauer or Nautilus Minerals are developing vehicles for deep-sea mining, pledging they are in the position to readily develop techniques to operate down to 5,000 metre depth. Indeed, the submarine vehicles required are already in existence and their operations are described in compelling animations.

Nautilus Minerals has brought together an extensive group of engineering and technology collaborators from the offshore oil & gas and the metals & minerals sectors - the two industry sectors fundamental to the mining of Seafloor Massive Sulphides. Nautilus is transferring current technology from these sectors to the new deep ocean mining industry. In order to do this, Nautilus has formed strong technical alliances with companies who are at the forefront of their industry and represent best-in-class technology.

Soil Machine Dynamics ("SMD") of the UK was awarded the contract to build the two remote operated SMT for Nautilus. SMD is one of the world's leading subsea engineering companies specialising in the design and manufacture of remotely operated vehicles ("ROV's") and seabed trenching systems. (See Fig 7.3)



Figure 7.3 Potato Picker Design for Nodules Mining from SMD

Source: www.smd.com.uk

Technip, an integrated group providing engineering, technologies and construction services to the oil/gas and petrochemical industry worldwide was awarded the contract for engineering, procurement and construction management of Nautilus's Solwara 1 Riser and Lifting System

("RALS"). With a workforce of 22,000 people worldwide, and annual revenues of almost 7 billion euros, Technip ranks among the 5 major players in full-service engineering and construction services in the field of hydrocarbons and petrochemicals.

Ocean Floor Geophysics Inc: Nautilus, together with its shareholder Teck Cominco Limited, partnered with the Vancouver based Ocean Floor Geophysics Inc. to develop, deploy and test new deep-ocean electromagnetic technology.

GE Oil & Gas: is a world leader in advanced technology equipment and services for all segments of the oil and gas industry, including drilling and production, LNG, industrial power generation, and refining and petrochemicals. GE Oil & Gas also provides pipeline integrity solutions, including inspection and data management. As part of its 'Innovation Now' customer focus and commitment, GE Oil & Gas leverages technological innovation from other GE businesses, such as aviation and healthcare, to continuously improve its performance and productivity in the oil and gas space. GE Oil & Gas employs more than 12,000 people worldwide and operates in over 70 countries. GE was awarded the contract to build the subsea slurry pump for the RALS, using their Hydril Pressure Control subsea pumping technology.

7.4 Assessment on Current LR's Rules and Regulations

LR is a company limited by shares, called Lloyd's Register Group Limited; they are the operating company of the Lloyd's Register organisation. The shares in Lloyd's Register Group Limited are owned by Lloyd's Register Foundation, a registered charity. Regarding to marine and offshore industry, Lloyd's Register has published the following rules, regulations and guidelines until now.

- Rules for Offshore Units
- Rules and Regulations for the Construction and Classification of Submersibles and Underwater Systems
- Rules for ships
- Provision Rules Construction and Classification of Submarine Pipelines
- Code for Lifting Appliances in a Marine Environment

Looking through the above rules and regulations, some parts of rules could be relatively unchanged or as a base for which to develop them in deep sea mining standards.

The proposed sea floor production system of Nautilus Minerals consists of three main components such as the production support vessel, riser and lifting system, and sea floor mining tools. In this following subsection, the tasks of each components are analyzed with LR rules and regulations whether it could apply or not. Firstly looking at surface operations of the production support vessel is to dewater the slurry on deck. The dewatered solid material is discharged to a transportation barge moored alongside. Used seawater is pumped back to the seafloor through the riser pipes and providing hydraulic power to operate the RALS pump. Discharge of the return water at the seafloor will avoid impacts to the warm surface seawaters, minimizing environmental impact of the operation. So, the tasks of production vessels are dewatering, discharge, launching of ROV and Seafloor mining tools, and support electrical power to pump and return of water. The current LR rules and regulations which could be applied into deep sea mining are listed with respective tasks as shown in Table 7.1 and 7.2. This is first attempt and it needs to be further developed.

Task	What LR can do	Remarks	Rules and Regulations
Production Risers	Consultancy services	LR has experience on lifting system. However these are limited to installations fixed to the seabed. Assume however that problems are similar.	1. Rules for Classification of Offshore Units 2. Various Standards like API RP 17B, API RP 17J and others
Riser connectors			
Power and control umbilical			
Booster pumps			
Bouyancy modules, mid-water arches	Consultancy services	As described on LR rules. The mid-water arche is not the only problem: collission, marine growth, ice-loadings etc will also influence the riser design. Noise prevention will be an issue.	1. Rules for Classification of Offshore Units 2. Various Standards like API RP 17B, API RP 17JQ and others
ROV	Consultancy services		1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems

Table 7.1: Proposed Rules for Riser System(Mid-water Level)

Task	What LR can do	Remarks	Rules and Regulations
Survey	class and statutory approvals	AUV launch and recovery systems, currently the Code for Lifting appliances would apply.	1. For the mother vessel: LR's ship rules. 2: Rules for Classification of Offshore Units 3: Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
Support	class and statutory approvals		Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
Deployment	class and statutory approvals		1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems 2. Code for Lifting Appliances in a Marine Environment
Recovery	class and statutory approvals DP	ROV launch and recovery systems currently the Code for Lifting appliances would apply	1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
Cargo transport & handling	class and statutory approvals DP		Code for Lifting Appliances in a Marine Environment

Table 7.2: Proposed LR rules and regulations for PSV

Regarding underwater and seabed operations, there are several tasks such as grinding and collecting ores, pumping up by riser, supplying power cable for mining tools, discharging return water, manoeuvring the ROVs and so on. Table 7.3 represents the proposed idea to apply some existing LR rules on certifications of seabed tools and consultation of operations. For environmental rules and regulations, ISA published the recommendations and regulations for polymetallic nodules, polymetallic sulphides and cobalt-crust for contractors to follow so it can avoid potential impacts for marine environment system. Recommendations state that

5.1 The Contractor shall take necessary measures to prevent, reduce and control pollution and other hazards to the marine environment arising from its activities in the Area as far as reasonably possible applying a precautionary approach and best environmental practices.

Area	Task	What LR can do	Rules and Regulations
Mining	Grinders and Crushers	Appraisal of engineering systems	1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
Collecting	Conveyors, pumps	Appraisal of engineering systems	1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
	Manipulator arms	Appraisal of engineering systems	
	Intervention tools	Appraisal of engineering systems	
	Emergency Disconnect	Consultancy services	
Power	Power cable		1. Rules and Regulations for the Construction and Classification of Submeribles & Underwater Systems
	Subsea Termination and Distribution Unit	Consultancy services	
	Junction boxes, subsea	Consultancy services	
	Subsea Power Unit	Consultancy services	
	Emergency Disconnect	Consultancy services	
Control	Subsea Termination and	Consultancy services	Rules for offshore units
	Junction boxes, subsea	Consultancy services	
	GPS, sonar beacon locator	Consultancy services	
	Emergency Disconnect	Consultancy services	

Table 7.3 Proposed Rules and Regulations on underwater operations

5.2 Prior to the commencement of exploration activities, the Contractor shall submit to the Authority:

(a) An impact assessment of the potential effects on the marine environment of the proposed activities;

(b) A proposal for a monitoring programme to determine the potential effect on the marine environment of the proposed activities; and

(c) Data that could be used to establish an environmental baseline against which to assess the effect of the proposed activities.

5.3 The Contractor shall, in accordance with the Regulations, gather environmental baseline data as exploration activities progress and develop and shall establish environmental baselines against which to assess the likely effects of the Contractor's activities on the marine environment.

5.4 The Contractor shall, in accordance with the Regulations, establish and carry out a programme to monitor and report on such effects on the marine environment.

The Contractor shall cooperate with the Authority in the implementation of such monitoring.

5.5 The Contractor shall, within 90 days of the end of each calendar year, report to the Secretary-General on the implementation and results of the monitoring programme referred to in section 5.4 hereof and shall submit data and information in accordance with the Regulations.

As mentioned in recommendations, LR could offer their services to contractors in preparing environment impact assessment and surveying during exploration activities. Furthermore, LR has good knowledge and experience in environmental solutions which has already existed for offshore oil and gas industry and wind energy. So there could be a lot of opportunities for LR to enter the deep sea mining industry by developing current rules and regulations from offshore sector.

8 CONCLUSION

The seabed holds vast and diverse resources capable of sustaining human demands for centuries ahead. The mining of minerals from the deep seabed still remains in its infancy. However, in the authors' view, pressure on unexplored natural resources will eventually lead to a significant expansion of human mineral recovery activities to the deep sea. Furthermore, with advanced technologies and a greater understanding and appreciation for the marine environment, the recovery of marine minerals in the seabed has become ever more feasible.

The first part of this research examined the geographical features of the seabed and characteristics of the minerals found on the sea bed. The occurrence and distribution of the resources are presented together with economic relevance. This study has shared many insights about sea bed minerals and their economic market analysis. This idea could encourage more interest and research into deep-sea mining, particularly in regards to gain more interest in economic view.

The focus of research has moved to the guidelines, recommendations, rules and regulations of the seabed mining in national and international water. Then, the history, background and activities of international seabed authority are reviewed and discussed on the framework of ISA and their relationship with other international organization how they produce the exploration licenses to contractor. This section has given the general knowledge about the current rules and regulations, the contact of authorized international organization and their functions, and the procedure to apply for exploration contract in area.

The chapter four provided the information of current exploration activities in international water which is allowed by ISA. Total fifteen exploration licenses are generated by ISA until now and some contracts are in government level investment like China and India. Since the author worked for LR EMEA Hamburg office, research activities and national legislation of EU members are highlighted in this section and especially for Germany. This information gives a greater understanding for LR to attain more opportunities in regional area.

In the chapter five, the potential impacts on environment and ecosystem of mining area on the seafloor are examined and discussed about the risk and damage which arises from exploration and prospecting. Then, mitigation strategies are discussed on the protection and avoiding the impact during operation. Environmental management plan of CCZ is reviewed as standard plan for developing in future work. Valuable lessons gained from this part have helped to

concern more on environmental care. It is really important to generate awareness about the environmental impacts and to be publically transparent.

The case study provided a review on the status of the Solwara 1 project of Nautilus Minerals. It presented the publically available specifications on the engineering system, implying the seafloor tools, riser and lift system as well as the production vessel. Furthermore, a brief summary of the estimation of the CAPEX and OPEX is indicated, which served as a starting point for economic modelling in seabed mining. The oceanic environmental background was reviewed and the potential environmental impacts and mitigation strategies were investigated. Lastly, the author discussed what LR can do in the deep sea mining market, what is missing in their services and interactions with other LR sectors such as Energy to develop rules and regulations for upcoming industry.

In overall terms, the main concluding statements drawn from the research work undertaken in this study are summarised and introduced as follows:

- The potential resources of seabed regarding their characterisation, occurrence, economic and societal relevance are identified and classified.
- The state-of-the-art evaluation and review of the different relevant technologies for exploration and exploitation of seabed mining as well as cultivation and harvesting is conducted. The existing engineering technology challenges are identified.
- Engineering systems are seen as generally ready for seabed mining. The largest developments needed are seen in exploration technologies, particularly for environmental impact assessments, seafloor tool and lifting system development and energy supply of seafloor machinery.
- The guidelines, rights, regulations and responsibilities of nations regarding the seabed resources are assessed and defined. The seabed resources and their associated exploitation technologies and legal regulations were extensively reviewed.
- The potential environmental impact and the mitigation strategies were evaluated. Extensive guidelines for sustainable seabed mining key issues were developed and presented. These give an information base for the industry and a benchmark for seabed mining.

Throughout this project I have found deep-sea mining industry to be interested and open to environmental discussion to identify, minimize, and mitigate impacts. I hope that this paper provides some real solutions and will lead the way for the stewardship of our ocean resources.

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