



Study to investigate state of knowledge of Deep Sea Mining

Revised Interim report under FWC

MARE/2012/06 - SC E1/2013/04

Client: European Commission - DG Maritime Affairs and Fisheries

Rotterdam/Brussels, 28 April 2014

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Preface

This interim report provides an overview of the progress of the study till end of March 2014, with a main focus on three tasks that are most advanced, i.e.

- Task 1 technology analysis
- Task 3 legal analysis
- Task 6 environmental analysis

For the tasks referred to above, a detailed presentation of preliminary findings is included in subsequent report parts A, B and C. In part D, a summary of the progress and initial results of other tasks is given.

A number of annexes is included in this report in which more detailed information related to the said tasks can be found.

The preliminary findings will serve as input to the two workshops that will be held 29 and 30 April in Brussels. Any additional information and feedback received there, or through the Steering Committee, will be taken up in an update of the relevant sections as part of the (draft) final report.

Rotterdam/Brussels, 28 April 2014

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1 Introduction

1.1 Background and objective

Marine mining and deep sea mining are part of the EU's Blue Growth strategy under the thematic area of marine mineral resources. The development of technology allows us to exploit previously unreachable deposits.

At this stage, the Commission is preparing a position vis-à-vis the development of this activity. To this end, a scoping study was commissioned.

Study purpose

The main purpose of this study is to feed information, data and specific examples that will serve the European Commission to prepare a position vis-à-vis the development of deep sea mining.

This study looks to collect all available information – as accessible – on the technology, the economic, legal, geological, environmental and social factors that are relevant for deep sea mining operations. Consequently, the study focuses on the operations that are being planned or are being carried out as opposed to presenting general discussions on deep sea mining.

This study versus other (research) projects

The study has a main focus on gathering and integrating information and knowledge already accessible at this moment. At the same time, a number of research projects are ongoing or about to start that aim to raise knowledge level and develop new means, applications or technologies. As these projects will run for multiple years, at this moment no research results are available yet. Rather, this scoping study will serve projects such as MIDAS or Blue Mining, both co-funded by the European Commission's 7th Framework Program (FP7), to set the scene and help focussing research work on the areas where key knowledge gaps are found.

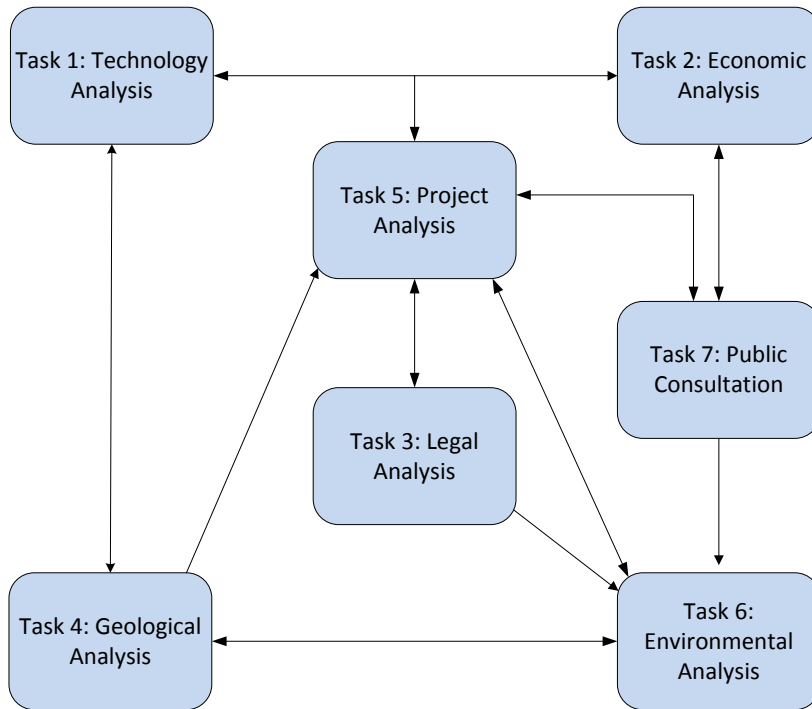
1.2 Set-up of the study

Following the terms of reference, the study is organised in seven tasks, that are closely interrelated and that will feed into each other. The seven tasks are:

- Task 1: Technology Analysis;
- Task 2: Economic Analysis;
- Task 3 Legal Analysis;
- Task 4: Geological Analysis;
- Task 5: Project Analysis;
- Task 6: Environmental Analysis;
- Task 7: Preparation for public consultation.

The interrelation between the tasks is presented in the figure below.

Figure 1.1 Interrelationships between the tasks



1.3 Purpose of this interim report

This interim report presents the preliminary results for the technology, legal and environmental analyses (tasks 1, 3 and 6) and serves as input to further discussions with the Steering Committee. Moreover, the preliminary findings of these tasks are input to discussions with selected stakeholders in two workshops, on technology and environment, that will be held on the 29th and 30th of April. While legal aspects are not the main topic of these workshops, the study results of this task will be included in the workshop discussions to the extent relevant.

Apart from these three tasks that are most advanced in terms of study progress, an overview of the progress of other tasks is also presented in this report.

A.Task 1 Technology analysis

2 Approach

2.1 Aim and main elements within this task

Aim

The aim of the technology analysis task is to identify and describe the value chain of deep sea mining from extraction to refining. A value chain analysis will be followed that takes into consideration separate options for processing, and include both land and sea-based processing technologies.

Main elements

Following the terms of reference and our inception report, the technology analysis task entails:

- The description of the deep sea mining value chain. As part of the work until date we have composed an 'aggregate' value chain in the form of a 'toolbox', from which sub-chains for particular types of deposits or segments can be drafted as necessary. The findings till date however show that in principle, the overall value chain is the same but rather the technologies used in particular steps of the chain may vary for the different types of deposits;
- Description of the technologies used in each link of the value chain;
- Where relevant, address any differences from land-based technologies, or transfer possibilities.
- Assessment of the stage of development of each technology. For this we make use of the TRL classification (Technology Readiness Levels), see section 1.3;
- For each technology, identify the most important suppliers. This gives an impression of the activity of EU-based companies versus those based elsewhere.

Information was gathered using literature review and desk research as well as a number of expert discussions within the team.

The findings of these steps will be used as input to a workshop that will be organised on the 29th of April and for which selected experts are invited. Aims of this workshop include:

- Validation of the research findings;
- Identification of skills base status and skills + technology gaps;
- Prioritisation of development needs – building on the TRL assessment for the value chain links.

Subsequently all results from the workshop as well as other feedback will be included afterwards.

2.2 The Value Chain concept

Following the assessment of published information a value chain concept has been developed (see below) of which each stage has been further elaborated in the subsequent chapters of this section.

It is noted that information on the technology state of play and on-going research and development is found mainly at two categories of sources: scientific research (university-based, including work funded by the EU such as Framework Programme 7 projects and peer-reviewed scientific publications) and industry players, with also cooperation models between the two. To some extent industry may consider their data confidential, though several large players appear very active in marketing their technologies and have shown willingness to share information and data already in the Blue Growth study and through other platforms.

As there may be industry bias in data gathered on stages of development (and associated costs, necessary for task 2), a scientific judgement of the information is made and views over realistic levels of development and outlooks on trends therein are provided as part of this task.

Within the value chain concept of deep-sea mining, six main stages from exploration to sales are identified. In principle, independent from the type of ores to be mined, the value chain of DSM consists of the following main steps:

1. **Exploration;**
2. **Resource assessment, evaluation and mine planning;**
3. Extraction, lifting and surface operations;
4. Offshore and onshore logistics;
5. Processing stage;
6. *Distribution and sales* (this stage is not included in this study's analysis).

As project plans of various industry players have shown, it depends on each project how the exact components and stages are shaped within a deep-sea mining project. So far, there has not yet been one system fully proven to be operational. The current focus of mining projects is therefore aimed at exploration, evaluation and planning rather than at exploitation. In these stages, the extraction, lifting and surface operation techniques, needed for exploitation, are also tested on a small scale. The development of these techniques is therefore merely part of the exploration phase.

Exploration

In the exploration stage, a variety of techniques are used to locate mineral deposits and assess their characteristics. After mapping areas of deposits e.g. using multi-beam echo sounders (side-sonars) and deep-tow sonars¹, camera surveys and sampling techniques are used to gather samples and assess their composition and density of materials.

Resource assessment, evaluation and mine planning

This phase assesses the feasibility of a possible mining project in terms of technological and metallurgical, economic, marketing, legal, environmental, social and governmental factors. In the end a quantitative assessment of recoverable reserves will be made. The result should also serve as a bankability proposal.

Extraction, lifting and surface operations

This stage, which is a core part of the exploitation phase, encompasses the excavation of the deep-sea minerals, their transportation to the surface and eventual processing and handling operations taking place offshore. For the first part, several cutter and rising systems are identified. Also, pre-processing can take place already at the seabed. The vertical transport system is a critical part as well. The support vessel is a crucial component for the operations on the surface. The vessel may function as dispatching system, storage facility, should have dewatering systems and may act as an on-board processing facility. Depending on the extraction technologies used, distance to shore and volumes, the sediment may be dewatered at the ship or platform and the fines can be recovered by cyclones. The lifted water can be returned into the water column, which however requires proper filtering/cleaning facilities and monitoring devices. When the extraction sites are located at a large distance from shore, adequate storage on a platform is required as to manage the logistics process.

Offshore and onshore logistics

The (partially processed) commodities must be shipped to a processing location on shore. It depends on the type of commodities, quantities and distances to cover what type of ships are required for ocean transport. Those vessels might be 'traditional' bulk carriers used for the shipment

¹ ISA (2006a) Polymetallic nodules. Available at <http://www.isa.org.jm/files/documents/EN/Brochures/ENG7.pdf>

of minerals mined on land, or alternatively they could be the same vessels also used to extract the ores, in such case Hayden (2004) argues that price for shipping will be a key condition for where mining activities will first take place.

Like all commodities being shipped, also deep-sea minerals need to be unloaded from the vessels and (temporarily) stored at the same location as the processing site or maybe within strategic depots in ports.

Processing

Due to the large quantities of ore, and – in some cases – complex chemical process involved, the final processing will most likely take place on-shore², following one or more steps of pre-processing on the seabed and/or on board of the support vessel. Several techniques for processing e.g. manganese nodules have been suggested. In general two techniques have been tested: hydrometallurgy, where the metals are separated with acids (hydrochloric or sulphuric) or basic reagents (ammonia), and smelting.³ The extent to which these processes differ from the processing of land-based minerals will depend on sediment characteristics and will be further analysed in this task.

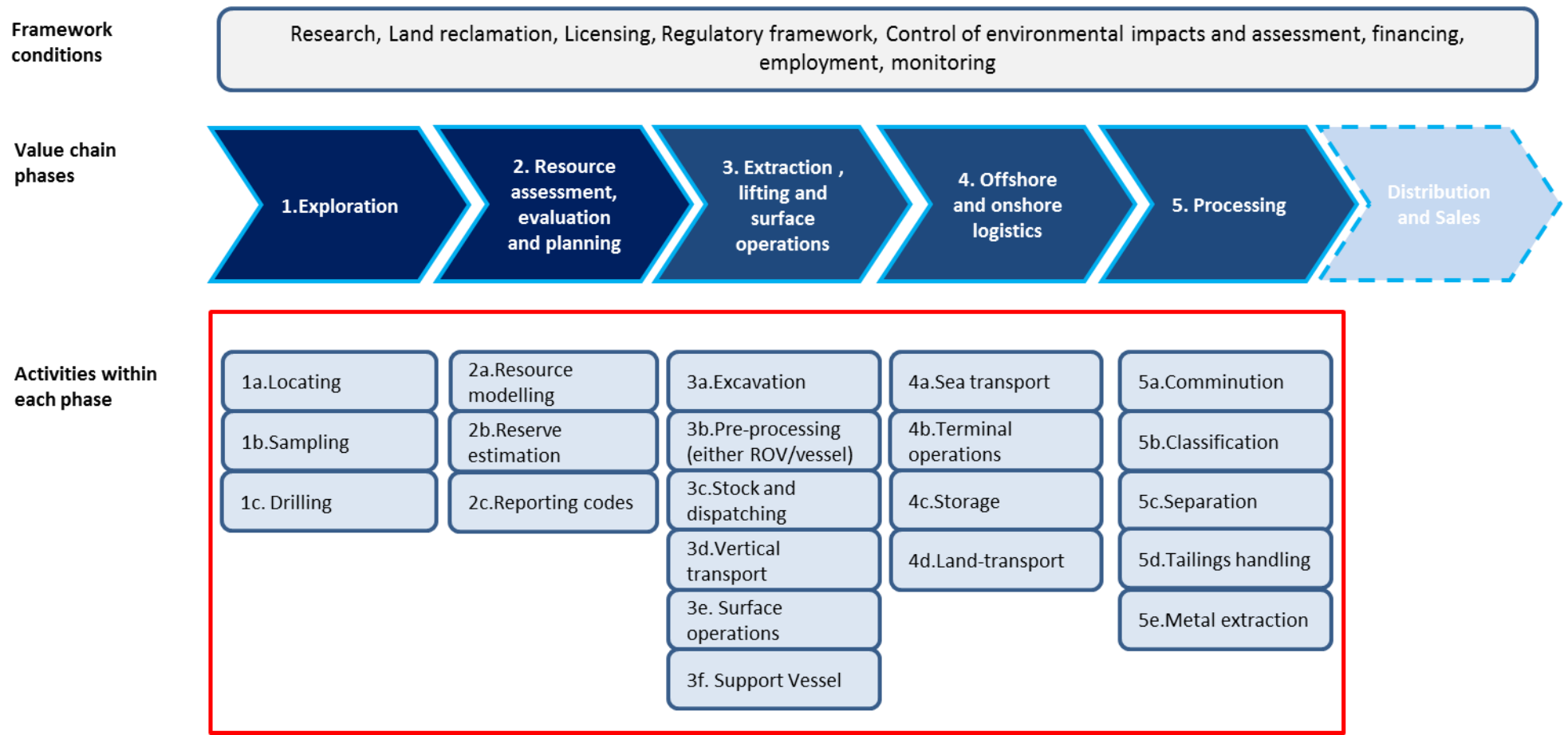
Distribution and sales

This is the final stage of the value chain and the least related to deep-sea mining as such. From a technology perspective, this stage is also not very relevant. However, it is an important phase in terms of economic value added. In many cases it will not be different from the distribution and sales of land-based minerals.

² Hayden, David (2004) Exploration for and Pre-feasibility of mining Polymetallic Sulphides - a commercial case study. David Hayden, Nautilus Minerals Ltd. ISA Workshop presentation 2004.

³ ISA (2006a) Polymetallic nodules. Available at <http://www.isa.org.jm/files/documents/EN/Brochures/ENG7.pdf>.

Figure 2.1 Value chain phases and activities



2.3 Technology assessment approach

Within the main deep sea mining value chain stages, each stage consists of several activities. The technology assessment will identify and review the available technologies for each value chain activity, as shown in Figure 2.1 above.

For each activity, an inventory is made of the available technologies per type of sediment after which each technology is assessed on the following:

1. To what extent have the techniques shown to be successful?
2. Which companies are known to be currently developing and providing the technologies?
3. What is the overall stage of development of each technology? For this we use the ranking method of TRL-stages.

TRL-stages

Within this report, we use Technology-Readiness-Levels (TRL) to assess the maturity of the evolving techniques to be used within deep-sea mining activities. This framework is developed recognizing the several stages a certain technology needs to go through before it is a widely tested and proven technology.

Several industries use the TRL-stages and there are some different definitions of each stage. For example, the US Department of Defence uses slightly different definitions for stages than the NASA or ESA. Within this study, the following definitions of the TRL-stages are applied.

Table 2.1 Technology readiness levels

TRL	Definition
TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment ⁴
TRL 6	Technology demonstrated in relevant environment
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment

Source: European Commission (2013) Horizon 2020 Work programme

The technological readiness level is visualised within this report by using the following colour-scheme.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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An overview of estimated TRL levels for the main technologies assessed is given in the table below.

⁴ Industrially relevant environment in the case of key enabling technologies

Table 2.2 Main DSM technologies and their TRL levels

Value Chain Phase	Phase Activities	Ore Deposit Type(s) Involw Technique	Technological Readiness Level									Comments	
			TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9		
Exploration	Prospecting	SMS, Nodules, Crust		X								Analogues from marine geotechnics and Petroleum need to be adjusted for Ressource/Reserve Exploration	
	Geophysics	SMS, Nodules, Crust		X								Analogues from marine geotechnics and Petroleum need to be adjusted for Ressource/Reserve Exploration	
	Sampling	SMS, Nodules, Crust		X								Advanced drilling tools for deep sea applications should be developed to penetrate deeper into the SMS deposits and allow for representative sampling	
Resource Assessment, Reserve Evaluation and Mine Planning	Resource Modelling	SMS, Nodules, Crust			X							3D spatial Modelling need to be adapted to account for multiple data sources (direct and indirect) + Geometallurgy	
	Reserve Estimation	SMS, Nodules, Crust		X								Cutting method and transportation requires a new definition of SMU, losses due to current ...	
	Reporting Codes	SMS, Nodules, Crust		X								Extension of currently available codes for deep sea mining incorporating all sustainable aspects	
Excavation Design & Excavation Operation	SMS	Drum Cutter ROV		X								Limited tests performed with land based cutter drum at 1600mbsl, technical issues need to be solved, especially effective cutting and removal of cuttings from rock face	
	SMS	Rotating Cutter Head ROV		X								Cutter heads are successfully applied in shallow depth dredging operations today, experiments should focus on applicability of techniqueto cut SMS deposits in a deep marine environment	
	SMS	Clamshell Grab		X								Already deployed successfully today, the focus should be on efficiency in combination with a subsea rock crusher or skip hoist system.	
	Nodules	Passive Collectors					X					Inefficiency and lack of control combined with the large environmental impact (massive plume formation) resulted in the abandonment of this method.	
	Nodules	Active Mechanical Collectors					X					Mechanical collector systems proved to work and the technique was tested at 410m depth by NIOT (India), and tests currently scheduled to test at depth of 6000m (operating environment)	
	Nodules	Active Hydraulical Methods					X					Developed since early 1990's by COMRA (China) this technique was sucesfully tested in a laboratory using simulated conditions. Needs testing in real operating environment	
	Crust	none		X								Equipment requirements have been identified but due to limited thickness of the deposit and hence difficult mining operation crusts are not considered technically,economically and environmentally viable at the moment.	
	Pre-Processing on the sea floor prior to despatch												
	SMS, Nodules, Crust	Identification			X								Sensor solutions for Presorting before cutting (Ore identication), and sampling to obtain a 'real time' quality map to decide to mine or not / decide on production orde/combination of areas
	SMS, Nodules, Crust	Separation			X								Separation principles are well understood and finds various applications in terrestrial materials processing. The technique can significantly upgrade the value of the ore stream and sediments displacement is minimized. Apart from nodules/sediment separation by simple screening no research has been carried out in a sub-sea environment.
	SMS, Nodules, Crust	Size Reduction			X								Crushing is required to separate valuable material from some of the invaluable material and is applied in combination with concentration
	SMS, Nodules, Crust	Concentration		X									This step should not aim to produce a concentrate ready for shipping but aim to pre - upgrade the average grade of the material that is sent to the dispatch system prior to vertical transportation.
	Dispatching												
	SMS, Nodules, Crust	Stock & Dispatch Systems		X									A stock and dispatch system is required as it will act as a buffer between the excavator(s) and the continuous riser system or batch lifting system. Also allows for ore blending to retain a merely constant headgrade.
	Vertical Material Transport												
	Nodules	Continuous Line Bucket						X					Lack of manoeuvrability, lack of production control, heavy plume formation and low cutting power make that the method is inefficient and abandoned.
	SMS, Nodules, Crust	Airlift System						X					Proven technique and widely applied in limited water depth dredging operations, method validated to transport nodules from a depth of 15.000ft.in a pilot test. Largely replaced by hydraulic pumps in recent studies due to high power requirements of airlift systems and vulnerability to clogging. Maturation is adressed by FP 7 Blue Mining project.
	SMS, Nodules, Crust	Hydraulic Pump System				X							Technique already exists and is applied in oil & gas industrie to transport drill cuttings in deep ocean drilling operations. The system should be tested for deep sea ore transportation (partide sizes, clogging and wear on the system). Maturation is adressed by FP 7 Blue Mining project.
	SMS, Nodules, Crust	Batch Cable-lift System		X									No such system exists to date. Technique should be relatively easy to apply if one can also successfully lower/lift heavy ROV's to and from the seafloor. Simple to increase TRL by experimental modeling and field test.
	Surface Operations												
SMS, Nodules, Crust	Dewatering								X			The dewatering plant has a simple flow sheet and installing such a plant on board a vessel/platform should not be problematic. Not demonstrated on ship	
SMS, Crust	Concentrating				X							Known land based applications. Limited testing of techniques to concentrate deep sea ores. Issues that need to be resolved are: Handling of wet ore, Power, Tailings disposal	
SMS, Nodules, Crust	Metallurgical Processing				X							Metallurgical processing on board a vessel/platform is unlikely due to; very high energy costs, requirement of extraction chemicals	
Logistics	Sea-transport and Terminal Opera	SMS, Nodules, Crust											
	Storage	SMS, Nodules, Crust											
	Land Transport	SMS, Nodules, Crust											
Processing	Comminution												
	SMS, Nodules, Crust	Crushing/Milling		X									Well developed for land based operations processing dry ore. Experiments should be conducted to evaluate comminution efficiency of equipment when processing wet/moist ore.
	Classification												
	SMS, Nodules, Crust	Screens/Hydrocyclones							X				Well developed method capable of handling wet material. Classification separates material according to size before further processing (e.g. separation) and can send different size range material streams to different processes (e.g. undersize to flotation, oversize back to grinding mill). Screening is routinely used in offshore diamond mining. Hydrocyclones not demonstrated on board ship (likely to work)
	Separation												
	SMS, Crust	Spiral Concentrators, Gravity Separation Tables, Jigs, Magnetic Separation, Froth Flotation				X							Some individual separation techniques have been tested in laboratory experiments (e.g. flotation). Attempts should be made to design a pilot processing plant to identify the best concentrating technique.
	Tailings Handling												
	Tailings Disposal		X									Especially when processing takes place at sea, a solution must be found to deal with (very fine grained) process tailings.	
Metal Extraction													
SMS	Concentrating, acid leach, smelting, electrowinning								X			The chemical characteristics of SMS deposits are similar to land based VMS deposits, hence the metal concentrate can be delivered to a smelter. Not yet demonstrated on board ship. Scale of anticipated mine & requirement for stockpile buffer are problematic for shipboard application. Energy requirements & safety concerns may also be problematic in a shipboard application.	
Nodules	Cuprion Process, Sulphuric Leaching, Smelting				X							Several metals extraction methods have been proposed and tested on a small scale	
Crust	Concentrating + Smelting, Magnetic Separation + Smelting				X							Concentrating of the mined material to separate ore from substrate and subsequent extraction of the ore using the same processes as used for nodules.	

Framework conditions

The technology value-chain does not incorporate the regulatory, financial and environmental stages which should facilitate the whole operation of deep-sea mining. We do not neglect the fact that these stages are in fact crucial for successful project achievement, but they do not involve the deep-sea mining techniques as considered in this report. Therefore, licensing, environmental impact assessments, financing and employment are considered as framework conditions which should be present for successful mining operations and not as value chain activities.

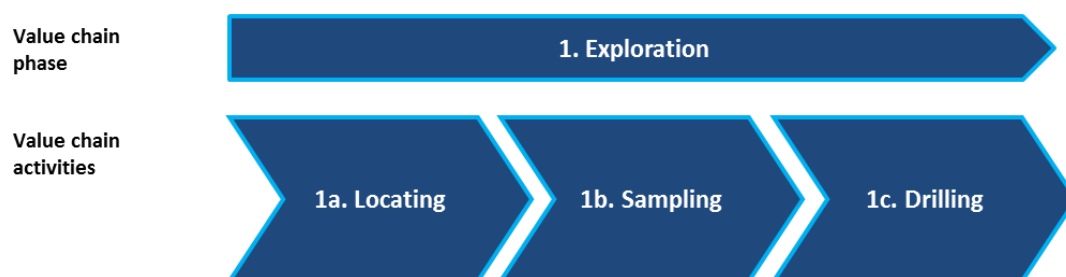
3 Exploration techniques

3.1 Introduction to exploration

In order to assess the potential of mining resources on the seabed, one has to identify, test and delineate the deep sea mineral resources. To achieve this, the geographical and geological conditions need to be investigated. Different types of equipment and techniques have been developed for this investigation, which will be reviewed in the subsequent paragraphs.

Several activities and stages can be pursued in the exploration phase, also depending on the type of resources to be mined. However, these phases or exploration steps often involve the same type of technologies for different purposes. By grouping the technologies to their technical purpose (not per se exploration steps), we identify the following main activities within the exploration phase for deep sea mining.

Figure 3.1. Activities within the Exploration phase



For each of these activities, advanced technologies are used such as echo sounders, autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), water sampling equipment, video systems, and more (see Figure 3.2).

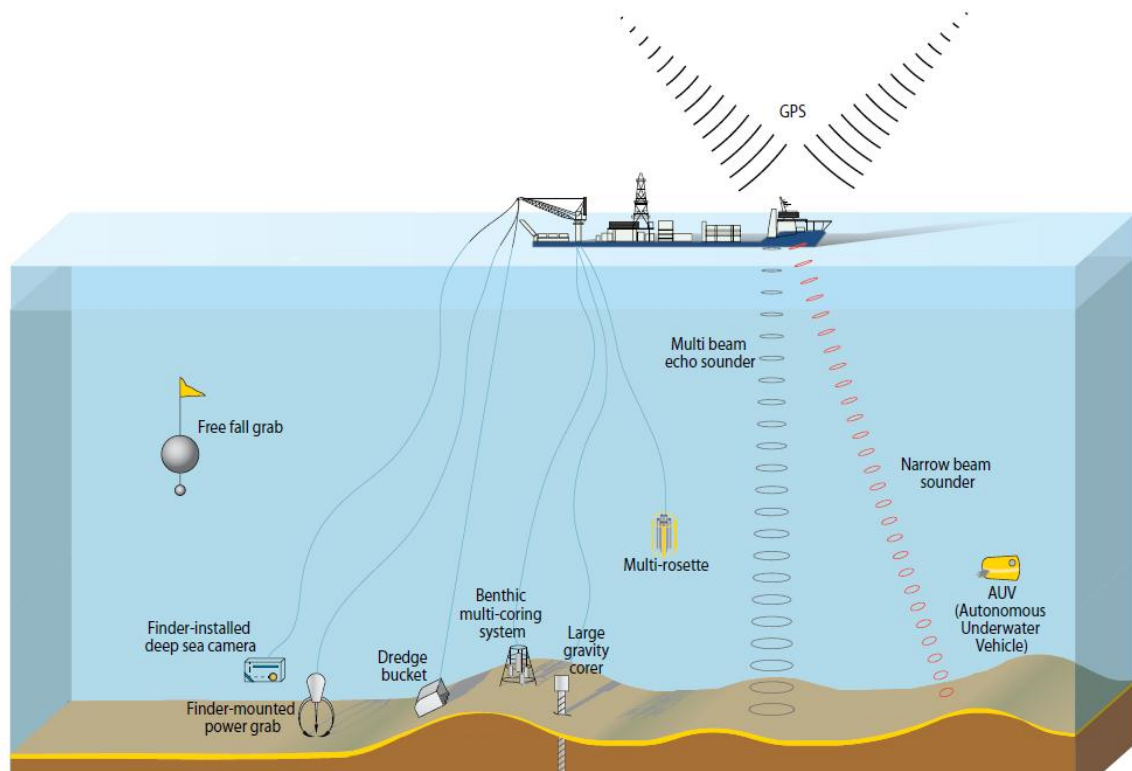
Box: Exploration strategy for Solwara 1

As an example, Nautilus Minerals Inc. aims to follow the next steps within their exploration strategy for the Solwara 1 project in the territorial waters of Papua-New Guinea:

1. Project Generation – Identify and secure title over the most prospective areas for Seafloor Massive Sulphides (SMS) mineralisation.
2. Target Generation – Identify and rank sufficient high quality targets to ensure new SMS systems can be discovered at a sufficient rate to provide continual growth options to Nautilus.
3. Target Testing – Discover new SMS systems at a sufficient rate to provide continual growth options to Nautilus.
4. Prospect Delineation – Focus resource evaluation work with mapping, sampling and geophysics.
5. Resource Evaluation – Drilling, resource estimation, metallurgical test work and environmental impact statement.

Over these steps, the locating, sampling and drilling exercises are performed at multiple stages but with different intensities and at different depths and levels of accuracy.

Figure 3.2. Examples of exploration techniques and tools



Source: SPC (2013). Deep Sea Minerals: Sea-Floor Massive Sulphides, a physical, biological, environmental, and technical review. Baker, E., and Beaudoin, Y. (Eds.) Vol. 1A, Secretariat of the Pacific Community

3.2 Technology assessment: Locating

In order to identify the locations of mineral deposits at the seafloor and to delineate these areas, several geophysical and geochemical techniques are used to map the seafloor. These methods are quite similar to those used for marine scientific purposes and the basic techniques are for most type of deposits already developed and currently in use for exploring the seafloor for both scientific and commercial purposes.

The techniques available and used for locating and mapping the seafloor are the following:

- Research vessels
- Echo sounder bathymetry (single beam, multibeam, sidescan)
- Electromagnetics
- Water-chemistry testing
- Remotely operating vehicle (ROV)
- Autonomous Underwater Vehicle (AUV)

3.2.1 Research vessels

Deep-sea exploration is facilitated through the use of modern research vessels. These vessels facilitate and host the multi-purposes research activities for exploring the seafloor. Almost all techniques used for locating, sampling and drilling require some sort of support from the research vessel.

A typical research vessel is capable of operating for a maximum of 200 days per year due to passage time, maintenance and port time. Often, these vessels are chartered out for multiple purposes, not only deep-sea research. If 30% of that time is allocated to deep-sea research then 60

scientific days per ship represents the limit of current capability, per year. Through the use of multiple autonomous vehicles and techniques at once, research time is maximized as much as possible⁵. This poses substantial equipment control requirements for these mother ships.

Literature⁶ provides the following common requirements for modern deep-sea research vessels:

- wide operation range throughout all climatic zones;
- protected deck areas with sufficient space;
- a high number of cabins for technical and scientific crew;
- a wide range of winch- and crane-based operability;
- multipurpose laboratories;
- excellent seafloor mapping and environmental sensing capabilities;
- advanced data distribution, storage and communication systems;
- dynamic positioning and navigation systems.

Figure 3.3. The Research Vessel Dorado Discovery



As an example of a dedicated research vessel for exploring polymetallic sulphides, the Dorado Discovery is shown here. Being chartered by Odyssey Marine Exploration (U.S.), this 100m x 18m vessel is exploring the seabed for SMS deposits. Odyssey provides these year-round exploration services for Neptune Minerals (US).

Source: courtesy of Odyssey Marine Exploration.

The table below provides some insights in the features and specifications of such research vessel.

Table 3.1. Features of the Dorado Discovery

Features	
Principal features	
Gross Tonnage	5099 GT
Built	Gdansk, 1997
Length	100m
Breadth	18m
Depth	7m
Accommodations	
Cabins	42 single + 6 double
TV Lounge	2
Labs	Survey, Geological, Exploration, Technical and Scientific
Other	
	Refrigerated storage of samples and cores
	Water chemistry lab
	Briefing room

⁵ EC(2007) The Deep-Sea Frontier: Science challenges for a sustainable future

⁶ EC(2007) The Deep-Sea Frontier: Science challenges for a sustainable future

Features	
	Gym
	Seafloor Drill
	Launch and Recovery System

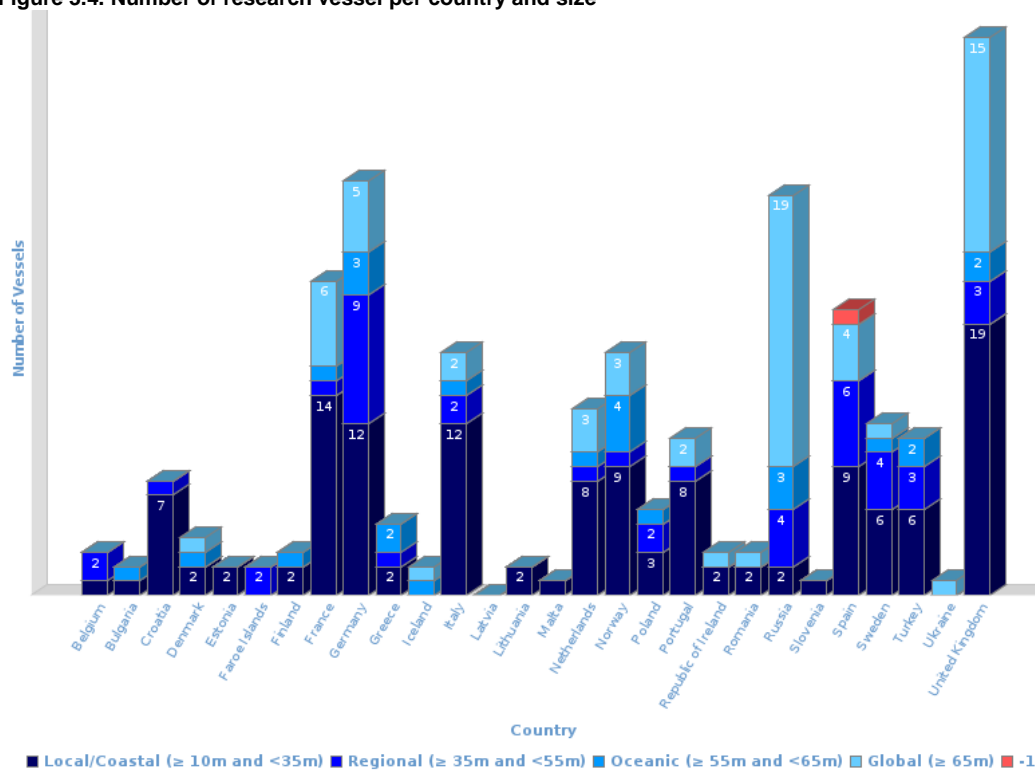
Source: Odyssey Marine Exploration

Availability/companies

Currently only a few European ships, most of them owned/operated by research institutions, meet these requirements and they need strategic replacement and improvement. Since the research fleets are operated and planned on a national level, an effort is needed on a European level to improve access, management and strategic planning of ship replacement and innovation.

Europe's research fleet is its main asset for realising the scientific goals and tasks associated with understanding deep-ocean processes. In Europe, around 260 research vessels are currently operated, of which 90 have the size for ocean and global operations. The figure below presents the vessels per country.

Figure 3.4. Number of research vessel per country and size



Source: Eurocean; European research vessels infobase

TRL

Technological Readiness Level

TRL - TRL - TRL - TRL - TRL - TRL - TRL - TRL - TRL -

1 2 3 4 5 6 7 8 9

Technical readiness level: 9, actual system proven in operational environment

Research vessels are currently in use for exploring the deeper seabed. The research technologies used on/from these vessels may however be in other stages of development, see subsequent sections.

3.2.2 Echo sounding (sonar) bathymetry

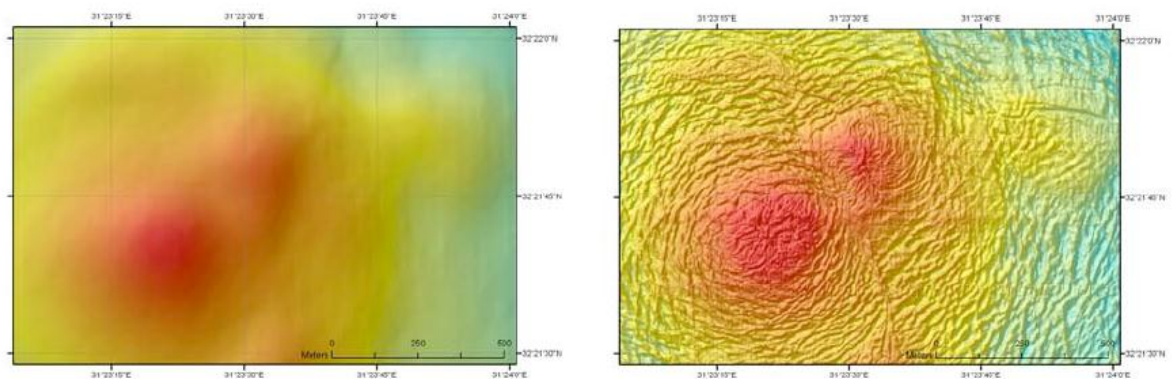
Echo sounding technologies are being used since the 1930s to investigate the topography of the ocean bottom. Echo sounders emit sound waves in a broad-angle cone and from the time interval separating the emission of a sound pulse and the reception of its echo from the seabed, the depth can be calculated. Acoustic methods are ubiquitous in marine applications, since electromagnetic radiation is rapidly attenuated in the ocean so radio waves and visible light for example, which are used extensively in air, are of little use.

In particular, three types of equipment can be distinguished:

- Single beam echo sounder
- Multibeam echo sounder
- Sidescan sonar

The single beam echo sounder sends a single acoustic signal vertically below the vessel. The signal returns local depth information. The echo is picked up by the transducer located on the hull of the vessel. The multibeam echo sounder however transmits multiple echo sounds with a different gradient to the seafloor and therefore collects info on a wider scale at either side of the vessel's track. For mapping exercises, the multibeam has therefore superseded the single beam applications. The ship-based multibeam systems are used to map shallow and deep water. However, when used on an Autonomous Underwater Vehicle (AUV), more detailed mapping can be acquired. These multibeam echo sounders make it possible to produce a map of the ocean floor on board the ship within a minute, making it possible to 'read' the topography of a strip of ocean bottom in real time. An example of the different images of the seafloor from ship-based and AUV based sonars is shown below.

Figure 3.5. Bathymetry maps of a mud volcano at 1000m depth with left: ship-based multibeam and right: AUV application.



Source: Expedition METEOR M70/2 BIONIL, ESF EUROCORES EuroMargin project MEDIFLUX, from EC(2007) *The Deep-Sea Frontier: Science challenges for a sustainable future*

The third application is the sidescan sonar. These sonar systems are best used on a 'towed' fish which is connected with the vessel. By having the sonar close to the seafloor, the angle of which the sonar hits the floor is small. This allows to identify shapes on the seabed. In addition, some information on the morphology and substrate can be gathered as well by measuring the reflectivity of the signal.

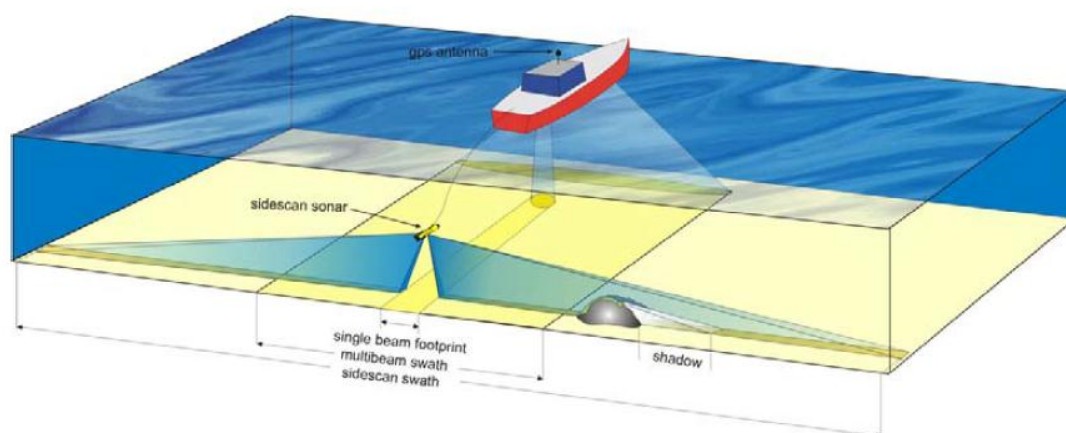
Figure 3.6. Typical side-scan sonar fish



Source: Acoustic Techniques for Seabed Classification (2005)

In order to compare the application of the three devices, the following picture can be used. It shows the mapping coverage of each of the systems.

Figure 3.7. Single beam, multibeam and sidescan coverage



Source: Acoustic Techniques for Seabed Classification (2005)

These systems help to explore and detect the presence of deposits at the seafloor. But besides that, continuous optical imagery together with precise navigation and positioning helps identifying and characterise habitat diversity and distribution as well as seafloor activity and composition. These observations are therefore crucial in order to understand the ecosystem diversity which should reduce the impact on deep-sea ecosystems.

Stage of development

The three techniques can all be used for the exploration of nodules, crusts and SMS and may work in unison. For polymetallic nodules, the first phase is involves large scale surveys where the multibeam systems can provide the bathymetric maps. On this basis, areas not suited for mining can be eliminated. The second stage involves more detailed imagery, often established through sidescan sonars.

For seafloor massive sulphides and ferromanganese crusts, the combination of ship-mounted multibeam sonars and sidescans is also sufficient for the first stage of detecting SMS sites. However, these structures are more difficult to locate and therefore AUV's are often used for providing high resolution images. For sulphides, there is distinction between active and inactive sites. So far, most exploration efforts focused on the active sites. Research is necessary to develop methods for better detection of inactive sites as well.

Company – overview

Edgetech (US)

Kongsberg (NO)
 L-3 Klein Associates (US)
 Teledyne Reson (US)
 C-MAX(UK)
 Tritech (UK)

Technology readiness level

The echo sounding systems are proven techniques already applied in the deep-sea environment.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

Technical readiness level: 9, actual system proven in operational environment

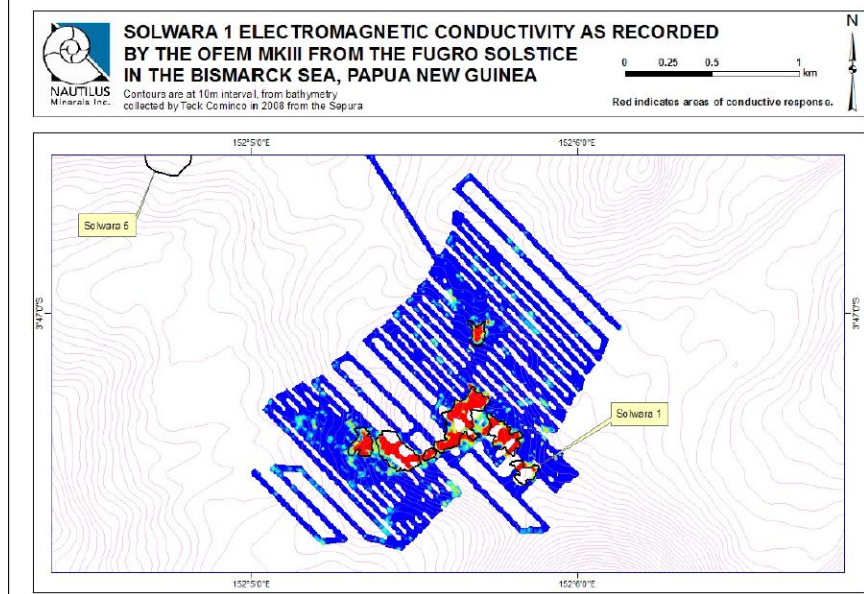
3.2.3 Electromagnetics

Offshore electromagnetic exploration technologies include: controlled-source electromagnetic (CSEM) surveying and magnetotelluric (MT) surveying.

In CSEM surveying, a powerful horizontal electromagnetic transmitter is connected to a ship with a long cable and towed about 30m above the seafloor. The transmitter source transmits a carefully designed, low-frequency electromagnetic signal into the subsurface. An array of electromagnetic seabed receivers measure the energy that has propagated through the sea and the subsurface. Data processing, post-modelling and inversion are performed to produce 3D resistivity volumes. These datasets are integrated with other subsurface information such as to enable to make important drilling decisions with greater confidence.

Within the Solwara exploration phase for SMS at PNG by Nautilus Minerals, the following type of records were made by using electromagnetics systems on the vessel Fugro Solstice.

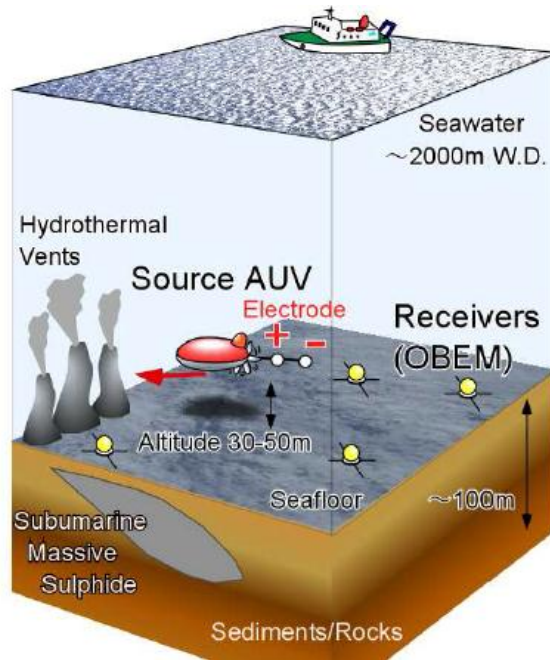
Figure 3.8 Example of electromagnetic exploration survey results for Solwara 1



Source: SRK Consulting (2010)

More recently, research efforts have been conducted to apply CSEM surveying by applying the method on AUVs for SMS exploration.

Figure 3.9 CSEM applied on AUV for SMS exploration, graphics.



Source: Goto et al. (2012) Electromagnetic survey around the seafloor massive sulphide using autonomous underwater vehicle

In a similar way to CSEM surveying, the MT technique is sensitive to resistive bodies in the subsurface. Marine MT surveys map subsurface resistivity variations by measuring naturally occurring electric and magnetic fields on the seabed. The sensitivity of receivers enables to acquire high-quality MT data inherently as part of a CSEM survey when the controlled source is inactive. The naturally occurring electric and magnetic fields are generated by the interactions of solar wind with the Earth's magnetic field, which when strong, are known as geomagnetic storms. The source fields are very low frequency, which offers excellent depth penetration.

The low-frequency, deep-sensing nature of MT surveying makes the technique excellent for mapping and interpreting regional geology. MT technology does not have the same sensitivity towards thin horizontal resistors as the CSEM technique; rather it can penetrate the thicker resistive layers that might otherwise be challenging for CSEM and seismic techniques. (Sinha et al., 1990)

Companies – overview

- EMGS(NO)
- WesternGeco (UK)
- PetroMarker(NO)

Technology readiness level

The technology has been proven as ship-mounted operation (TRL-9), for electromagnetics applied at AUVs, there has so far only been tests (TRL-7).

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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TRL 7 - system prototype demonstration in operational environment

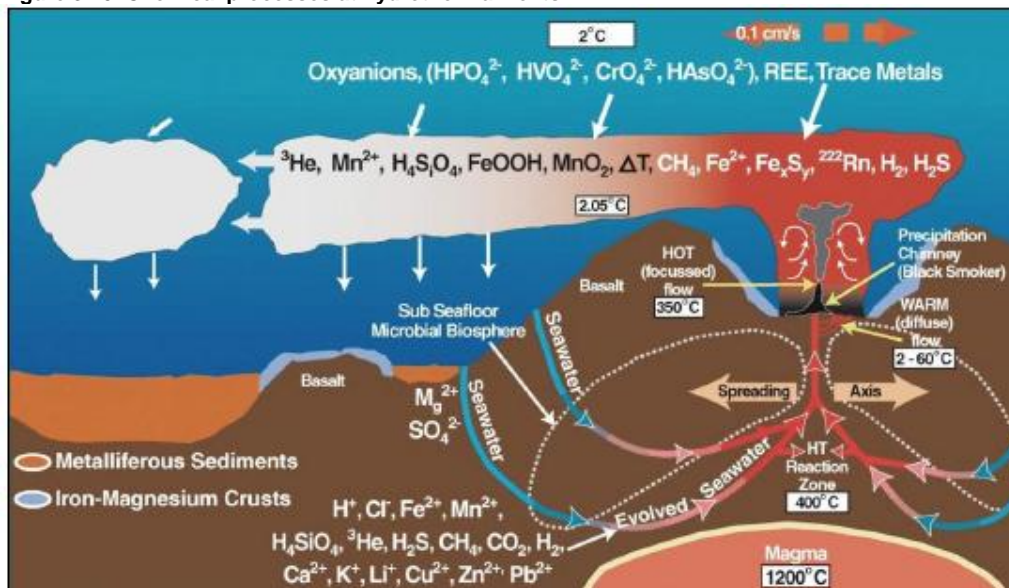
TRL 9 - actual system proven in operational environment

3.2.4 Water-chemistry testing

At hydrothermal vents near the oceanic ridges, new oceanic crusts are being formed through the divergence of two tectonic plates. At these vents, the so-called black and white smokers (metal and sulphur rich mineralised type of chimneys) react with sea water. Because of the very high temperatures of the chimneys, a chemical reaction takes place causing the metals such as copper, zinc, and iron to fall back down the seabed forming mineral deposits. These deposits are called polymetallic (massive) sulphides.

Because of these chemical processes taking place near these vents and deposits, as shown in the figure below, testing the chemical composition of the water can reveal information about the presence of such deposits.

Figure 3.10. Chemical processes at hydrothermal vents



Source: <http://www.pmel.noaa.gov/eoi/chemistry/images/plume2.gif>

At this stage of the study, we have insufficient information about the exact techniques used to test the chemical composition of the water in order to trace these hydrothermal vents.

Companies

None identified

Technology readiness level

The technologies and knowledge is so far mainly restricted to active vents, in order to trace inactive vents as well, new technologies and research is required.

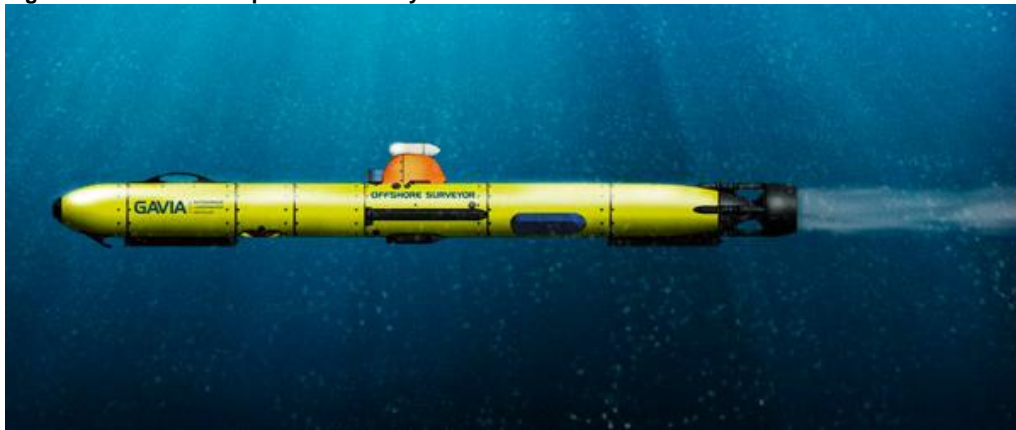
Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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3.2.5 AUV (Autonomous underwater vehicle)

AUVs are commonly used in subsea oceanographic investigations and may be deployed with a range of sensors (bathymetry, side-scan, photo/video, or other) to gather data about properties of sea water and the seabed. It does not require input from an operator.

Figure 3.11. Example of the Teledyne GAVIA AUV



Source: Teledyne Benthos

AUVs are often equipped with echo sounders and various measurement sensors, often depending on the purpose of the exploration. Some AUV's are therefore built upon several modules. Additionally, AUVs can be configured as tow-vehicles to deliver customized sensor packages to specific locations, and return to the ship after a deployment of about 20 hours.

As described earlier, AUVs are used to explore more precisely the morphology of the seafloor. High resolution images can be derived this way, compared to ship-mounted systems. Therefore, AUVs are used within the more targeted phases for exploring and determining the coverage of SMS, crusts and nodules.

Companies – overview

- Kongsberg (NO)
- Teledyne Benthos (US)
- Bluefin Robotics (US)
- International Submarine Engineering (ISE) Ltd (CAN)
- FESTO (DE)
- Evologics (DE)

Technology readiness level

AUV's are ready for deepsea usage and replace many of the ship-mounted systems. However, there is still potential for further development in software integration between different systems, applying new sensors and longer endurance and accuracy.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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TRL 9 - actual system proven in operational environment

3.2.6 ROV

To be elaborated

3.3 Technology assessment: Sampling

Identified technologies available for sampling include

- Free fall devices;
- Grab samplers;
- Cable-operated grabs and cameras.

3.3.1 Free-fall devices

To be further elaborated.

Description and stage of development

Quality/Reliability/Productivity/Maintenance

Free-fall devices can descend to the bottom, take samples and photographs and return to the surface on their own. A few kilograms of nodules can be collected from an area of 0.25 m² in each dive, and pictures covering 2-4 m² can be taken (ISA, polymetallic nodules).

Company – overview

PM

Technology readiness level

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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Tbd

3.3.2 Grab samplers

To be elaborated

Description and stage of development

Quality/Reliability/Productivity/Maintenance

Company – overview

Technology readiness level

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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3.3.3 Cable-operated grabs and cameras

To be elaborated

Description and stage of development

Quality/Reliability/Productivity/Maintenance

Company – overview

Technology readiness level

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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3.4 Technology assessment: Drilling

Also: Coring (multi coring systems) See odyssee.

- Piston corers
- Vibrocoring

To be elaborated

Description and stage of development

Quality/Reliability/Productivity/Maintenance

Company – overview

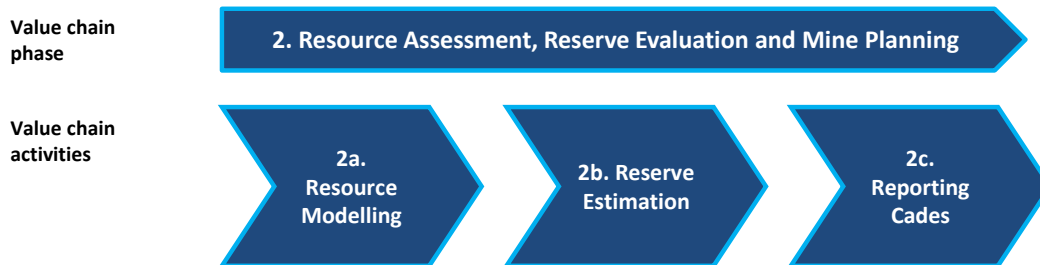
Technology readiness level

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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4 Resource Assessment, Reserve Evaluation and Mine Planning

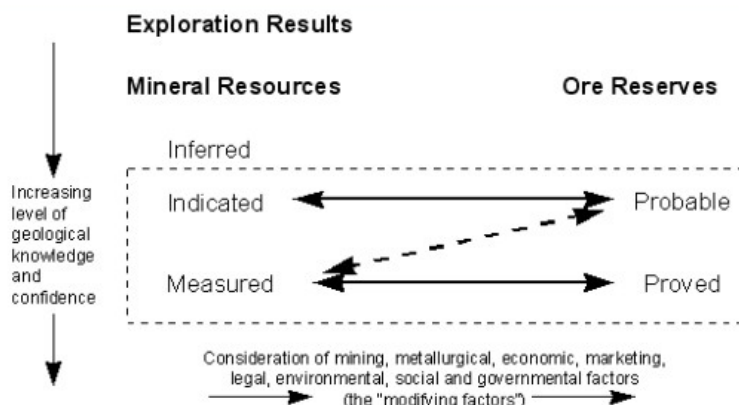
4.1 Introduction into demonstration and extraction



The phase of resource assessment, reserve evaluation and mine planning is the essential project planning phase, where exploration data are synthesized in a numerical 3D resource model and its uncertainty is assessed. Intermediate results lead to an estimate of geological in-place resources. During reserve estimation strategic-, long- and medium term mine planning decisions are derived with its associated investment and operating costs. At the feasibility level critical aspects including mining technological and metallurgical, economic, marketing, legal, environmental, social and governmental factors are assessed and a quantitative assessment of recoverable reserves.

Results of resource assessment and reserve estimation are documented and reported for stakeholders and investors according international reporting standards, e.g. the JORC code. The use of this code is standard for all conventional/terrestrial mining business cases. However the only deep sea project to have attempted this is Nautilus and only achieved inferred resources (low level of confidence).

Figure 4.1 International Reporting Standard (e.g. JORC, 2012)



4.2 Procedural Assessment: Resource Modelling

Identified potential modelling techniques include:

- 3D Geometallurgical Modelling (for polymetallic sulphides);
- 2D Multivariate Modelling (for nodules and cobalt-rich crusts).

4.2.1 3D Geometallurgical Modelling of Polymetallic Sulphides

The value carrying ore-types in polymetallic Sulphides are spatially distributed in all three dimensions. This requires a full 3D resource model capturing both the geological structure and the spatial grade distribution inside the different rock zones. To comply with International Reporting standards, modelling techniques should be designed to provide beside the local estimate as well a realistic quantitative assessment about the uncertainty in estimation.

Currently the availability of direct exploration data is not sufficient for spatial modelling. A solution is to incorporate indirect data, such as areal measured geophysical data including seismic and electric relevant properties. To further support the reliability of the models the integration of expert knowledge about the associated geological processes is necessary.

This leads to the following requirements for an integrated 3D Geometallurgical Modelling technique:

- 3D techniques modelling the spatial variability and uncertainty of geological structures;
- 3D techniques modelling the spatial variability and uncertainty of grades, extractability and processing relevant properties;
- Methods should be designed as algorithm integrating scarce direct, highly dense indirect measurements and expert knowledge about geological processes.

Stage of development

The requirements described above are not met in one consistent method. Modelling of geology based on expert knowledge is known in reservoir engineering using Multi-point statistical methods (e.g. Strebelle, 2010) or high order statistics (e.g. Dimitrakopoulos et al). Methods for simulating linear properties are state of the art and include classical sequential Gaussian simulation (Isaaks 1989) or the generalized sequential Gaussian Simulation (Benndorf and Dimitrakopoulos, 2007). Both methods are available as well for integration of secondary data (Boucher, 2009). However the computational stability and performance for the case of a large secondary data density compared to direct data has to be further evaluated. Process based modelling may be based on compositional data analysis using log ratios of data.

Further research is required to transfer these concepts to a consistent framework applicable in a deep sea environment.

Company – overview Potential: Companies for implementing Modelling Techniques in commercial software include: Geovariances (France), gOcad (France), Dessault/Geovia (UK).

Technology readiness level

TRL 3 - experimental proof of concept.

3D spatial Modelling need to be adapted to account for multiple data sources (direct and indirect) + Geometallurgy

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

4.2.2 2D Multivariate Modelling

Polymetallic nodules and cobalt rich crusts can be characterized as a 2D object with associated attributes, such as abundance, thickness or metal grades. Direct or indirect sampling techniques

are available. The data basis is evaluated as sufficient for modelling the spatial distribution and its associated uncertainty can be modelled using available techniques.

Stage of development

Techniques are already commercially available. No further development needed.

Company – overview

See 4.2.1

Technology readiness level

TRL 3 - experimental proof of concept.

3D spatial Modelling need to be adapted to account for multiple data sources (direct and indirect) + Geometallurgy.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

4.3 Procedural assessment: Reserve Estimation and Mine Planning

Utilizing 3D Resource Models, recoverable reserves need to be evaluated, processes planned on a strategic-, long-, medium and short-term basis. The actual duration of this stage depends on the complexity of the project: geometry, spatial distribution & continuity of the deposit, variation in metal content, grades, differences in processing recoveries. A proper assessment requires comprehensive resource – reserve assessment data, the formulation of a sequential mine plan, mine layout, and needs to incorporate anticipated metal recoveries versus CAPEX & OPEX. The latter also needs to incorporate marketing, legal, social and governmental factors.

4.3.1 Long-Term Deep Sea Mine Planning

For a comprehensive long-term mine planning process all boundary conditions including

- mining license area;
- mining technology;
- processing technology;
- available space for waste disposal;
- environmental impact;
- capital and operational expenditures;
- necessary permits;

need to be understood fully. The subsequent design and optimization process includes the definition of an ultimate pit, mining phases, smallest minable units and selectivity, annual production of waste and ore, annual usage of space, annual reclamation and environmental impact mitigation actions (e.g. Hustrulid and Kuchta, 2004). Based on the previous detailed studies capital and operational expenditures (CAPEX and OPEX) can be estimated on an annual basis leading to financial project performance indicators.

Stage of development

At the current state it is not possible to conduct a long-term mine planning process leading to proven reserves. In combination with resource modelling, mine planning standards for deep sea mining have to be developed and can be seen as a platform integrating all modifying factors including mining technological and metallurgical, economic, marketing, legal, environmental, social and governmental factors.

Technology readiness level

TRL 1 - basic principles observed.

Cutting method and transportation requires a new definition of SMU, losses due to current.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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4.3.2 Medium- and Short-Term Deep Sea Mine Planning

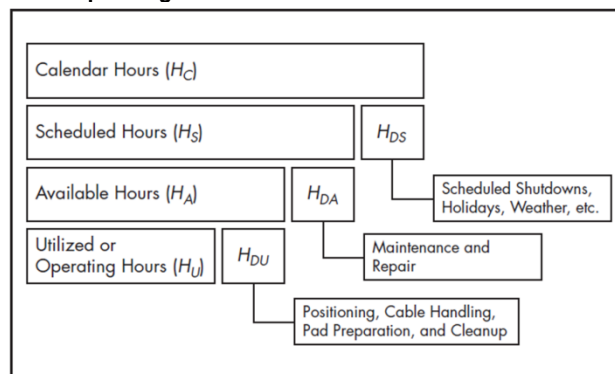
Medium and short-term mine production plan typically expands one to three years with a monthly down to a weekly resolution. It takes into account the defined development sequences, production characteristics, quantities and rates from the Life of Mine Plan. These rates are validated against production capacity constraints, for example due to planned maintenance activities. The result is a feasible mining production plan. A critical component of the short-term mine plan is the capacity.

The capacity is the product of

- effective production rate; and
- effective operating time.

The effective production rate is determined by the equipment specifications and the medium to cut or transport. The effective operation time depends on scheduled hours, technical availability, maintenance strategy and operational processes (see figure below)

Figure 4.2 Effective operating time



Stage of development

Both critical items: effective production rate and effective operating time are understood only with a very low level of confidence (+/-60%). Reasons are:

- missing understanding on cutting effectiveness in deep sea conditions (hydrostatic pressure in 4km-6km depth);
- detailed understanding of auxiliary processes for a deep sea mining operation are not understood, including:
 - site preparation;

- deep sea maintenance (scheduled and break down) and preparation: mechanical and electrical;
- operational processes such as cable handling;
- short-term sequencing, ore blending and grade control;
- options of pre-upgrading;
- direct waste material handling.

These points involve only some selected aspects to be considered. Depending on the mining system chosen further work has to be dedicated to deep sea mining system simulation to understand the available time fond. Please note that the uncertainty in time fond directly influences operational costs and is this linearly linked to uncertainty in expected cash flows.

Technology readiness level

to be developed.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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4.3.3 Comparison with land-based techniques for pre-processing

Potential resources for analogies include off-shore engineering, maintenance concepts, time fonds, operational handling experiences can be used as a prior guess for inputs in short term planning. However, the physical extraction of deep sea resources is a material ware intensive process. A large focus has to be out on deep sea maintenance strategies. Due to high investment and operating costs the system reliability is essential. Reliability centred maintenance concepts as applied for maintaining airplanes or in large continuous mining systems should be adapted and proven in a deep sea environment.

4.4 Resource/Reserve Reporting Codes

To be developed.

Insufficient knowledge on the sea bed application of reporting codes at present. Are the standard reporting codes sufficient (ie JORC) ? Do the existing codes require definition of special sections purely for Deep sea deposits (this is the case for e.g. diamonds, coal) but it is unknown if this will be required for Deep Sea Deposits.

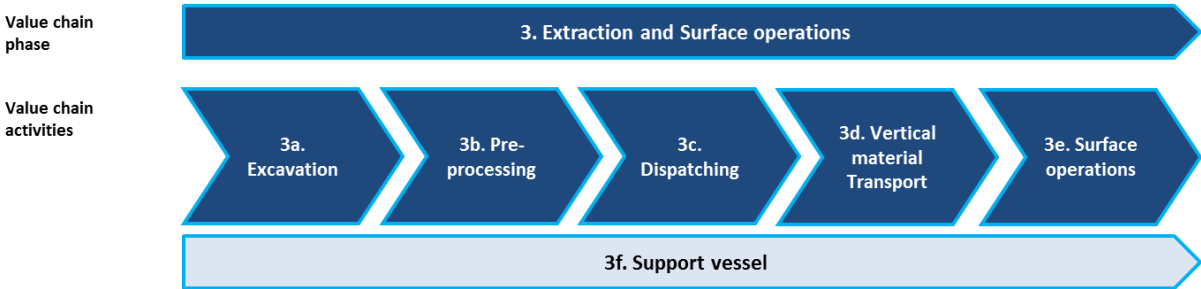
5 Extraction, lifting and surface operations

5.1 Introduction into extraction, lifting and surface operations

After resource assessment, reserve evaluation and mine planning the next phase in the value chain is excavation and materials handling. This phase covers the liberation of the minerals (excavation or collection) from the seafloor, pre-processing of the ore on the seafloor, dispatching and vertical transportation to surface and any surface operations prior to shipping of the material to shore.

Many of the techniques to be used during this phase are concepts and have not been built or tested in practice. It is noted that there has not been any large scale extraction till date so there is not market yet to share. There are no production systems: only models or “concepts”. There is no market share. For example Aker Wirth plans to implement a system in 2020 for Mn nodule extraction. Nautilus has commissioned 1 cutter. We don’t think there is public information available on state of the art in China etc.

Some techniques assume modifications of existing techniques that are being applied in terrestrial surface mining, land based mineral processing or the oil & gas industry.



5.2 Technology assessment: Excavation

Although the development of deep-sea mining excavation machinery has only resulted in a limited amount of real equipment to date, research projects were conducted over the last decades resulting in multiple conceptual excavation techniques. With the applicable excavation techniques largely depending on the ore type this section will provide an overview of these techniques accordingly.

Ores	Identified Excavation Techniques		
Polymetallic Sulphides (SMS)	Drum-cutter ROV	Rotating-cutter head ROV	ROV Clamshell grab
Polymetallic Nodules	Passive Collectors	Active Collectors	
Cobalt-rich Crusts	None to date		

5.2.1 Polymetallic Sulphides (SMS)

SMS deposits present several challenges for extraction technology. First, the ore body is comprised of a combination of loose material such as fallen chimneys, and solid fused minerals such as re-

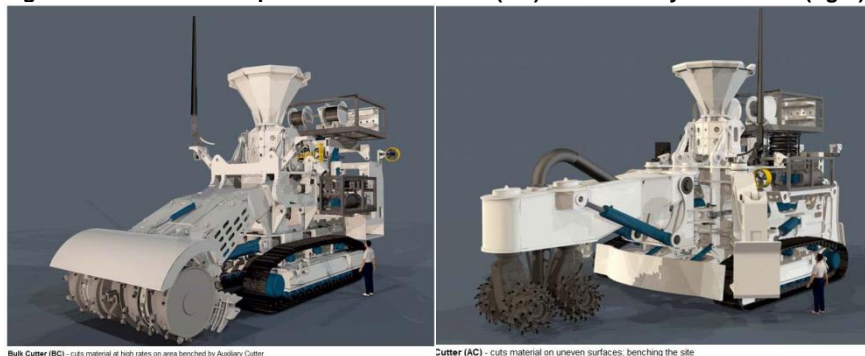
crystallized sulphides and deposition layers. Second, the seafloor terrain may be rugged due to tectonic activity⁷.

Extraction technology for the mining of Polymetallic Sulphides has been adapted from that used in deep-ocean petroleum operations, such as seabed pipe trenching operations, and from offshore placer diamond mining, the latter of which is being adapted from shelf-depth operations to deep-water operations⁸.

Polymetallic Sulphides rock has been shown to have strength properties similar to coal and as such, terrestrial coal mining techniques form the basis for the design of seafloor mining equipment⁹.

Technique: Drum-cutter ROV (+ collector)

Figure 5.1 Conceptual Drum-cutter ROV (left) and Auxiliary cutter ROV (right)



Stage of Development: conceptual/small-scale field test

An example of the drum-cutter concept is presented in Figure 5.1. Proposed by Nautilus this design is based on methods used in terrestrial coal extraction. The electrically driven ROV is fitted with a drum-cutter and is moving over the seafloor on tracks. The cutting teeth on the drum are optimized to produce particles averaging 50mm in size whilst the production of ultra fine particles is minimized.

The ROV is designed to create its own flat working surface “after one track length”. Whenever very uneven terrain is encountered a second auxiliary ROV may be required to flatten the seafloor prior to excavation with the drum-cutter ROV.

The drum cutter ROV is cutting the rock and the ore is either transported by a pump that is built into the ROV close to the cutter drum or the ore is left on the seafloor for a collector ROV that will collect the loosened ore and transports the material to the pre-processing or dispatch system on the seafloor.

Placer Dome Technical Services Ltd, a subsidiary of Barrick Gold and Nautilus Minerals Inc, conducted a technology test program in 2005 in support of the conceptual design of a subsea mining system. As part of this test program a subsea excavator was fitted with a land based rock-cutting tool to investigate the ability of such a tool to cut rock at depths of 1600m. The results of this

⁷ Herzig, P. (1999). Economic potential of sea-floor massive sulphide deposits: ancient and modern. London: Phil. Trans. R. Soc. London.

⁸ Hein et al. (2013). Deep-ocean mineral deposits as a source of critical metals for high- and green-technology applications: Comparison with land-based resources (Vol. 51). Santa Cruz: Ore Geology Reviews, Elsevier.

⁹ Jackson, E., & Clarke, D. (2007). Subsea Excavation of Seafloor Massive Sulphides. New Westminster, BC, Canada: Cellula Robotics Ltd.

research project are used in the design of subsea excavators that will be used to mine the Solwara-1 ore deposit¹⁰.

Construction of the Nautilus deep-sea excavation system started in 2007 by SMD but was put on hold in November 2012 as a result of a financing dispute between Nautilus and the state of Papua New Guinea.

Company – Overview

- SMD (Soil Machine Dynamics)
- Nautilus Minerals
- Placer Dome Technical Services Ltd. (Barrick Gold & Nautilus Minerals)
- Perry Slingsby Systems (ROV manufacturer)
- Voest Alpine (cutter/roadheader manufacturer)

The technology test program as conducted by Placer Dome Technical Services Ltd (PDTS) revealed that¹¹;

4. A land based rock-cutting tool could effectively cut the mineralized rock at ocean depths of 1600m;
5. Higher specific energies and cutting forces are required and smaller rock chippings are produced compared to dry cutting conditions;
6. Regrinding of subsea rock due to inefficient material removal from the 'rock face' is considered a main contributor to the increased specific energy. Specific energies can be reduced if the material removal becomes more effective;
7. The hydrostatic pressure at depth does not seem to be a major factor in cutting performance.

Birney¹² notes that deep-sea plumes can be caused through the production of ultra-fine particles (<10 microns) where the cutter teeth meet the rock face. The crushing force of the tooth creates the fine material as a pressure bulb is formed between the tooth and the rock. Due to the open design of the drum cutter it may be difficult to handle the ultra-fine particles and minimize plume formation. The initial tests results as obtained by PDTS are promising in terms of the application of the cutter-drum to loosen rock at the seafloor. The overall success of the technique will depend on.

The effective removal of material from the rock face and transportation into the subsequent ore handling system.

Due to the hydrostatic pressure at the seafloor ore does not fall off the rock face in the same way as in terrestrial mining. On land, after cutting the ore will immediately fall off of the rock face, as the atmospheric pressure is too low to hold the cuttings in place. Due to the pressure regime at depths of a few kilometres below sea-level, the cuttings will not fall off the rock face fast and as a result rock is being cut multiple times resulting in smaller cuttings and higher energy requirements for cutting.

The ability of the ROV to provide the necessary cutting force and power to cut the rock.

Both in terms of the weight on the cutter drum as well as power to drive the cutter drum. To increase the weight on the cutter drum requires the ROV to be very heavy. This increases the required power for the ROV to crawl over the seabed and may have a negative impact whilst driving over soft sediments (ROV may get stuck).

¹⁰ Jackson, E., & Hunter, J. (2007). Subsea Massive Sulphide Mining - Technology Test Program. Denver, CO: SME.

¹¹ Jackson, E., & Hunter, J. (2007). Subsea Massive Sulphide Mining - Technology Test Program. Denver, CO: SME.

¹² Birney et al. (2007). Potential Deep-Sea Mining of Seafloor Massive Sulfides: A Case Study in Papua New Guinea. Santa Barbara: Donald Bren School of Environmental Science & Management.

The fact that the ROV is electrically driven means that a significant power source is required to run the operation; this is especially the case if multiple excavators are being used simultaneously.

The ability to avoid the formation of ultra-fine particles during the rock cutting.

This is both an environmental as well as a technical requirement. The formation of plumes should be avoided to minimize the environmental impact to sea-life surrounding the operation. The technical issue with ultra-fine particles lies in the processing of the ore. These processes fail to efficiently separate ore from gangue once the particle size becomes too small (<10-15 microns) resulting in the devaluation of the ore.

Technology Readiness level

TRL 2 - technology concept formulated (TRL 3 - experimental proof of concept).

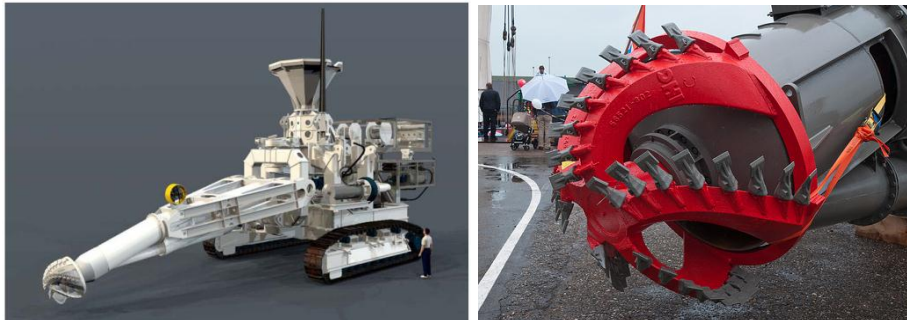
The technology concept of the cutter-drum is formulated and is based on terrestrial coal mining. An experiment was conducted with a land based cutter head mounted on an ROV at 1600m depth. However, this experiment did not consider collecting the excavated material and revealed several technical issues that need to be solved mainly with the effective cutting of the rock and removal of excavated material from the rock face. There is no record of further conducted experiments; hence the technological readiness remains at TRL-2.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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Technique: Rotating cutter head ROV

Figure 5.2 Rotating cutter head ROV (left) and cutter suction dredger cutter head (right)



Stage of Development: conceptual

The concept of this type excavation machine is based on the equipment that was originally designed for ocean diamond mining operations off the coast of Namibia (De Beers Marine) in water depths of up to 140m.

The cutter head is mounted on a flexible drill string and its design is comparable to the cutter head used on cutter suction dredgers in alluvial dredging/mining. The cutter head design draws the crushed ore towards the centre of the cutter where the lift hose opening is located.

The rotating cutter head is more flexible to navigate compared to the drum-cutter. This would allow the ROV to work on more rugged terrain compared to the drum-cutter ROV and allows to more selectively mine ore. The rotating cutter head ROV can also be used as a collector ROV that is following the drum cutter ROV.

Company – Overview

- SMD (Soil Machine Dynamics)
- Nautilus Minerals
- De Beers Group
- IHC Merwede
- Perry Slingsby Systems (ROV manufacturer)
- Voest Alpine (cutter/roadheader manufacturer)

The success of this excavation method is comparable to the success of the drum-cutter ROV in that the ROV should be able to deliver the required cutting force to crush the polymetallic sulphide rock. However, where the drum-cutter has only been successfully used on a production scale in dry terrestrial coal mining, the rotating cutter head is already applied today in wet dredging operations (cutter suction dredger) that provide a valuable source of performance data.

Birney¹³ also notes that the cutter head design may reduce pluming because the rotating cutter heads draw the ore towards a central point where the inlet towards the lift hose is located. If confirmed, this method would greatly reduce the environmental impact of deep-sea mining.

Technology readiness level

TRL 2 - technology concept formulated (TRL 3 - experimental proof of concept)

Although cutter heads are successfully applied today on cutter suction dredgers there is no record of any experiments to test the behaviour of such cutter-heads to cut SMS deposits and the behaviour at significant ocean depths. At the same time, ocean crawlers with cutter suction heads are used today for marine diamond mining in shelf environments (upto 150m depth). It can be concluded that there is some experimental proof for the concept but it should be further investigated to validate the applicability of the technique in a deep-sea environment to move to TRL-3.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

Technique: ROV Clamshell grab (+ seabed rock crusher or skip hoist system)

Figure 5.3 Clamshell grab



¹³ Birney et al. (2007). Potential Deep-Sea Mining of Seafloor Massive Sulfides: A Case Study in Papua New Guinea. Santa Barbara: Donald Bren School of Environmental Science & Management.

Stage of Development: applied in shallow depth dredge applications

Proposed by Neptune Minerals Plc this ore recovery system consists of a ROV clamshell grab that will remove the sulphide chimneys and top layer of the SMS deposit¹⁴. An A-frame on the production vessel will deploy the clamshell grab and thrusters installed on the grab allow lateral movement over the seafloor. The ROV will work together with a seabed rock-crusher that downsizes the ore between 25 – 50mm before transporting it to the vertical riser system. Because the ore is directly dumped into a seabed rock-crusher, the process is more efficient compared to existing applications of the clamshell grab in which the grab is pulled up to the support vessel to be discharged. The ability of the ROV clamshell grab to move laterally should further increase efficiency as the support vessel can remain in the same position for extended periods of time.

An alternative to the seabed rock crusher may be the use of a discontinuous skip hoist system for which the skips can be filled with ore lumps that can subsequently be lifted to surface. The benefit of such a system is that the irregular size and shape of the ore is of less concern as long as it fits into the skip.

It is believed that by removing the top layer of the SMS deposit first, prior to deploying a seabed mining system, sediment plumes are minimized. Furthermore, continuous suction on the rock crusher will minimize plume formation as a result of crushing activities.

ROV-guided clamshell grabs do exist today and are being used for dredging activities. Current bucket capacity varies between 10 and 16 m³ and must be adapted before they can be applied in deep-sea mining activities. This means that the bucket and teeth may need to be redesigned in order to better penetrate the SMS deposit and the A-frame needs to be upgraded to deal with the increased working load as a result of the increased rope length, ore inside the bucket and any other increased weight and/or associated dynamics.

Company – Overview

- Neptune Minerals Plc
- IHC Merwede

The applicability of the clamshell grab will depend on the deposit shape and size as well as the practicality of the seabed rock crusher or skip hoist system. A significant amount of loose material must be present in order for it to be worthy to deploy a clamshell grab as the grab cannot excavate material. Due to the depth below sea level of deep-sea mineral deposits it is impractical to transport single bucket loads to surface. The clamshell grab can therefore only be successfully deployed if a seabed collector is available. A rock crusher to handle the irregular ore sizes would in that case be required if the ore is to be transported through a vertical riser system. An alternative would be the use of a skip batch hoisting system for which the individual particle size may be less important.

Technology readiness level

TRL 2 - technology concept formulated

Although clamshell grabs are already deployed successfully today, the applicability of the grab in deep sea mining environments remains uncertain to date. Current applications of the clamshell grab are mainly in soft soils and gravel and the efficiency for rock collection should be investigated. Although the operating depth of the system is said to be only depending on rope length, transporting individual bucket loads to surface is not economic. Hence rock crusher or skip hoist system is an integral part of this technique and their conceptual stage make that this technique is overall conceptual.

¹⁴ Feenan, J. (2009). Seafloor Massive Sulphide Mining Concept. Offshore Technology Conference (pp. 1-11). Houston: Offshore Technology Conference.

Technological Readiness Level

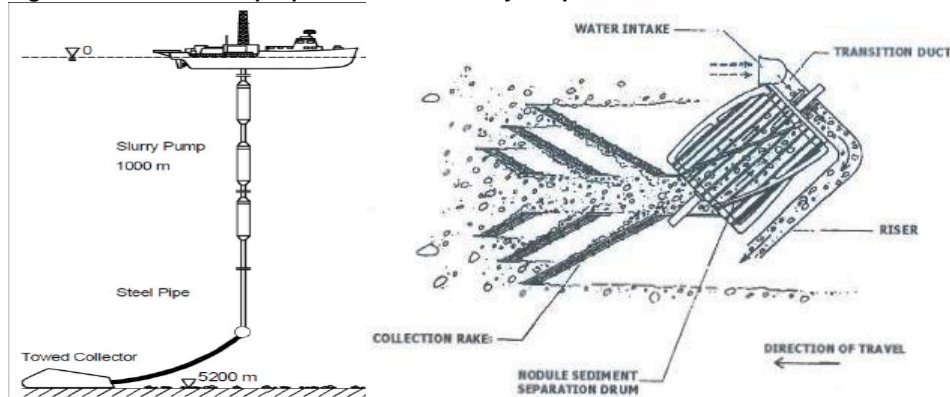
TRL - **TRL -** TRL - TRL - TRL - TRL - TRL - TRL - TRL -
1 2 3 4 5 6 7 8 9

Polymetallic Nodules

Polymetallic nodules are usually distributed on the seabed at depths of 4000 to 6000 metres (ISA, 2010). Because the polymetallic nodules are not locked into a matrix, there is no need to break the rock during excavation. The excavation equipment is therefore often referred to as collectors. Two main types of collectors have been proposed over the last decades; namely passive and active collectors. This section will introduce the both systems and sub-systems.

Technique: Passive Collectors

Figure 5.4 Example passive collector - 'Hybrid passive rake'



Source: Brockett, T. (1999). 'Nodule collector subsystem',. Workshop on Proposed Technologies for Deep Seabed Mining of Polymetallic Nodules (pp. 67-93). International Seabed Authority.

Stage of Development: largely abandoned method

Most passive collectors fulfil two functions; gathering and concentrating. The passive collector is being towed along the seabed and gathers nodules and sediments. The material is forced into an inlet and both nodules and sediment are transported vertically to the support vessel.

The positives of using passive collectors are its simple design and the fact that no additional power is required to operate. The advantages over active collectors are thus low cost and simplicity. The disadvantages of passive methods include the lack of control in quantity and quality of nodules and sediment collected, huge sediment plumes on the seafloor and a relatively large amount of sediment entering the riser system¹⁵. There is no sophisticated mechanism to separate the nodules from the sediment and passive collectors have a tendency to only accept nodules of a certain size range and leave oversized nodules on the seafloor¹⁶.

Company – Overview

Abandoned method.

Implementation of passive collectors is highly unlikely due to their inefficiency and lack of control. Technical limitations together with the environmental impact of the method (very large sediment plumes) make it unlikely for the method to be successfully applied on a commercial scale.

¹⁵ Brockett, T. (1999). 'Nodule collector subsystem',. Workshop on Proposed Technologies for Deep Seabed Mining of Polymetallic Nodules (pp. 67-93). International Seabed Authority.

¹⁶ Agarwal et al. (2012). Feasibility Study on Manganese Nodules Recovery in the Clarion-Clipperton Zone. Southampton: The Print Centre, University of Southampton.

Technology readiness level

TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

This method was tested in an operating environment and proved unsuccessful.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

Technique: Active Collectors

Active collectors require an extra power source to perform nodule collection and pre-processing functions. Both mechanical and hydraulic systems exist as well as a combination of mechanical and hydraulic systems (hybrid). The active collector systems are more complex compared to the passive collectors but are able to satisfactorily separate the nodules from the sediments before vertical transportation takes place. Another advantage of the active collectors is that the possibility exists to implement a crushing system to allow for the handling of oversized nodules.

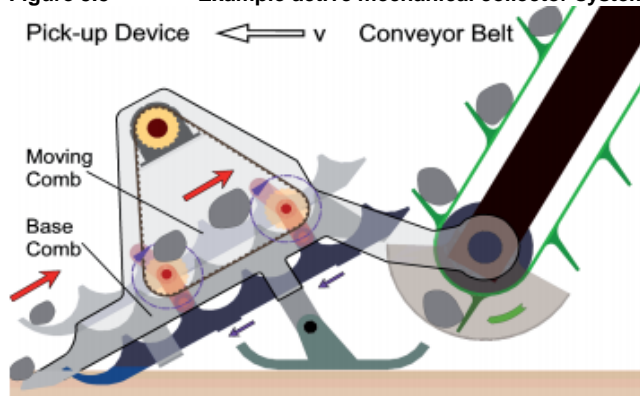
Stage of Development: conceptual/small scale field test

Mechanical systems

Mechanical systems consist of moving parts only to collect, process and transport nodules into the riser system. Figure 5.5 shows an example active mechanical system that was introduced by Schwarz¹⁷. The system consists of a moving comb mechanism that cuts layers off of the seabed. A vibrating mechanism installed at the base of the comb is used to mechanically separate the nodules from sediments. Only the nodules are transported onto a conveyor belt that feeds into an integrated crusher before entering the vertical transport system.

Due to the great number of moving parts in the collector system, the risk of mechanical breakdown is high and the systems are therefore considered less reliable than hydraulic systems that have less moving parts that can break down. Also, the power consumption of an active mechanical system is higher than a hydraulic system¹⁸.

Figure 5.5 Example active mechanical collector system.



Hydraulic systems

Considered the most popular system to collect nodules as it is more robust and reliable than mechanical systems due to the limited number of moving parts and overall less complicated nature of the system (Agarwal et al, 2012). The hydraulic system minimizes the interaction between the

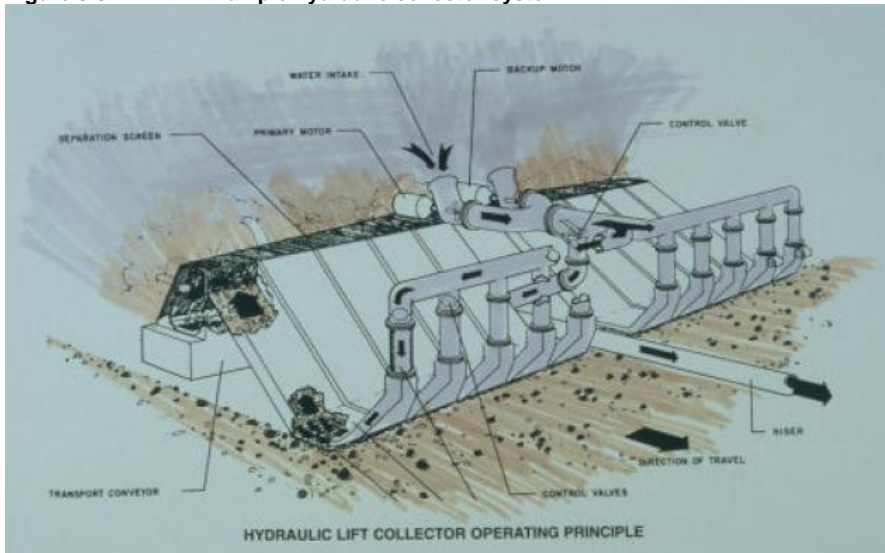
¹⁷ Schwarz, I. W. (1999). Deep sea mining - lift subsystem. Workshop on Proposed Technologies for Deep Seabed Mining.

¹⁸ Brockett, T. (1999). 'Nodule collector subsystem'. Workshop on Proposed Technologies for Deep Seabed Mining of Polymetallic Nodules (pp. 67-93). International Seabed Authority.

collector and the seabed whilst extracting nodules therefore reducing the environmental impact. Mechanical systems use moving parts to separate a layer of nodules and sediments from the seafloor whereas the hydraulic system uses spray nozzles (moving seawater) for the same process (Brockett, 1999).

An example hydraulic collector system is presented in Figure 5.6¹⁹. Compared to the mechanical collector systems, this system does not cut into the seafloor whilst harvesting nodules. Aligned nozzles on the intake produce low pressure and a scouring action to lift nodules from the seabed. Subsequently a waterjet is used to separate nodules from sediment.

Figure 5.6 Example hydraulic collector system



Source: Brockett et al. (2008). Updated Analysis of the Capital and Operating Costs of a Polymetallic Nodule Deep Ocean Mining System Developed in the 1970s. Polymetallic Nodule Mining Technology: Current Status and Challenges Ahead (pp. 54-81). Chennai: International Seabed Authority.

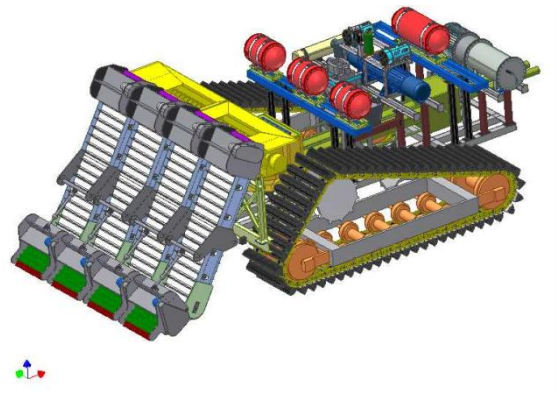
Companies

- Aker Wirth
- NIOT (National Institute of Ocean Technology, India)

Both mechanical and hydraulic methods are still under investigation and time should learn which one is the ultimate method. Both types of harvesting systems are being developed and tested at the moment such as the mechanical Underwater Mining System with Collector crusher (NIOT). A prototype of this excavator has been tested at a depth of 410m and it is planned to test it at a depth of 6000m.

Figure 5.7 Underwater Mining System with Collector crusher (NIOT)

¹⁹ Brockett et al. (2008). Updated Analysis of the Capital and Operating Costs of a Polymetallic Nodule Deep Ocean Mining System Developed in the 1970s. Polymetallic Nodule Mining Technology: Current Status and Challenges Ahead (pp. 54-81). Chennai: International Seabed Authority.



Agarwal et al.²⁰ note that overall the hydraulic system for nodule-sediments separation performs best. Hybrid systems (mechanical collector and hydraulic separator) are therefore also being considered as they combine the mechanical collection system with the effective hydraulic separation functionality.

Technology readiness level

TRL 4 - technology validated in lab (TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)).

Both mechanical and hydraulically driven collectors are being developed at the moment. Experiments have been conducted in laboratory environments and systems like the NIOT Underwater Mining System with Collector crusher have been tested at shallow depth.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.2.2 (Cobalt-rich) Ferromanganese Crusts

Ferromanganese Crusts are found at depths between 400 and 4000m below sea-level. The crusts that are found at shallower depths have a higher mineral content than the crusts found at larger depths. The thickness of crust can reach up to 250mm requiring yet another approach to excavation.

Stage of Development: limited research conducted to date

The technology that is required to mine ferromanganese crusts is more complicated than the techniques used to mine polymetallic nodules. Where polymetallic nodules are individual, relatively small units that need to be lifted and separated from the soft sediments in which they are found, the ferromanganese crusts are bonded to their substrate rock and require breaking from it (Erry et al, 2000). The texture of these crusts can vary from knobby to smoothed which can have consequences for potential mining methods.

The most important step in the mining of ferromanganese crusts is the separation of the actual crust from the substrate. If not successful, the average grades of the ore would greatly deplete. Due to the more difficult mining technique compared to the mining of nodules, no real equipment has been constructed to date although some methods have been suggested.

²⁰ Agarwal et al. (2012). Feasibility Study on Manganese Nodules Recovery in the Clarion-Clipperton Zone. Southampton: The Print Centre, University of Southampton.

The proposed method of Fe-Mn crust recovery consists of a bottom-crawling vehicle attached to a surface mining vessel by means of a hydraulic pipe lift system and an electrical umbilical. The mining machine provides its own propulsion and travels at a speed of about 20 cm/s. The miner has articulated cutters that would allow Fe-Mn crusts to be fragmented while minimizing the amount of substrate rock collected²¹.

Other suggestions are to use a continuous line bucket system in areas where crusts are only loosely attached to the substrate, water jet stripping of crusts, in-situ leaching and heavy-duty rollers to crush the crusts.

The likelihood of implementation of crust-mining in the near future is low. The required techniques to effectively separate crust from substrate rock are not available yet and are key to the success of crust mining. Without correct separation of the crust from the substrate on the seafloor, ore grades would greatly deplete. A difficulty with correct separation is that crust is found on uneven surfaces. Mining without dilution means that the working surface remains uneven. It is difficult to design equipment for such surfaces (Nautilus, 2004).

Another limitation to the development of crust-mining techniques is the nature of crust-type deposits. Known crust deposits are thin compared to for instance SMS deposits (40mm vs. 15-20m average thickness). This means that 2Mt of crust covers an average surface area of 16 square kilometres whereas the same sized SMS deposit would cover a surface area of only 200 square meters (Nautilus Minerals Ltd, 2004). This has significant implications for both economical extraction and environmental impact and makes crust mining unlikely at the current knowledge state.

Technology readiness level

TRL 1 - basic principles observed

No real concepts have been developed for crust mining so far. The basic principle as to what the equipment should be capable to do (separate the thin ore layer from the rock substrate) has been observed but has not yet resulted in real excavation techniques. It is unlikely that this will change in the near future due to the limited thickness and hence very large mining operation surface are as well as very large environmental impact.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.3 Technology assessment: Pre-processing

Research projects on deep sea deposits has focused on the following subsequent mining steps:

1. Excavating/Cutting of the deposit and associated sediments;
2. Vertical transport of both the ore and sediments to the support vessel;
3. Separation of SMS ore from associated sediments and disposal of sediments;
4. Transportation of ore to shore for further processing.

From this existing strategy it can be concluded that pre-processing of excavated material prior to vertical transportation could significantly increase the value of the mined material. Less 'waste material' in the material flow means decreased vertical transportation costs per tonne of ore.

²¹ Erry, B. J. (2000). SEABED MINING: A technical review. Greenpeace. Greenpeace Research Laboratory.

Furthermore the environmental impact of the mining operation is reduced, as less tailings will have to be disposed from the vessel, which could result in disruption of the environment at various water depths.

Some initial attempts haven been made in the mining process of polymetallic nodules. The nodules are collected from the seafloor and separated from sediments mechanically or hydraulically. This reduces the material flow to the support vessel/platform and at the same time increases the value of the material since the average grade of the material that is shipped to shore is increased.

It can be concluded that the higher the average grade of the ore and as early in the production process, the higher the value of the mining operation and the more profit can be made. By pre-processing of the ore on the seafloor or on-board the vessel/platform prior to shipping, we can increase the average grade.

This section will introduce several ideas as to how to increase the average metal grades in the ore stream. These concepts can be subdivided into Identification, Separation, Sizing and Concentration processes and are discussed accordingly.

5.3.1 Identification

Sensors

Location: seafloor

The excavator ROV should be equipped with sensors, camera equipment and sonar in order to rapidly identify the material that is to be excavated. It is likely that the visibility within the mining area will be limited as a result of sediment being lifted from the seafloor, hence identification equipment such as sonar, electro magnetic tools is required. Identification of ore and waste will determine the decision to mine the area or leave the waste behind. These sensor-based observations can be improved by continuous sampling of the excavated material.

Sampling

Location: seafloor

By sampling of the excavated material it is possible to get a 'real-time' quality map of the exposed seabed (with some processing delay). The real-time data can be used as a decision tool as to mine the material or not. It may also be used to determine an appropriate excavation order or combination of several mining areas in order to obtain a certain average grade in the ore stream. Sample analysis will have to take place at the excavator because it is impossible to retrace the source of excavated material once it reaches the surface.

Alternatively, a separate auxiliary ROV could be deployed to sample large areas before mining commences. This will significantly increase the excavator availability as it is not required to stop excavating whilst the sample is analysed.

The ability of the sea floor excavator to identify ore from waste in a low visibility environment is a necessity in the success of a subsea mining operation. Continuous measurement of ore grades is common practice in terrestrial mines and is required for appropriate mine planning and scheduling. Implementing these techniques is therefore a necessity.

Technology readiness level

TRL 4 - technology validated in lab / TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).

Techniques for identification in subsea environments do exist and are already being used in ocean floor exploration. As such it should be relatively easy to install these systems to identify ore zones from waste zones. In situ grade measuring tools using XRF/XRD do exist and should also be relatively easy to implement in an ROV.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.3.2 *Separation*

Ore/loose sediments separation

Location: seafloor / (surface)

As a first processing step the ore needs to be separated from the loose sediments that may have been excavated together with the ore and sucked into the collector. Already proposed for the mining of polymetallic nodules the separation of ore and sediments can be applied in the mining process of other deep-sea deposits and already takes place at the seafloor. This reduces the dilution in the ore stream before expensive vertical transportation or shipping to shore takes place. To remove the fine sediments from the ore stream one can think of using screens or hydro cyclones.

Separation of ore and sediments on the seabed has been tested for polymetallic nodules mining and is necessary to avoid excessive ore dilution. Besides diluting the ore, sediments transported to surface in the ore stream need to be separated and transported back to the seafloor, which increases operating expenses. Finally, too much fines in the riser system increases the risk of clogging up the riser pipe and could shut down the whole operation.

Technology readiness level

TRL 3 - experimental proof of concept.

Experiments with the separation of nodules and sediments at the seafloor have been conducted and proved successful.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.3.3 *Size reduction*

Crushing

Location: seafloor / surface

With the loose sediments removed from the ore stream crushing is required before further separation of ore and waste is possible. As the valuable minerals may be present as concentrations in a matrix of 'waste' material (no value), they have to be physically separated before further upgrading of the ore stream can take place. A first step to reduce the particle size and liberate the minerals from the matrix is crushing of the rock. The resulting particles can either be pieces of mineral or pieces of matrix or a combination of the two. These particles need to be separated further.

Size reduction (crushing) is an essential process step prior to concentration.

Technology readiness level

Seafloor: TRL - 2: No sea floor crusher system has been developed to date, it is still conceptual.

Surface: TRL - 9: Applied in day-to-day terrestrial mining operations. No problems to be expected when implemented on board a production support vessel/platform.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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5.3.4 Concentration

Gravity concentration

Location: seafloor / surface

The crushed particles that consist of mineral, matrix or a combination of the two can be separated by gravity concentration (e.g. hydro cyclone). Although this method has been successfully applied in terrestrial mineral processing applications it should be investigated whether it can actually be applied in a wet seafloor setting using seawater.

Magnetic concentration

Location: (seafloor) / surface

Depending on the ore being mined magnetic separation may be a viable option as well (assuming that the valuable material is magnetic). However, most sulphides are non-magnetic leaving the method only applicable to ferromanganese crusts. Sulphide ores can be separated from waste material by use of high-gradient magnetic separators but this method requires high energy.

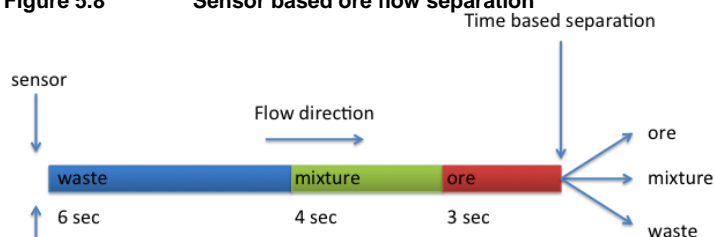
Sensor based sorting

Location: seafloor / surface

Based on for example XRF, sensor based sorting can separate mineral rich rock from waste material in a dry environment (although the material feed is allowed to be moist) and these methods can be applied on board a platform or vessel.

Similar techniques can be applied to slurries in order to separate ore from waste for example on the seafloor. The technique is time based and analyses flow in a tube. By measuring the time it takes for sections of ore and waste to pass they can be separated into an ore flow, a waste flow and a mixture.

Figure 5.8 Sensor based ore flow separation



All of the methods for mineral concentration mentioned above are proven techniques that are being used in terrestrial mining operations. The goal of these methods is to upgrade the ore stream before it is fed into the processing plant where the ore is grinded to liberate the minerals for subsequent flotation or leaching. In situations where such a processing plant is situated on-shore, it can be beneficial to pre-process the ore at the mine-site to increase the value of the shipped product. For instance ferromanganese crusts, require pre-processing and concentrating due to the substrate rock that is heavily diluting the ore stream.

Technology readiness level

Surface: TRL – 9: Pre-processing steps to concentrate the ore stream are applied in terrestrial mining operations today and performing these operations on a production support vessel/platform should not be a problem.

Seafloor: TRL – 1: None of the concentration steps mentioned above have been tested in deep-sea environments. All conceptual studies to date do not consider concentration of the ore flow on the seabed.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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5.4 Technology assessment: Stock & Dispatch systems

After excavation, the broken ore needs to be transported to surface. In order to retain a stable and efficient flow of material in the vertical transportation system it may be necessary to temporarily stock the excavated material on the seabed. Depending on the excavation method, and if a certain particle size is required in the vertical transportation system, it may be necessary to crush the ore to a suitable size range.

Ultimately, the goal is to have a continuous flow of material whilst the vertical transportation system is running in order to keep the process as cost efficient as possible. Also, in case a more advanced processing plant is installed on board the support vessel/platform, this processing plant will require a continuous ore feed at a certain head grade to run efficiently. This can be achieved by creating multiple seafloor stockpiles of different grade that can be blended to retain a continuous flow of ore with a relatively constant head grade. Creating a large stockpile at surface seems unlikely due to the limited space available on board a production support vessel or platform.

Various technologies have been proposed and are partially similar to terrestrial mining techniques. Nautilus has proposed the use of an excavator ROV that excavates the rock and leaves it on the seabed, combined with a collector ROV that collects the broken ore and ensures a continuous slurry flow to the vertical transportation system. Other options involve multiple excavators that feed a seabed stockpile from which the ore is subsequently transported to surface.

For relatively small-scale operations it may not be economically and/or technically viable to use continuous transportation systems like airlift or hydraulic pumps. Under such circumstances it may be beneficial to use a discontinuous batch transport technique comparable to terrestrial underground shaft-type mine operations. Buckets are filled on the seafloor and are cable-lifted to the production support vessel/platform. Advantages of this method are its simplicity and the fact that the transport system is only activated when ore needs to be transported. Furthermore, the size ranges of the ore lumps is less important compared to hydraulic or airlift systems.

As mining is expected to progress at a fluctuating rate of production, some sort of stock and dispatch system will be required on the seafloor. Either it being stockpiling before transportation via a continuous riser system or batch transportation using a skip hoist system. The other purpose of stockpiling (retaining a constant head grade) is important if an advanced processing plant is available on board the vessel/platform.

Technology readiness level

TRL 1 - basic principles observed (TRL 2 - technology concept formulated)

Several ideas have been proposed but a properly developed concept was not found in publically available literature besides the concept of an excavator ROV and collector ROV by Nautilus Minerals. This is a major knowledge gap in the development of a subsea mining system.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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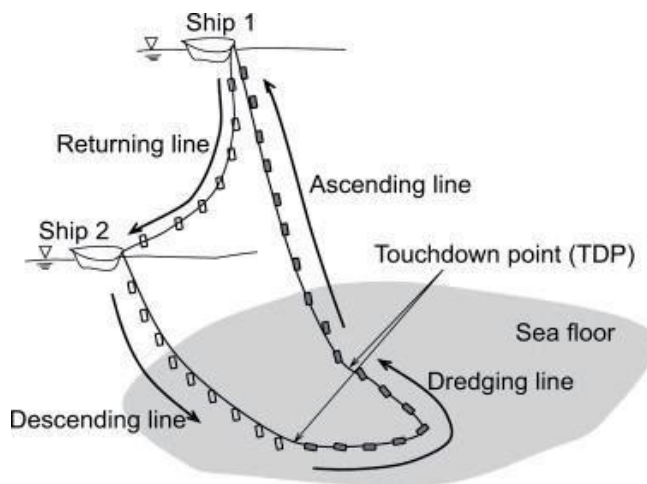
5.5 Technology assessment: Vertical transportation

Vertical transportation of excavated ore is a critical step in the mining sequence of deep-sea mineral deposits. Vertical transport is the vertical transportation of an ore from the seabed to surface for further processing on board the production support vessel/platform. Both mechanical transportation methods (Continuous Line Bucket, Batch cable-lifting) and slurry-based methods (air lift, hydraulic pump) have been proposed to bring the ore to surface (bucket system only for nodules). The production efficiency of the vertical transportation system depends on several components such as particle concentration in the slurry, riser friction factor and/or chosen lifting system²².

5.5.1 Technique: Continuous Line Bucket

Stage of Development

This system consists of buckets that are connected to a continuous line. The line is being towed across the seabed whilst the buckets collect loose material. The continuous line is dragged via two ships that are connected to the ends of the line. The separation between the ships determines the sweep area. A syndicate of 30 companies in Japan first tested the method in 1972. Some nodules were picked up but the method was abandoned after entanglements of the bucket line.



Company – Overview

None - discontinued

The main disadvantages of the continuous line bucket system are the lack of manoeuvrability, lack of production control and heavy plume formation²³. Also the cutting power of the system is low

²² Agarwal et al. (2012). Feasibility Study on Manganese Nodules Recovery in the Clarion-Clipperton Zone. Southampton: The Print Centre, University of Southampton.

²³ Agarwal et al. (2012). Feasibility Study on Manganese Nodules Recovery in the Clarion-Clipperton Zone. Southampton: The Print Centre, University of Southampton.

making it impossible to 'excavate' material. The inefficient ore collection system together with the environmental implications of the method make that the likelihood of implementation of this method is low.

Technology readiness level

TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).

This method was tested in an operating environment and proved unsuccessful.

Technological Readiness Level

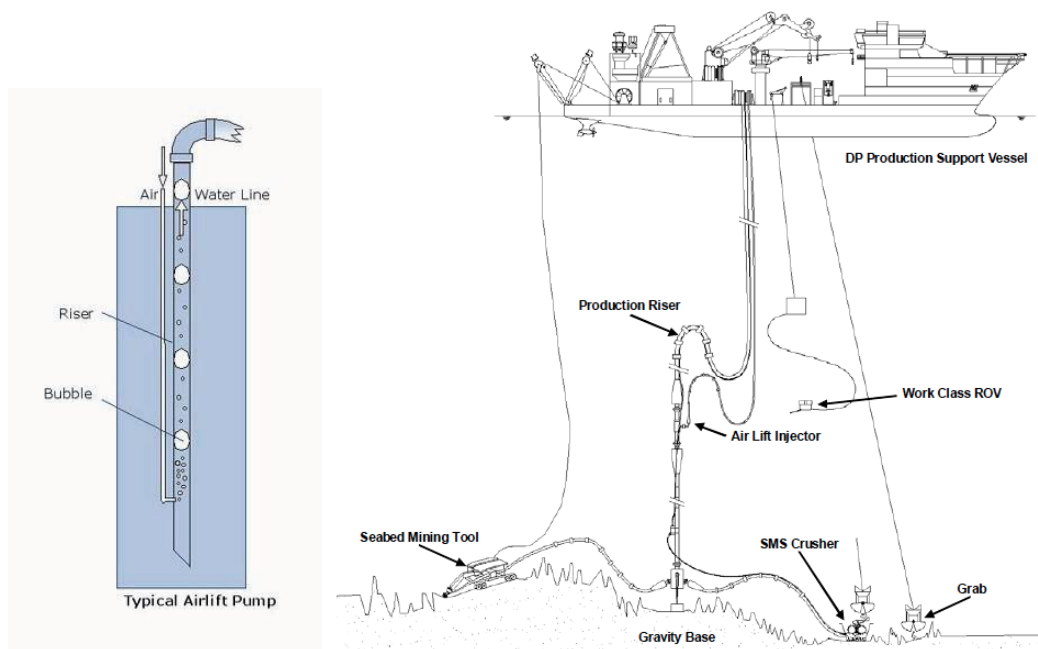
TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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5.5.2 Technique: Air Lift System

Stage of Development

Airlift systems are three-phase flow systems based on the injection of compressed air into the riser pipe at intermediate depth. By injecting compressed air, the density of the slurry water above the injection point reduces and displaces the hydrostatic pressure equilibrium. As a result a vertical flow of water is induced towards the surface that can lift the ore to the surface production vessel^{24 25}. The technique has been used in the past on a pilot-scale to dredge polymetallic nodules from a depth of 15.000 ft (~4.500 m).

Figure 5.9 Air lift system



Company – Overview

- Aker Wirth

²⁴ Brockett, T. (1999). 'Nodule collector subsystem'. Workshop on Proposed Technologies for Deep Seabed Mining of Polymetallic Nodules (pp. 67-93). International Seabed Authority.

²⁵ Feenan, J. (2009). Seafloor Massive Sulphide Mining Concept. Offshore Technology Conference (pp. 1-11). Houston: Offshore Technology Conference.

- IHC Merwede

The airlift system is a simple system but has several disadvantages. In order to send air down to depths of thousands of meters below sea level requires very high power. The mechanism is also very vulnerable to clogging²⁶. Given that a solution to the clogging problem is found, the energy requirements are likely to limit the application of the technique to shallower depths. For deposits at large ocean depths the airlift method has been largely surpassed by the hydraulic lift system. This method requires less energy.

Technology readiness level

TRL 5 - technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

The airlift system is a proven method to transport slurry in a vertical riser pipe. The method is applied in dredging operations within limited water depth environments. The method has been validated in transportation of nodules from an ocean depth of 15.000ft. in a pilot test but the method is now largely replaced by hydraulic pump systems in conceptual deep sea mining studies. This is a result of the development and successful application of such pumps in deep-sea oil and gas drilling.

Technological Readiness Level

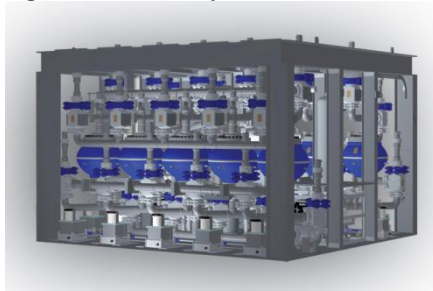
TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.5.3 Technique: Hydraulic Pump System

Stage of Development:

Hydraulic lift systems are considered simple and reliable and have a high lifting capacity. The required systems already exist as the same hydraulic pumps are currently applied in deep-ocean drilling of oil and gas wells. During these drilling operations, slurry (drill cuttings and drill-fluids) is transported to surface whereas in deep-sea mining applications it is the excavated ore that is being transported. An example existing hydraulic pump is the Hydriil Pressure Control Subsea Pump by GE (Figure 5.10) that is capable of transporting particles up to 50mm in diameter.

Figure 5.10 Hydriil Pressure Control Subsea Pump.



Source: General Electric, 2011

This hydraulic pump system is part of the conceptual mining plan of Nautilus minerals in which several excavators are extracting the ore from the seafloor to provide a continuous ore flow to the hydraulic pump system and up to the production support vessel (Figure 5.12).

²⁶ Agarwal et al. (2012). Feasibility Study on Manganese Nodules Recovery in the Clarion-Clipperton Zone. Southampton: The Print Centre, University of Southampton.

A first prototype of the subsea hydraulic pump system was built and successfully tested during test drilling in the Gulf of Mexico (SRK study Solwara 1, 2010). Instead of placing electrically driven pumps at the seafloor, the system was redesigned to be powered by seawater supplied from surface through a conduit to the pump located on the seafloor.

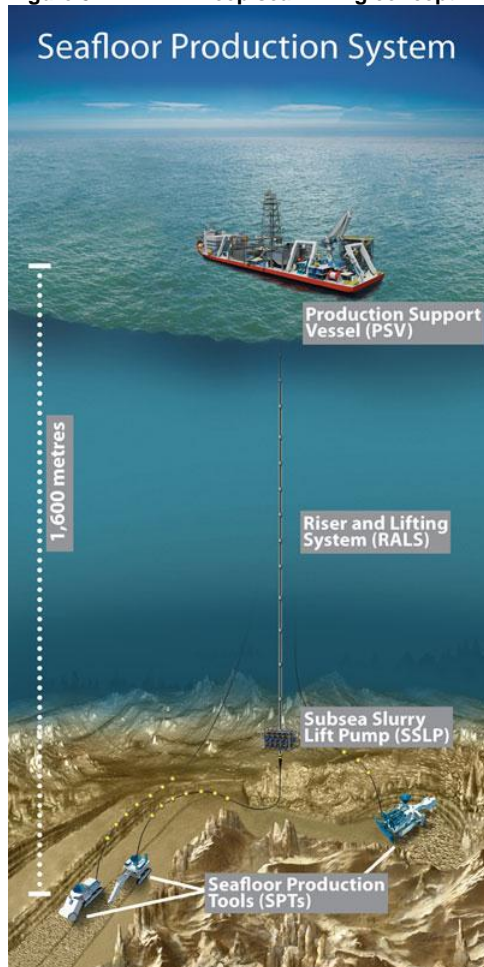
The benefit of using such a system is that all the power-generating components are located at the surface and thus, in case of failure, can be repaired without having to pull the subsea portion of the pumping system. A backup pump can be installed to allow continued production in case of maintenance or breakdowns.

Figure 5.11 Typical offshore drilling riser pipe system



Source: SRK, 2010

Figure 5.12 Deep sea mining concept



Source: Nautilus Minerals Ltd, 2014

Company – Overview

- GE Oil and Gas

Because the hydraulic pump system is already successfully applied in deep water oil and gas well drilling, the method seems promising for deep sea mining applications. Although the two applications for the hydraulic pump system seem similar, some differences should be investigated. Drill cuttings are more uniform in shape and size compared to ore lumps coming from deep-sea mining operations. This may result in different behaviour of the slurry in the riser pipe. Furthermore, when drilling an oil well, cuttings are only transported through the system for a limited amount of time after which only fluids (oil) will travel through the system. In deep sea mining applications the wear on the system is likely to be much higher due to the continuous transportation of sharp angled, abrasive ore particles.

Experiments and pilot tests should really indicate the direct compatibility of the system with deep-sea mining applications.

Technology readiness level

TRL 3 - experimental proof of concept.

The similarity of the conceptual riser system with systems currently applied in deep-sea oil and gas drilling make this system promising for deep sea mining. The system is capable to transport rock cuttings as slurry over large vertical distances of several kilometres and this can be seen as an experimental proof of concept. However, with the technology concept defined, the behaviour of the system should be investigated in a series of experiments and field tests.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.5.4 Technique: Batch cable-lifting

Stage of Development: conceptual

Siemag investigated this lifting technique for Nautilus Minerals²⁷. Siemag is specialized in the development of underground hoisting systems in terrestrial mining applications and has proposed a subsea lift system that can operate at a depth of up to 2000 metre below sea level. The system will hoist 100t skips and has a production rate of 400tonnes per hour.

The cable lifting system is very simple compared to the hydraulic and airlift systems that were discussed previously. The system does not require large pumps to transport the material from the seabed to surface and the batch type operation makes that it is cheaper to operate.

The overall likelihood of implementation of this system will largely depend on the size of the mining operation and the depth of the deposit below sea level. The system proposed by SIEMAG has a hoisting speed of 1.8m/s whereas in terrestrial applications speeds can be up to 10 times faster. The hoisting speed is therefore an important bottleneck for this method.

The excavation and lifting system together should be able to provide a steady supply to the processing/dewatering plant on board the production support vessel/platform. In order to achieve this it may be necessary to retain a small stockpile on-board the vessel/platform.

Company – Overview

- Siemag

²⁷ Heydon, D. (2004). Exploration for and Pre-feasibility of mining Polymetallic Sulphides - a commercial case study. ISA workshop September 2004. ISA.

Technology readiness level

TRL 2 - technology concept formulated,

The technological concept for a batch-lifting system has resulted in a proposal by Siemag but no evidence of experiments or field tests was found in technical literature. The technique should however be relatively simple to apply and if one can lower/lift a heavy ROV to/from the seafloor the transportation of large skips filled with material should also be relatively simple. Experimental modelling and field tests of such a system should identify whether it can be used effectively (technical and economic) and identify potential issues with the technique.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.6 Technology Assessment: Surface Operations

Once the ore is transported on to the production support vessel/platform several subsequent upgrading options are available prior to shipping of the ore:

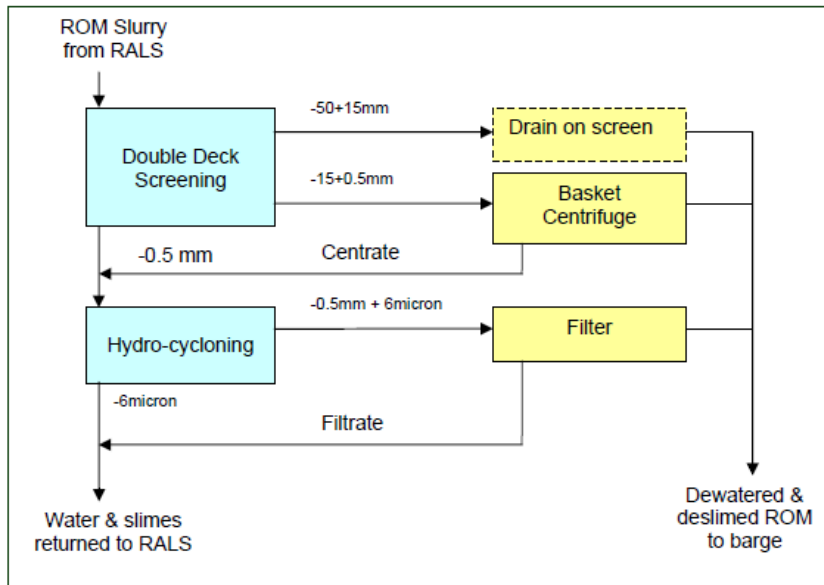
- 1 - Dewatering => Shipping of raw product
- 2 - Dewatering + Concentrating => Shipping of ore concentrate
- 3 - Dewatering + Concentrating + Metallurgical Processing => Shipping of final product

5.6.1 Technique: Dewatering

Dewatering is the first and simplest method to upgrade the value of the ore. Whilst an increased value of the material being shipped is a key result of the process the main reason for dewatering is to obtain a product below the transportable moisture limit (TML). Whenever the moisture content of the ore is too high, there is a risk of liquefaction, which is very dangerous and can result in the sinking of transport vessels.

A conceptual dewatering plant for the Nautilus Solwara-1 project was described by Ausenco Minerals and included in the SRK Production System Definition and Cost Study report (2010). In the dewatering process, coarse size fractions are removed first by screening. The fine fractions are expected to meet the TML for shuttle barges (<8-9%).

Figure 5.13 Dewatering Plant



Source: Ausenco Minerals

This is a necessary step in the mining of deep sea minerals. Without proper dewatering of the mined material it is impossible to ship it. The dewatering plant does not include any process steps to separate ore from loose sediments that may have been transported to surface together with the ore. Depending on the amount of sediments in the ROM slurry it may be worthwhile to include a ore/sediment separation step in the flow sheet prior to dewatering.

Technology readiness level

TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).

Dewatering plants are well known and to install such a plant on board a seagoing vessel or platform should not lead to any complications.

Technological Readiness Level

TRL - 1 TRL - 2 TRL - 3 TRL - 4 TRL - 5 TRL - 6 TRL - 7 TRL - 8 **TRL - 9**

5.6.2 Technique: Dewatering + Concentrating

Simple dewatering and subsequent shipping of the raw material on board a vessel is the primary method being considered in scoping/feasibility studies to date. Main reasons for this method are processing plant costs and environmental impact.

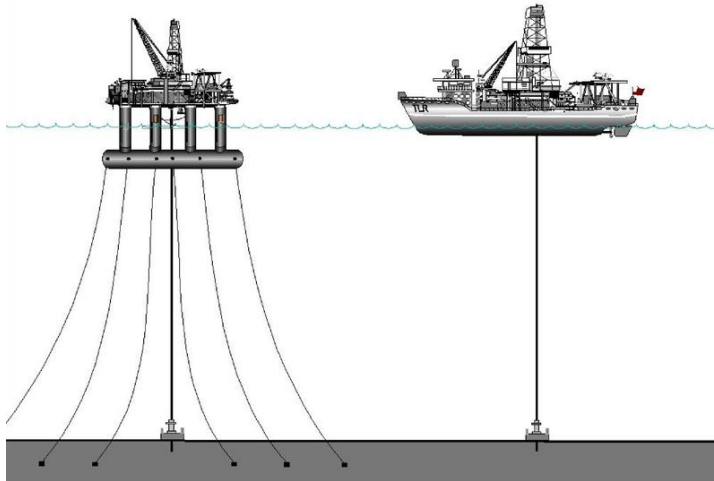
The development a floating concentrating plant requires large capital investments. In order to offset these investments a significant mineral reserve should be available (high revenue). Existing mineral resource knowledge is too little to justify the investment in a floating concentrating plant.

Furthermore, the environmental impact of concentrating at sea is not properly understood. The concentrating of minerals will inevitably result in tailings (waste material) that have to be disposed. Legislation on tailings disposal will determine whether concentrating at sea is a viable option.

Other reasons for not processing the ore at sea are the limited space on board a vessel and the wave-ship interaction that would prohibit the use of certain terrestrial processing methods such as froth flotation or spiral concentrators. A solution to these technical problems may be found in the

offshore oil & gas industry where semi-submersible platforms have been used for decades to operate in continuously increasing water depths and provide considerably more space for processing equipment. These platforms are especially designed to remain stable and are very seaworthy making concentrating or even producing a final product prior to shipping technically a more viable option given the required electrical power for such a plant can be provided. The potential processing and mineral extraction techniques and equipment are discussed in more detail in the respective chapter of this report.

Figure 5.14 **Deep-water Semi-submersible and Drillship**



There is definitely potential in concentrating ore at sea, the main advantage being the increased value of the material that is shipped to shore. The large capital investment that is required to develop a vessel/platform based concentrating facility can only be offset if there is a large amount of ore to be processed (large mineral reserve). Finally, impact of disposing processing tailings should be investigated in an environmental impact study.

Technology readiness level

TRL 3 - experimental proof of concept.

No record of vessel/platform based concentrating was found but the concentration principles are known from terrestrial mineral processing operations and some experiments have been conducted to prove their applicability in the concentrating of deep sea ores.

Technological Readiness Level

TRL - 1	TRL - 2	TRL - 3	TRL - 4	TRL - 5	TRL - 6	TRL - 7	TRL - 8	TRL - 9
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5.6.3 Technique: Dewatering + Concentrating + Metallurgical Processing

A third option is the dewatering, concentrating and subsequent metallurgical processing of the ore at sea. However, this seems highly unlikely due to the massive space and energy requirements for such a combined concentrating and metallurgical processing facility. No attempts have been made to design such a floating metallurgical processing plant.

Due to the massive space and power requirements for a concentrating and metallurgical processing facility, this technique is highly unlikely. Furthermore, the concentrate feed of a single processing plant is unlikely to be large enough to efficiently run a metallurgical plant.

Technology readiness level

TRL 1 - basic principles observed

The necessary metallurgical processes have been identified but no attempt has been made to design a floating plant.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

5.7 Technology assessment: Support vessel

5.7.1 Production support vessel

The Production Support Vessel (PSV) is at the centre of a deep sea mining operation, supporting the surface and subsea mining operations. The PSV is not a value chain activity as such, but it supports several phases and activities of the value chain. Operationally, the PSV is similar to many of the vessels used for deep-sea oil and gas drilling, dredging, or transportation industries. Its purpose is to supply a large deck space and a stable platform from which the mining operations are controlled, including the seafloor mining tool(s), the lifting, on board pre-processing and the transfer of the ore from the PSV to the transportation vessel²⁸. The extraction, lifting and surface operation processes including pre-processing activities are described in previous sections. The transportation activity will be described in one of the following sections.

Although in the past some test vessels for manganese nodules mining have been developed, as the mining of manganese nodules (polymetallic nodules) and cobalt-rich crusts is not yet technologically feasible²⁹, for these ores it not possible to describe the techniques that are currently being used. The vessel itself, however, will probably not be that much different, as only the on-board techniques might be different. Construction a PSV is not a challenge as extensive experience from other industries is available.

²⁸ Grid Arendal. Deep Sea Minerals - Vol 2 - Manganese Nodules - page 48.

²⁹ Allsopp et. al. (2013) 'Review of the Current State of Development and the Potential for Environmental Impacts of Seabed Mining Operations'. Greenpeace Research Laboratories Technical Report (Review). 50pp.

Figure 5.15 Production Support Vessel



Source: Nautilus Minerals. <http://www.nautilusminerals.com/s/resourceextraction.asp#PSV>

Company – overview

Nautilus Minerals Inc. planned to extract Seafloor Massive Sulphides within the Exclusive Economic Zone of Papua New Guinea and was developing a Seafloor Production System (SPS). However, in November 2012 it was decided to terminate this development as a result of a dispute with Papua New Guinea’s government³⁰. In the original plan, Nautilus Minerals started developing a PSV including dewatering facilities. An image of such a vessel is displayed above.

The below list is a non-exhaustive overview of European off-shore shipyards:

- IHC Merwede (NL)
- Damen (NL)
- Wagenborg (NL)
- Bodewes (NL)
- Flensburger Schiffbau-Gesellschaft mbH & Co. (DE)
- DCNS (FR)
- STX France (FR)
- Arno Dunkerque (FR)
- Lisnave (PT)
- ENVC Shipyard (PT)

Technology readiness level

The development by Nautilus Minerals of an SMS PSV is currently on hold. However, as the ship itself is not specifically revolutionary, we can assume that relatively few problems can be expected with the reliability and the quality of such a vessel.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

³⁰ Nautilus Minerals (2014). <http://www.nautilusminerals.com/s/Projects-Solwara.asp>. Page visited: 10-03-2014.

5.7.2 Platform

Although the name 'production support vessel' suggests that production should always be supported by a vessel, a platform similar to an oil platform could also be an option. Depending on the circumstances, the platform may be fixed to the ocean floor, may consist of an artificial island, or may float.

Company – overview

As far as we know, no company is developing a platform specially for deep-sea mining.

Technology readiness level

As with the Production Support Vessels, Production Support Platforms will not be very different from platforms as being used in other industries. It is the techniques on-board for the DSM activities that are different. So although, as far as we know, no DSM PSP has been developed so far, the technology to manufacture such a platform is available.

Technological Readiness Level

TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -	TRL -
1	2	3	4	5	6	7	8	9

6 Offshore and onshore logistics

6.1 Introduction into transportation, handling and storage

This part of the value chain entails the logistics between the offshore surface platform or vessel and land-based destinations where final processing takes place. The bgraph below indicates the main elements of the value chain.



6.2 Technology assessment Transhipment from platform to ore carrier

There is wide experience in ship-to-ship transhipment of bulk cargoes, notably for the lightering of large bulk carriers using barges close to ports of destination. The main reasons then are shallow water/port access limitations for large draught ships.

However such operations usually take place near ports in safe or protected sea areas where weather and nautical conditions are reasonable. There is no experience in using these technologies in the open ocean.

TRL 9 (near shore) / TRL 5 (deep-sea).

6.3 Technology assessment: Sea-transport

The trans-ocean shipping of ores is widely applied and also the construction of ore carriers is well-developed. It is assumed that the specific composition of deep-sea mined ores, which may differ from land-originating ores does not affect the ship specifications or navigation conditions.

TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

6.4 Technology assessment: Terminal-operations

As for sea-transport of ores, the unloading in seaports is also well-developed and a variety of systems exists, all proven and in use for many years.
(PM elaborate).

TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

6.5 Technology assessment: Storage

Storage of ores in ports or elsewhere is being done for many years already. The level of sophistication required varies with local regulations (e.g. air dust from ore particles near residential areas, requiring f.i. coverage or watering of the ore storage) and possibly the ore composition (e.g. oxidation). Whether such requirements will differ for sea-originating ores is unknown.

TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

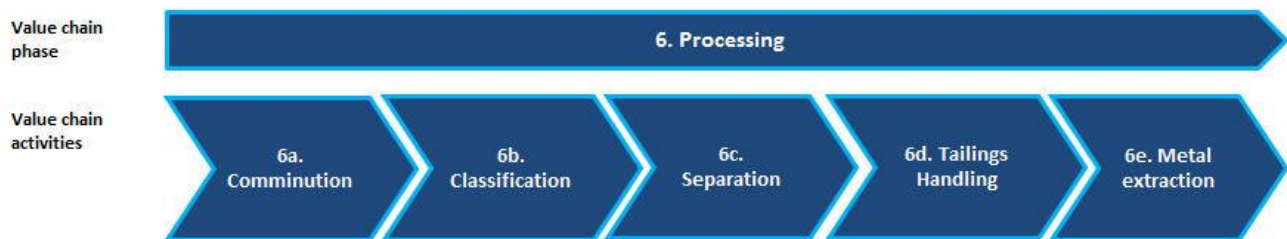
6.6 Technology assessment: Land transport

The transport of ores on land is usually done by train or barge as for e.g. iron ores it concerns high volume low value/low time-critical cargoes. For higher value sea-bed ores this might differ and truck transport might be used. All modes have sophisticated transportation means available.

TRL 9 - actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

7 Processing techniques

7.1 Introduction into Processing



7.1.1 Metals extractable from deep sea ore

1. Polymetallic Nodules:

Manganese, nickel, copper, and cobalt can be extracted from **polymetallic nodules**.

2. Cobalt-rich crusts:

These are also termed **cobalt-rich ferromanganese crusts**, and are found on the flanks and summits of seamounts, ridges and plateaux, throughout the world's oceans, where seafloor currents have swept the ocean floor clear of sediment for millions of years. The crusts do not occur at places where sediment is present on the ocean floor. Cobalt-rich crusts are obviously a new source for *Cobalt (Co)*. According to Hein et al. 2010³¹, ferromanganese crusts are likely to contain also: *Tellurium (Te)*, *Bismuth (Bi)*, *Zirconium (Zr)*, *Niobium (Nb)*, *Tungsten (W)*, *Molybdenum (Mo)*, *Platinum (Pt)*, *Gold (Au)*, *Titanium (Ti)*, *Thorium (Th)*; Platinum group elements (PGE, being *Platinum (Pt)*, *Rhodium (Rh)*, *Ruthenium (Ru)*, *Iridium (Ir)*, *Osmium (Os)*, and *Palladium (Pd)*) and also *gold (Au)* are of significance in the Co-rich ferromanganese crust of the Afanasiy–Nikitin Seamount in the Indo- Australian Basin³².

3. Polymetallic Sulphide Deposits

Also the terms *Volcanogenic Massive Sulphide deposits (VMS deposits)*, and *Sea Floor Massive Sulphide deposits (SMS deposits)* are applied. VMS is usually applied for such deposits found on land. These ores mainly contain *Iron (Fe)*, *Copper (Cu)* and *Zinc (Zn)*, but also *Lead (Pb)*, *Arsenic (As)*, *Antimony (Sb)*, *Gold (Au)*, and *Silver (Ag)* are encountered³³. (Herzig and Hannington, 1995, Known locations of these hydrothermal vents can be found in (Tivey, 2007).

With respect to size, SMS deposits are generally much smaller than their counterparts on land. Many of these land based deposits were formed in comparable, but much more ancient submarine environments. The size of a typical large onshore deposit is 50 – 60 Mt, whereas on the seafloor, most deposits are of the size of 1 – 5Mt. The metalliferous muds of the Atlantis II Deep in the Red Sea (90 Mt) may be the only SMS deposit similar in scale to the large onshore deposits³⁴.

³¹ Hein, J.R., Conrad, T.A., Staudigel, H. (2010) Seamount Mineral Deposits. A Source for Rare Metals for High-Technology Industries. *Oceanography*, 23, No. 1, 184–189

³² Banakar, V.K., Hein, J.R., Rajani, R.P. Chodankar, A.R. (2007) Platinum group elements and gold in ferromanganese crusts from Afanasiy–Nikitin seamount, equatorial Indian Ocean: Sources and Fractionation. *Journal of Earth System Science*, 116, No. 1, February 2007, pp. 3–13.

³³ Hoagland, P., Beaulieu, S., Tivey, M.A., Eggert, R.G., German, C., Glowka, L., Lin, J. (2010). Deep-sea mining of seafloor massive sulphides. *Marine Policy*, 34, 728–732

³⁴ Hoagland, P., Beaulieu, S., Tivey, M.A., Eggert, R.G., German, C., Glowka, L., Lin, J. (2010). Deep-sea mining of seafloor massive sulphides. *Marine Policy*, 34, 728–732

7.1.2 Mineral Processing

Mineral Processing involves all the work from

- resizing the ore from the mined pieces to manageable sizes for further processing;
- to classification in size categories;
- to mineral separation;
- to tailings handling;
- to metal extraction (some people consider this not to be mineral processing anymore – visions differ).

Mineral processing involves techniques like comminution (size reduction by breaking, milling), classification (e.g. sieving) to separation of valuable minerals from invaluable bulk. A famous overview of Mineral Processing Techniques can be found in Wills & Napier-Munn (2006)³⁵.

The mineral concentrates can then be used in extractive metallurgical processes to liberate the metals.

7.1.3 Ship and Platform

For efficient use of ships and equipment, use of a platform in a central place with respect to the mining locations should be envisaged. Platforms are very stable, and instability issues like on ships are not important. The technology for such platforms in deep sea is well established in the oil-industry.

A central platform where most of the processing is carried out is much more efficient, than carrying-out processing on a ship. The ship transports the mined ore to the platform, and then returns to the mining site taking back rock waste to be discarded. On the platform the ore is processed, and concentrates can be shipped to on-shore locations.

7.1.4 Dry versus Wet Processing

In mineral processing most often processing is carried out on **dry materials**. For deep-sea ores this will be **wet material**. This obviously concerns seawater, which may be corrosive. This has to be taken into account in design and construction of equipment. On the other hand, seawater is conductive, which may be of influence in the processing.

7.2 Technology assessment: Comminution

7.2.1 Stage of development

For use on land this is very well known. For use on sea-going vessels, this is not known.

The limited space on a ship is certainly important for the crushing and grinding stage, as the industrial scale equipment used for these is quite large, and rather heavy. Use of a platform would mitigate these problems.

There are several types of crushing machines that are commonly used. They are:

- Jaw crusher;
- Impact crusher;
- Cone crusher;
- Gyratory crusher;
- Roll crusher.

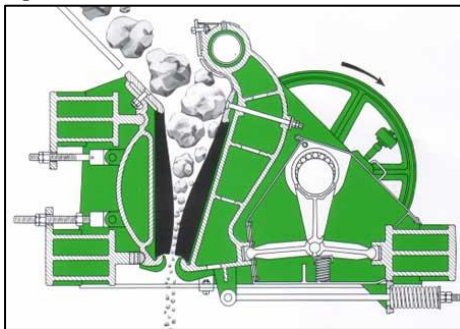
³⁵ Wills, B.A., Napier-Munn, T. (2006) Mineral Processing Technology (7th edition), Elsevier, 444pp.

Considering the unknown hardness of the material, a jaw crusher may prove a better solution than an impact crusher, which is generally used for softer material. Also a jaw crusher is a mechanically simpler machine, compared to an impact crusher. This is also an advantage, with respect to maintenance. Taking into account capacity, a cone crusher may be an even better solution. A cone crusher breaks rock by squeezing the rock between an eccentrically gyrating spindle. Cone crushers are quite similar in operation to gyratory crushers. However, a cone crusher has, in comparison to a gyratory crusher, less steepness in the crushing chamber and more of a parallel zone between crushing zones.

A fourth type of crusher is the roll crusher. Roll crushers, however, are less productive with respect to volume, and have a somewhat higher maintenance compared to a gyratory crusher or a cone crusher.

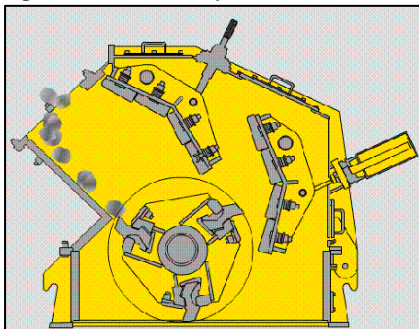
Of further importance is whether the crusher can handle wet material. Considering that material from deep-sea-mining will be wet, a cone crusher is probably the best solution, as this type of crusher can handle wet material. The material should, however, preferably not be sticky. In general, cone crushers are known to be “self-cleaning”, but with respect to this, testing with deep-sea ore samples should be carried out.

Figure 7.1 Jaw Crusher



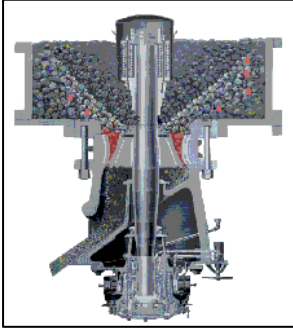
Source: Pennsylvania Crusher

Figure 7.2 Impact Crusher



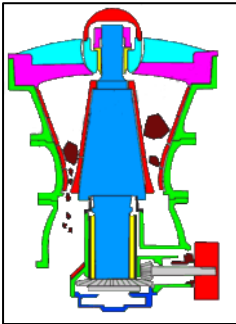
Source: <http://www.hotcrusher.com/products/crushing/pfw-impact-crusher.html>

Figure 7.3 Cone Crusher



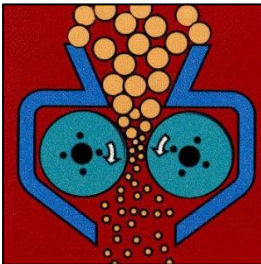
Source: http://www.mine-engineer.com/mining/cone_crusher.htm

Figure 7.4 Gyrotory crusher



Source: solidswiki.com

Figure 7.5 Roll crusher



Source: <http://www.mine-engineer.com/mining/rollcrush.htm>

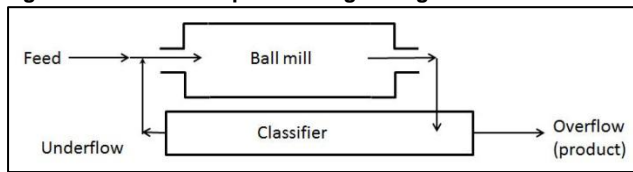
For further size reduction, the milling process is used. First stage grinding reduces the size of materials from 50 mm to 300 μ m. Second stage grinding reduces them from 300 μ m to the required size. Several types of equipment are usually applied here: rod mills, ball mills and semi-autogenous mills (SAG-mills). In the first, hard steel rods are used as the grinding medium. Such mills are usually applied for coarse grinding.

Rod mills are to be considered as fine crushers, or coarse grinding mills, and are used in the first grinding stage. Feed can be up to 50 mm, and they can make a product as fine as 300 μ m. Because of the typical grinding action of rods, which will preferentially grind the larger particles; the product has a relatively narrow size range. They are nearly always run in open circuit. They have however a severe disadvantage: when the rods wear down gradually during time, at a certain point the rods may break. To remove the broken rods, the rod mill must be shut down. For ball mills and SAG mills in case of a damaged ball this is not the case.

An alternative is the use of Autogenous (AG) or Semi-autogenous (SAG) mills. In the SAG-mills, attrition between grinding balls and ore particles causes grinding of finer particles. SAG mills are characterized by their large diameter and short length as compared to ball mills. In ore processing, a SAG mill is often used as a first stage grinding solution, replacing rod mills.

For second stage grinding, ball mills are applied. First stage grinding reduces the size of materials from 50 mm to 300µm. Second stage grinding reduces them from 300µm to the required size. Ball mills are thus used for the fine finishing, as they have a greater surface area per unit weight than rods. They are usually operated in a closed grinding circuit (see figure). Only material that is fine enough, leaves the grinding circuit, preventing overgrinding.

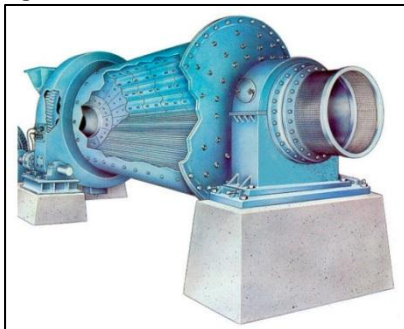
Figure 7.6 Simple closed-grinding circuit



Source: after Wills, 1997

But also here, one must consider that the material will be wet. Regarding this, SAG mills would again be a good choice, as they can handle wet material as well. One thing to test is the optimum amount of water in the slurry that is fed into the mill.

Figure 7.7 Rod Mill



Source: www.directindustry.com

Figure 7.8 Ball Mill



Source: www.limingmachinery.com

Figure 7.9 A SAG Mill



Source: <http://www.flsmidth.com>

Comminution is the first step in the liberation of valuable minerals from their host rock (the ore) and is therefore a necessary activity within the value chain. Both technical and environmental challenges lie ahead and will determine the practicality of comminution to take place at sea or on shore.

TRL - 2

The comminution technology is well developed for land based mining operations and has a TRL of 9. It seems logical to use the same techniques for the comminution of deep sea ores, however because most terrestrial ore is processed in a dry state, experiments should be conducted to evaluate the comminution efficiency of equipment when the feed consists of wet or moist ore.

7.2.2 Company – overview

A list of European Mining Grinding Mills Suppliers per country is obtained from an industry organisation³⁶:

UK

- Falcon Concentrators (was Sepro Mineral Systems)
- Tenova Delkor
- Bradken Resources Pty Limited
- Bridge Abrasives Ltd.
- Christy Turner Ltd
- Helipebs Controls Limited
- Kubota Corporation
- F.J. Brindley & Sons (Sheffield) Ltd
- International Innovative Technologies (IIT) Ltd
- Atritor Ltd

Germany

- Sepro Mineral Systems is now home to Falcon Concentrators
- L & N Grinding Systems
- Litzkuhn & Niederwipper GmbH
- Teknikum Ov
- Koppern Equipment Inc.

Turkey

- Sepro Mineral Systems is now home to Falcon Concentrators
- MIS Mak. Ins. San. Ltd. Sti.

³⁶ Infomine, <http://www.infomine.com>

France

- Ferry-Capitain

Ireland

- Coles Mining Limited

Spain

- Forjas Santa Barbara S.A.

Austria

- PMT-Jetmill GmbH
- Cemtec GmbH

Belgium

- Magotteaux International s.a.

Lithuania

- Geola Ltd.

Sweden

- Metso
- Komab Industriteknik AB
- Ståhle's Mining and Construction Ltd (SMC AB)

Finland

- Metso
- Teknikum Oy

Bulgaria

- Sepro Mineral Systems is now home to Falcon Concentrators

Norway

- King Pin International

7.3 Technology Assessment: Classification

7.3.1 Stage of development

For use on land this is very well known. For use on sea-going vessels, this is not known. Wet screening techniques will probably not lead to difficulties, probably not even when processing fine material. When hydrocyclones are applied as classifier, already fairly fine material is needed to make the hydrocyclones work optimally. A pitfall for hydrocyclones is that smaller high-density particles will behave similar to larger low-density particles.

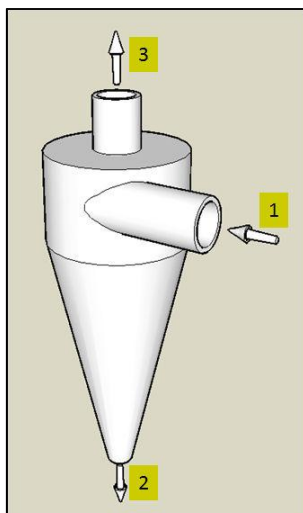


Figure 7.10 Hydrocyclone
Hydrocyclone:
1. Inlet.
2. Outlet for heavy solids.
3. Outlet for light solids.

Classifiers are used in mining operations today in both dry and wet environments (e.g. alluvial, dredging operations). Classification prior to mineral separation is required to obtain the optimal particle size feed for the mineral separation stage. For example, the undersize particles can be fed into the flotation process whilst the oversized particles are fed back into the grinding mill for further comminution.

TRL – 7

Particle classification is a well-known process and is applied in dry and wet mining environments. Implementing classification equipment in a deep sea mineral processing plant should therefore not result in any problems. Screening is routinely used in offshore diamond mining and hydro cyclones are likely to perform well on a seagoing vessel/platform although this has not been tested.

Company – overview

All Mining Suppliers, Equipment - Crushing & Conveying – Classification

- FLSmidth
- Quinn Process Equipment Co.
- Centrifugal & Mechanical Industries (CMI)
- ECUTECH Barcelona S.L.
- FMC Technologies, Inc.
- Haver & Boecker OHG
- LCA Detectores de Metais
- Mineral Engineering Processes Ltd.
- Minivevor Products Ltd.
- PMT-Jetmill GmbH
- Polydeck Chile S.A.
- Presanger Locação de Equipamentos Ltda
- Derrick Corporation
- Phoenix Process Equipment Co.
- Smico Manufacturing Company LLC
- Aggregates Equipment Inc.
- Europarts
- G & G Industrial S.R.L.
- Central Machine & Fabrication
- Classification & Flotation Systems Inc.
- Detecsul Indústria Eletrônica Ltda.
- Eagle Iron Works
- Eral, Equipos Y Procesos S.A.
- Gornye Tehnologii
- GTH, OOO
- Loesche GmbH
- Mactek Technologies Inc

- MBE Coal & Minerals Technology GmbH
- Milticor Comércio de Correntes e Engrenagens Ltda
- Piacentini & Cia Ltda
- Ural-Omega, PJSC
- Vibrosito
- Chuangye Metal Wire Mesh Co., Ltd. O
- DSM Osman Cubuk Ltd.Sti.
- Floatex Separations Ltd
- Maker Machinery and Production LLDC
- Mcl Argentina Srl

7.4 Technology assessment: Mineral Separation

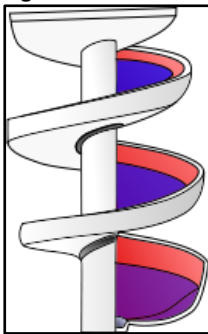
7.4.1 Stage of development

For use on land this is very well known. The movement of the ship due to wave action has especially an impact on wet techniques, making Gravity Separating Tables, Froth Flotation and Jigging seem unpractical. To counteract the motion of the ship due to wave action a stabilized platform could be envisaged, but wet, open, techniques still seem unpractical.

Gravity separating tables also take a lot of space, which is a serious disadvantage for use on a ship. The possibility of using spiral separators seems doubtful, but could be tried out experimentally.

Magnetic separation and hydro cyclones should not provide any difficulty for use on a seagoing ship. However, magnetic separation implies that at least one of the (valuable) minerals is magnetic (paramagnetic, ferrimagnetic or ferromagnetic). **Sulphides** are in general **non-magnetic**.

Figure 7.11 Humphrey's spiral, schematic



Source: wikipedia.org

Figure 7.12 Two spiral concentrators



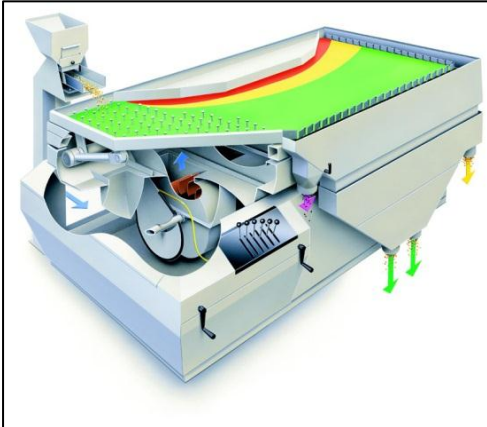
Source: University of Wyoming

Figure 7.13 Spiral concentrators



Source: Jiangxi Gandong Mining Equipment Machinery Manufacturer Factory

Figure 7.14 Gravity separation table, schematic



Source: E. Buttmer & Co.

Figure 7.15 A set of gravity separation tables in operation

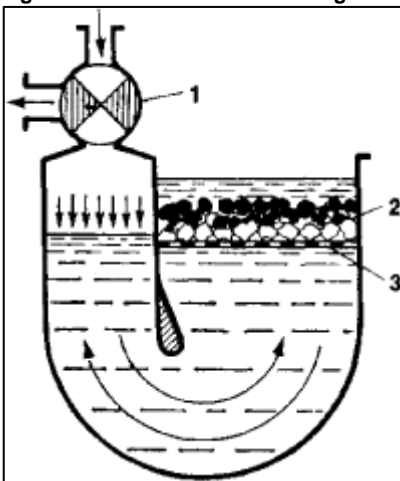


Source: Gongyi Hengchang Metallurgical Building Materials

Figure 7.16 A series of hydrocyclones



Figure 7.17 Schematic diagram of jigging: (1) pulsator, (2) jig bed, (3) jigging screen



Source: <http://encyclopedia2.thefreedictionary.com/Jigging>

Figure 7.18 Example of a Jig



Source: Yufeng Heavy Machinery

Figure 7.19 Magnetic separation, schematic

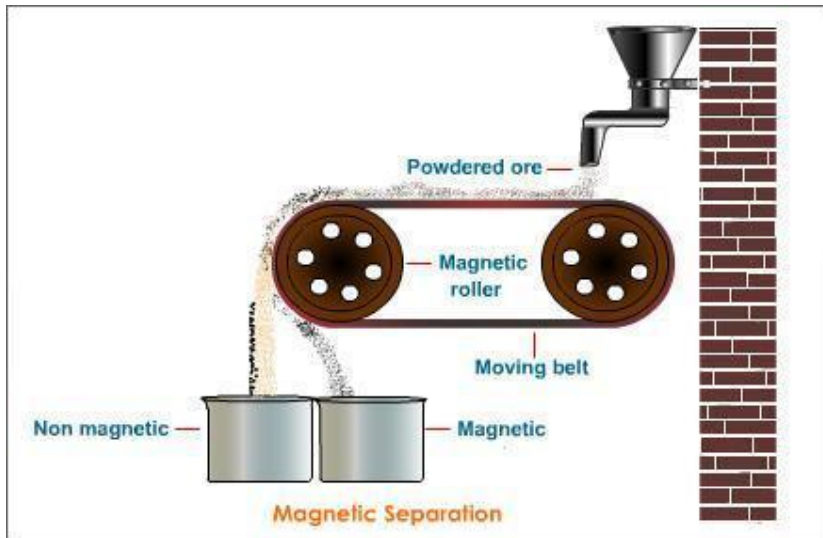


Figure 7.20 Froth Flotation



7.4.2 Likelihood of implementation

Several techniques exist to separate valuable minerals from invaluable gangue and most are suitable for wet material. Experiments should be conducted in order to determine the optimal techniques for the separation of deep sea ores. The size of the individual mineral crystals is an important factor in the selection of suitable separation equipment.

TRL – 4

The mineral separation techniques are well understood and documented. Research should focus on the determination of the best (combination of) technique(s) to maximize valuable mineral recovery and maximize mineral grades in the produced concentrate. Laboratory tests have been conducted over the last decades to determine the applicability of e.g. flotation to concentrate deep-sea ores. As a next phase, small-scale pilot plants could be developed to determine separation efficiency of a 'real' plant and according flow sheet.

7.4.3 Company - overview

- FLSmidth
- Gekke Systems Pty Ltd.
- Metso
- Tenova Delkor
- Westech Equipamentos Industriais Ltda.
- Sepro Mineral Systems is now home to Falcon Concentrators

7.4.4 Separation techniques for use on sea-going vessels

Ores	Separation Techniques					
	Spirals	Shaking Tables	Hydro-cyclones	Froth Flotation	Jig	Magnetic Separation
Poly-metallic sulphides	To be investigated	Unpractical	Possible	Unpractical	To be investigated	Not possible. Sulphides are in general non-magnetic*
Poly-metallic nodules	To be investigated	Unpractical	Possible	Unpractical	To be investigated	Depending on mineral content
Cobalt-rich crusts	To be investigated	Unpractical	Possible	Unpractical	To be investigated	Depending on mineral content

* **Pyrrhotite**, $Fe_{1-x}S$, is the only common sulphide that, depending on its composition, **can** be magnetic.

7.5 Technology assessment: Tailings Handling

Every separation technique produces tailings, which in many cases must be discarded.

The issue of discharging loose rocks waste, when no chemicals are involved, is merely damage to the underwater environment, but considering that damage is already done by the mining action, this may be considered of minor importance. For environmental reasons, flotation tailings probably cannot be discharged into the sea.

Legal issues however, are a matter of concern. When operating within the EEZ of a certain country, the laws of that specific country apply, but on the “*high sea*”, the rules of UNCLOS (1982) apply. Compliance with these rules is checked by the International Seabed Authority (ISA), and this should be taken into account in any case of Deep Sea Mining.

TRL – 1

As a result of sea-based processing, tailings will be produced. A solid plan to deal with these tailings is required if sea-based processing of the ore is considered.

7.6 Technology assessment: Metal Extraction

For use on land metal extraction is very well known.

Metal extraction techniques are pyro metallurgical (with heat, temperatures up to several hundreds or even above thousand degrees Celsius), hydrometallurgical (wet chemical) or electrometallurgical (wet chemical processes with electrolytic cells).

Different mineral extraction techniques can be applied depending on the type of deep-sea mineral deposit. Depending on the deposit, concentrating of the valuable minerals prior to mineral extraction may be necessary (SMS, Cobalt-rich crusts) or grinding and direct extraction may be possible (Polymetallic nodules). New extraction techniques may be required to obtain the final metals or existing terrestrial methods may be applicable directly.

Ores:	Identified Concentrating techniques		
Polymetallic sulphides	Flotation + Smelting	Magnetic Separation + Smelting	

Ores:		Identified Concentrating techniques	
Polymetallic nodules	Cuprion process	Sulphuric leaching	Smelting
Cobalt-rich crusts	Gravity Separation + Smelting		

7.6.1 Polymetallic Sulphides

More suitable for on-site upgrading prior to shipping by using traditional terrestrial methods such as crushing, grinding and subsequent concentration to obtain a metal concentrate that can be shipped to a smelter facility on shore. Because the chemical characteristics of Polymetallic Sulphides are similar to land-based deposits, the concentrate can be shipped to existing smelter facilities that are often easily accessible over water.

A difficulty of processing SMS deposits is the fine-grained mineral size that is partly a consequence of the manner in which the sulphides are precipitated from the hydrothermal fluids. Rapid quenching of the solutions as they mix with the cold seawater results in poor nucleation of minerals and limited growth of large crystals³⁷. Analyses of samples from the East Pacific Rise 11oN and Southern Explorer Ridge indicate particle sizes for pyrite, sphalerite and chalcopyrite in the range of 1-600 microns with an average between 22 and 37microns. Re-crystallization of more mature deposited minerals may result in larger particle sizes.

Herzig notes that treating methods for fine-grained ores are poorly developed and in order to liberate the individual grains, a lot of energy is required. In land based mining operations, significant losses occur in the ultra-fine particle fraction of less than 10 microns. It may be that the particle size of some deposits is simply too small to be processed economically as the main processing method for small particles (flotation) has limited effect on separating ultra-fine particles.

Fine grinding followed by high inductance magnetic separation has been tested for SMS deposits and resulted in a copper and zinc concentrate with a recovery of 81%³⁸. Grinding followed by magnetic separation could be applied on board the support vessel to upgrade the ore concentrate prior to shipping to shore.

Another challenge in the mineral extraction of SMS deposits is gold recovery. Gold typically also has a uniformly small grain size (<10 microns) which results in inadequate liberation of the gold particles during mineral processing. The ultra-fine gold particles require extra fine grinding (hence increased energy costs) and this compromises the recovery of copper and zinc. This is a major challenge that needs to be solved in order to extract the true value of SMS deposits.

7.6.2 Polymetallic Nodules

Whereas SMS deposits are metallic *sulphides ores*, Polymetallic Nodules are *oxides ores*. Hence, mineral extraction requires a different approach. For instance, froth flotation is not used to concentrate oxide ores because oxide minerals do not bind to the froth flotation chemicals.

The main challenge with polymetallic nodules is to effectively dissolve/reduce the manganese dioxide in order to free the economic amounts of cobalt, nickel and copper. Several extraction

³⁷ Herzig, P. (2000). TECHNICAL REQUIREMENTS FOR THE EXPLORATION AND MINING OF SEAFLOOR MASSIVE SULPHIDES DEPOSITS AND COBALT-RICH FERROMANGANESE CRUSTS. Minerals other than polymetallic nodules of the international seabed area (pp. 303-316). Kingston: ISA.

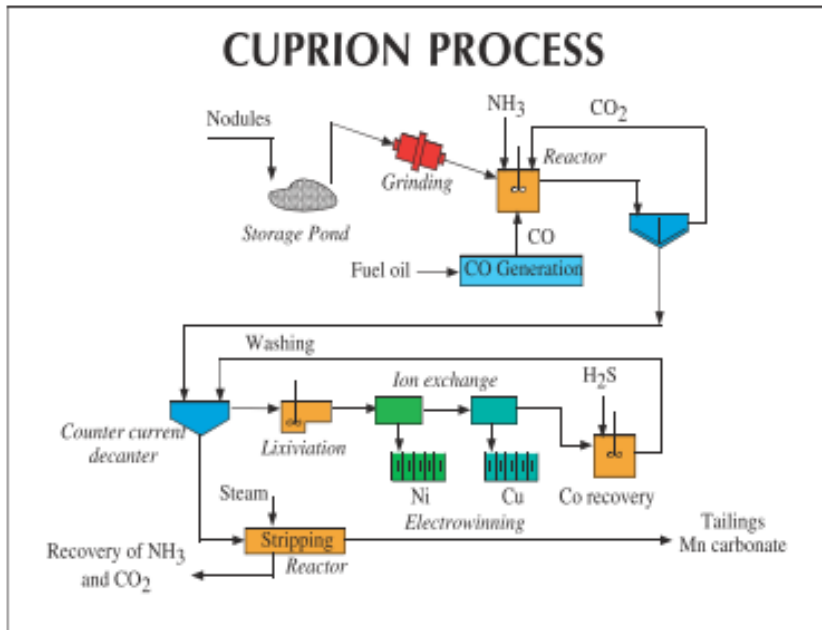
³⁸ Alton et al. (1989). Potential for processing seafloor massive sulfides by magnetic separation. Marine Mining(8), 163-172.

methods have been proposed over the last decades with some methods allowing for the extraction of manganese whilst other methods consider manganese extraction as being too difficult.

Cuprion process

In order to effectively use the Cuprion process the nodules are ground to and processed as fine slurry. The particles are subsequently reduced by carbon monoxide at low temperature and in presence of ammonia in an agitated tank. Copper, Nickel and cobalt are made soluble by counter current decanting in a series of thickeners. Nickel and Copper are then extracted by electrolysis and cobalt is removed by sulphide precipitation³⁹. All manganese is considered tailings when using this method as manganese extraction from the residue proved difficult.

Figure 7.21 Cuprion Process Flow Sheet



Source: International Seabed Authority, <http://www.isa.org/im/en/home>

Sulphuric leaching

Introduced by Fuerstenau in 1973, and later improved by the French Commissariat a l'Energie Atomique.

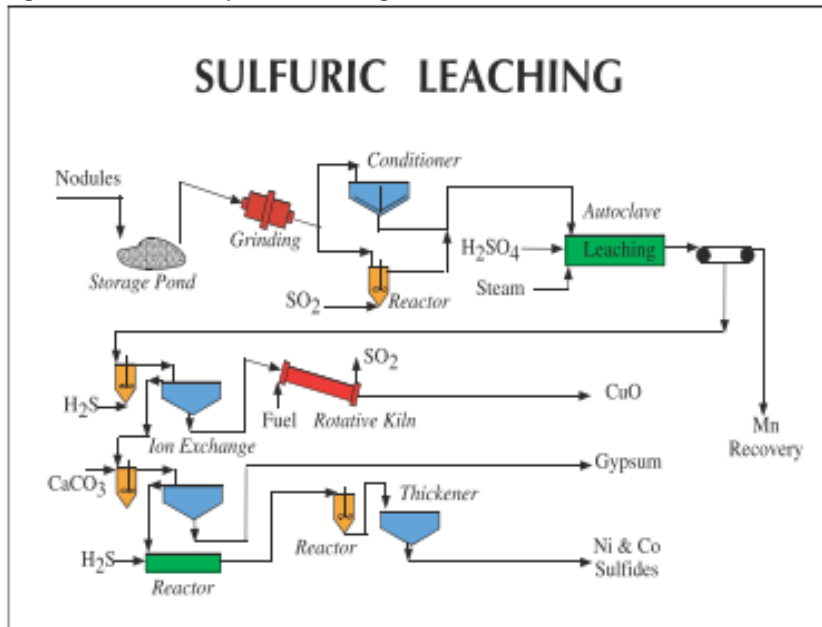
Nodules are crushed and sulphuric acid at 180 degree Celsius and a pressure of 1200 KPa dissolve the metals inside the particles. Bivalent manganese ions (Mn^{2+}), formed by pre-reduction of some of the nodules with sulphuric gas, are introduced into an autoclave (steam-pressured heating chamber) to increase the recovery of cobalt. Copper, nickel and cobalt are precipitated from the resulting solution using hydrogen sulphide. The copper sulphide is roasted to give an oxide concentrate, while the nickel-cobalt concentrate is kept as a sulphide (ISA, polymetallic nodules).

Further refining to obtain the final metals consists of:

1. Sulphuric acid leaching and subsequent electro winning of the copper oxide concentrate;
2. Nickel-Cobalt sulphide is further refined (elimination of iron and zinc) by melting it into chlorine & water and finally separated by ion-exchange solvents. The resulting cobalt chloride is sent to a cobalt refinery and the nickel is extracted by electrolysis;
3. The ferromanganese residue is dried and calcinated in an electric furnace and subsequently smelted.

³⁹ International Seabed Authority

Figure 7.22 Sulphuric Leaching Flow Sheet



Source: International Seabed Authority, <http://www.isa.org/im/en/home>

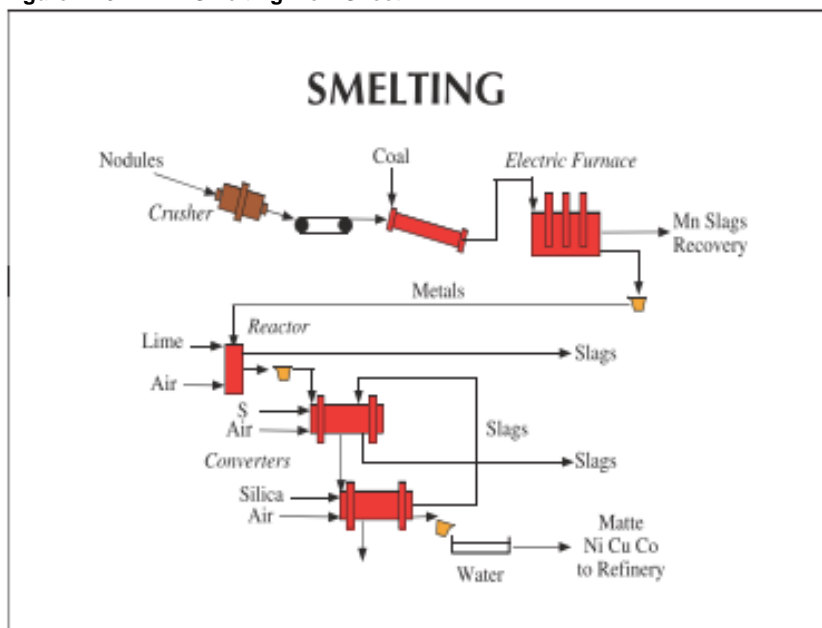
Smelting

Classic nickel and copper smelting processes have been investigated as a method for polymetallic nodules processing. First the nodules are crushed dried and calcinated in a rotary kiln after which the material is fed into an electric furnace for reduction. The output of this electric furnace process is a manganese rich slag and an iron-nickel-copper-cobalt alloy.

The alloy is further processed in a converter (which removes most of the remaining manganese and iron) and subsequently, by adding sulphur a nickel-copper-cobalt matte is obtained. This matte can be processed in a refinery.

The manganese slag is fed directly to an electric-arc furnace to remove residual heavy metals and much of the iron. The final product is a ferro-silico-manganese alloy.

Figure 7.23 Smelting Flow Sheet



Source: International Seabed Authority, <http://www.isa.org/im/en/home>

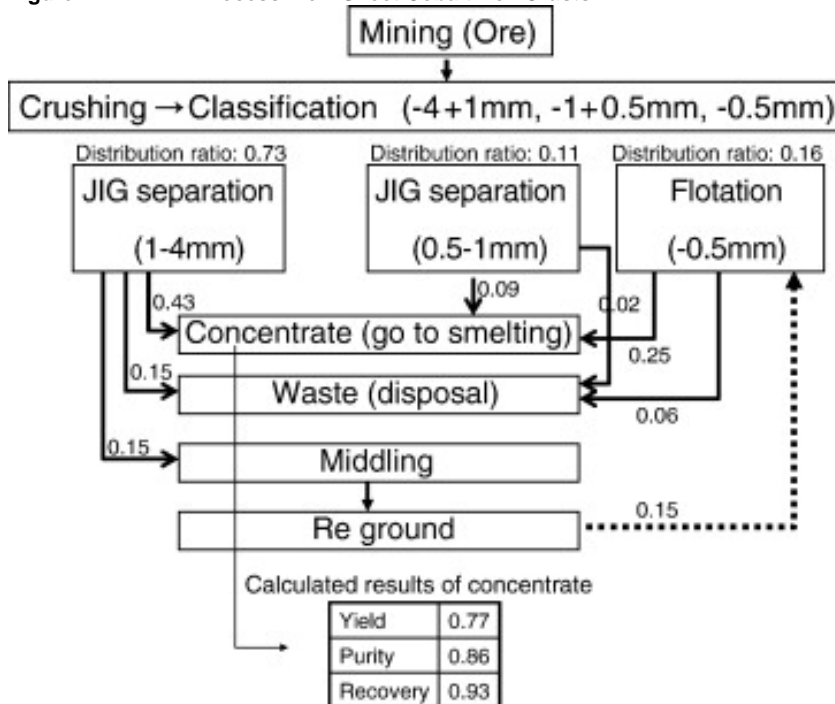
7.6.3 Cobalt-rich crusts

Cobalt-rich crusts are deposited as thin layers bonded to a substrate rock. This bonding together with the fact that cobalt-rich crusts are relatively thin, make it very likely that large amounts of substrate material are mined together with the ore. The valuable ore needs to be separated prior to mineral extraction. Because both crusts and nodules are ferromanganese oxides, metallurgical processing is expected to be similar.

Several small-scale research projects have been carried out in order to find the best method to separate the ore from the gangue^{40 41}. Flotation and JIG separation have been found to be appropriate separating methods and show recoveries between 89 and 94% whilst removing 62% of the feed weight when using flotation with particle sizes <600 micrometre⁴². Ito et al (2008)⁴³ estimate a recovery of 93% and purity of 86% whilst using JIGS and Flotation equipment simultaneously depending on grain size (see Figure 7.24). Using the same techniques as for polymetallic nodules the concentrate product can be further processed to extract the metals.

The increased product quality of the ore concentrate and significant mass reduction make that this processing step could very well be implemented on board a support vessel/platform to reduce transport costs. Also, the waste material can immediately be transported back to the seafloor at the same spot where it was extracted.

Figure 7.24 Process Flow Sheet Cobalt-rich Crusts



Source: Ito et al. (2008). Estimation of degree of liberation in a coarse crushed product of cobalt-rich ferromanganese crust/nodules and its gravity separation. *International Journal of Mineral Processing*(87), 100-105.

⁴⁰ Ito et al. (2008). Estimation of degree of liberation in a coarse crushed product of cobalt-rich ferromanganese crust/nodules and its gravity separation. *International Journal of Mineral Processing*(87), 100-105.

⁴¹ Hirt et al. (1991). FLOTATION OF COBALT-RICH FERROMANGANESE CRUST FROM THE PACIFIC OCEAN . *Minerals Engineering*, 4(5/6), 535-551.

⁴² Hirt et al. (1991). FLOTATION OF COBALT-RICH FERROMANGANESE CRUST FROM THE PACIFIC OCEAN . *Minerals Engineering*, 4(5/6), 535-551.

⁴³ Ito et al. (2008). Estimation of degree of liberation in a coarse crushed product of cobalt-rich ferromanganese crust/nodules and its gravity separation. *International Journal of Mineral Processing*(87), 100-105.

7.6.4 Overall likelihood of implementation

Due to size of the installations (pyro- and hydrometallurgy), high temperatures (pyrometallurgy), hazardous chemicals (hydrometallurgy), and large energy requirements (electrometallurgy), these techniques are either not possible or not very well feasible on a seagoing vessel or on a platform.

7.7 References

- **UNCLOS (1982) United Nations Convention on the Law of the Sea.**
http://www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm
- **ISA (International Seabed Authority):** <http://www.isa.org.im/en/home>

B.Task 3 Legal analysis

This chapter sets out preliminary findings for task 3, which calls for a description of the legal framework governing deep-sea minerals exploration and extraction and exploitation in four different, yet inter-linked, spatial and jurisdictional contexts:

- maritime areas under the jurisdiction of selected European Union (EU) Member States;
- maritime areas under the jurisdiction of the overseas countries and territories (OCTs) of the Member States;
- maritime areas of at least five other countries in which mining activity is already taking place or the results of underwater surveys have been promising;
- areas beyond the national jurisdiction of any country.

The applicable legal framework for DSM derives from multiple levels of law. The foundation of the framework is 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. EU law applies to the Member States of the EU and in certain circumstances may also apply to their OCTs. Finally, maritime areas under the jurisdiction of States are subject to the national legislation of those States as shaped by international law and, in the case of the EU Member States, EU law.

8 International law

The law of the sea is 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')⁴⁴ and its two implementing agreements: the Part XI Deep Sea Mining Agreement⁴⁵ and the UN Fish Stocks Agreement.⁴⁶ 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.⁴⁷ It is, however, important to note that around 30 States are not.⁴⁸

The sources of the law of the sea are identical to those of international law in general, namely agreements (treaties) and customary international law. Apart from UNCLOS a number of other international agreements are also relevant to DSM and these are considered below. Before, however, turning to the provisions of UNCLOS that relate directly to DSM it is important to note that the ongoing importance of customary international law cannot be ignored, especially with respect to those areas of conventional law that are not clearly articulated in existing treaties or in areas where State practice may have extended the application of some treaty provisions. This phenomenon has been clearly recognized by the International Court of Justice (ICJ) in its multiple decisions on the law of the sea.⁴⁹

8.1 UNCLOS

The basic reason why UNCLOS took so long to negotiate was due to the need to accommodate the different 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 DSM was particularly controversial in this respect and is also one of the reasons why UNCLOS was finally adopted by a vote (rather than by consensus as had been hoped at the time of the negotiations) 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 DSM, 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 States. These zones which determine the spatial competence and jurisdiction of States, and thus which specific legal regime applies to DSM, are considered next.

Maritime zones under UNCLOS

The sovereignty of a coastal State extends beyond its land territory and internal waters to an adjacent belt of sea described as the **territorial sea** that may extend up to twelve nautical miles

⁴⁴ United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982. In force: 16 November 1994, 1833 *United Nations Treaty Series* 396; <www.un.org/Depts/los>.

⁴⁵ Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982 New York, 28 July 1994. In force 28 July 1996, 33 *International Legal Materials* 1309 (1994); <www.un.org/Depts/los>.

⁴⁶ Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks New York, 4 August 1995. In force: 11 December 2001, 2167 *United Nations Treaty Series* 3; <www.un.org/Depts/los>.

⁴⁷ http://www.un.org/Depts/los/reference_files/status2010.pdf.

⁴⁸ Including the United States of America, Columbia, Israel, Libya, Peru, Syria, Turkey and Venezuela.

⁴⁹ Rothwell, D.R. & Stephens, T. *The International Law of the Sea*, 2010, Hart Publishing, Oxford at page 22.

(nm)⁵⁰ measured from the baseline (usually the low water mark⁵¹). Within its territorial sea the authority of a coastal State is in principle absolute except as restricted by UNCLOS and other rules of international law⁵². In general it is unlikely that DSM would take place in the territorial sea of a coastal State.⁵³ However DSM could take place within the territorial sea of an 'archipelagic State', which is defined in Article 46(a) of UNCLOS as "a State constituted wholly by one or more archipelagos and may include other islands". The term 'archipelago' is defined in paragraph (b) as:

a group of islands, including parts of islands, interconnecting waters and other natural features which are so closely interrelated that such islands, waters and other natural features form an intrinsic geographical, economic and political entity, or which historically have been regarded as such.

This is because UNCLOS contains specific rules on the drawing, in certain specified circumstances, of straight archipelagic baselines joining the outermost points of the outermost islands and drying reefs of an archipelagic State.⁵⁴

Beyond its territorial sea a coastal State may claim an exclusive economic zone (EEZ) that can extend up to 200 nm from the baseline. Within its EEZ a coastal State does not enjoy sovereignty as such but a more limited set of "sovereign rights" relating to living and non-living resources and with regard to other activities for the economic exploitation and exploration of its EEZ, such as the production of energy, as well as DSM.

Article 56(1) states that:

In the exclusive economic zone, a coastal State has:

(a) sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds;

A coastal State also has the necessary jurisdiction related to these sovereign rights as well as jurisdiction for the establishment and use of artificial islands, installations and structures, marine scientific research and the protection and preservation of the marine environment.⁵⁵ The sovereign rights and jurisdiction conferred upon a coastal State imply the power to regulate the terms of use relating to those activities. On the other hand the coastal State does not enjoy sovereignty in the fullest sense. Article 56(2) of UNCLOS states:

In exercising its rights and performing its duties under this Convention in the exclusive economic zone, the coastal State shall have due regard to the rights and duties of other States and shall act in a manner compatible with the provisions of this Convention.

In other words coastal State regulatory competence in the EEZ is not plenary, but confined to the matters expressly indicated in UNCLOS in respect of which sovereign rights or jurisdictional powers are granted to a coastal State. Such rights apply for the purpose of 'exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil' (article 56) as well as other activities

⁵⁰ 1 nm = 1,852 metres.

⁵¹ In some circumstances a coastal State may draw a straight baseline for example on heavily indented coasts and over the mouths of bays and estuaries.

⁵² The most important restriction is the right of 'innocent passage' through the territorial sea, which is enjoyed by ships of all States (article 17)

⁵³ UNCLOS provides for the creation of a number of other types of maritime zone, which are also not relevant to DSM.

⁵⁴ UNCLOS article 47.

⁵⁵ UNCLOS Article 56(1)(b).

for the economic exploitation of the zone.⁵⁶ Moreover UNCLOS subjects the exercise of this competence to various conditions and obligations explicitly foreseen, such as the freedom of navigation of other States' vessels.⁵⁷

UNCLOS also recognises the rights of a coastal State over its adjacent **continental shelf**, which comprises the seabed and subsoil of the 'submarine areas' beyond the territorial sea. The continental shelf may extend as far the natural prolongation of the land territory to the outer end of the continental margin or to a distance of 200 nm from the baseline in cases where the outer edge of the continental margin does not extend that far. In other words some but not all coastal States may be entitled an **outer continental shelf** that extends beyond 200 nm from the baseline and thus beyond the outer edge of the EEZ. In these cases the coastal State must submit information on its outer limits on the basis of criteria specified in Article 76 of UNCLOS to the Commission on the Limits of the Continental Shelf (CLCS). The limits of the outer continental shelf established by the coastal State 'on the basis of the recommendations of the CLCS are final and binding' (article 78(8)). A number of continental shelf submissions around the world have been made, including by States that are considered in this study, and await recommendations from the CLCS.⁵⁸ The regime for the outer continental shelf is essentially identical to that of the continental shelf save that rules on refusing consent to marine scientific research are stricter and a specific revenue sharing regime applies as regards DSM which is considered below.

With regard to its continental shelf, Article 77(1) of UNCLOS provides that a coastal State exercises 'sovereign rights for the purpose of exploring it and exploiting its natural resources'. In other words, as with the rights of a coastal State over its EEZ, something less than full sovereignty is conferred. Article 77 (2) goes on to clarify that the rights of the coastal State are exclusive in that if it does not explore its continental shelf or exploit its natural resources no one else may undertake such activities without the express consent of the coastal State.

The sovereign rights of the coastal State regarding the continental shelf include the exploitation of living organisms belonging to 'sedentary species' (which are defined as organisms, which at the harvestable stage, are either 'immobile, on or under the sea-bed or are unable to move except in constant physical contact with the sea-bed or the subsoil') drilling, tunnelling, and the use of artificial islands, installations, and structures as well as DSM.

Article 78(1) of UNCLOS states that:

[The rights of the coastal State over the continental shelf do not affect the legal status of the superjacent waters or of the air space above those waters.](#)

Thus in the absence of an EEZ claim (or claims to some, but not all, of the sovereign rights associated with an EEZ), the coastal State has no rights with regard to the waters over the sea-bed and the airspace above those waters, which have the status of high seas. Except to the extent necessary to make use of its economic rights on the continental shelf, a coastal State must avoid interference with navigation and other rights and freedoms of other States as laid down in the regime of the high seas (considered below).⁵⁹

A coastal State is entitled to a continental shelf of 200 nm (or more in the case of an outer continental shelf) even if it has chosen not to establish an EEZ. Moreover, unlike the EEZ, a coastal

⁵⁶ It follows too that a coastal State has jurisdiction over the harvest and culture of marine algae within its EEZ as well as its territorial sea.

⁵⁷ Freedom of navigation in the EEZ is not absolute, but a balancing exercise between the coastal State and the flag State, inasmuch as by UNCLOS Article 58(3) its exercise is subject to due regard to the coastal State's rights and duties and compliance with its laws in so far as they are not incompatible with Part V of the Convention.

⁵⁸ See http://www.un.org/depts/los/clcs_new/commission_submissions.htm

⁵⁹ UNCLOS, Article 78(2).

State gains its continental shelf by operation of law, without the need to claim it.⁶⁰ Otherwise the rights that a coastal State enjoys over the seabed within its EEZ are essentially the same as those it enjoys over its continental shelf. The question can therefore be legitimately asked as to why there are two separate, albeit similar, regimes over what is effectively the same seabed area? The short answer lies in the negotiating process that led to UNCLOS: disagreements between States as to the respective merits of the EEZ concept coupled with attachment to the idea of the continental shelf as a prolongation of land territory by those countries with larger continental shelves. In practical terms the key difference between the sovereign rights that a coastal State enjoys with regard to its EEZ and the sovereign rights that it enjoys with regard to its continental shelf relates to the scope of application of those rights: rights that derive from an EEZ apply on the surface, in the water column and on the seabed (and beneath) whereas those relate to the continental shelf apply only to the seabed (and beneath).

In practice most States seek to claim all of the maritime zones that they can.⁶¹ Most coastal States have therefore claimed an EEZ that by implication, also applies to the seabed of their continental shelf. Conversely, a State that has not claimed an EEZ still nevertheless enjoys the full range of legal rights over its continental shelf. In this chapter, for the sake of conciseness references to the rights of a coastal State over its continental shelf should also be understood to be a reference to EEZ rights where such a zone has been claimed.

Two other points need to be made about these maritime zones. First of all they can only extend as far as there is sufficient sea space. In the case of narrow or constrained seas, the breadth of the continental shelf and/or EEZ of a coastal State may be limited by those of States on the opposite shore. Moreover, the precise boundaries of such maritime zones (which in the ordinary course of things should logically be the same but in practice may not be⁶²) still need to be precisely delineated and agreed with neighbouring or opposite States or resolved through one of various forms of dispute resolution procedure foreseen by UNCLOS.

At seabed level, beyond the outer edge of the continental shelf (of 200 nm or more if the conditions for this are satisfied) lies the **Area**. This is 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.⁶³ Further provisions on the functioning of ISA are set out in the Part XI Deep Sea Mining Agreement and this will be considered in more detail below.

Above the Area (and 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.⁶⁴ The high seas are the subject of Part VII of UNCLOS. In other words the high seas are subject to a different legal regime to the Area. 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 outer continental shelf (to the extent applicable).⁶⁵

⁶⁰ UNCLOS Article 77(3).

⁶¹ Although the Mediterranean Sea is a partial exception in this respect.

⁶² Such a situation can arise where the continental shelf and EEZ are delimited at different times including where the baseline changes. The legal test for delimitation is however identical as regards the EEZ and continental shelf.

⁶³ Article 137.

⁶⁴ In other words if a coastal State does not claim an EEZ the waters above its continental shelf may also be considered to form part of the high seas.

⁶⁵ For a comprehensive discussion see A.G. Oude Elferink, "The Regime of the Area: Delineating the Scope of Application of the Common Heritage Principle and Freedom of the High Seas", 22 *International Journal of Marine and Coastal Law* 143-176 (2007).

All States enjoy the freedoms of the high seas, which include the freedom of over-flight, fishing and scientific research. Moreover no State may seek to subject any part of the high seas to its sovereignty.

In this connection, though, it should be noted that most of the provisions in UNCLOS relating to maritime zones are generally considered to be declaratory of customary international law.

DSM on the continental shelf

While UNCLOS clearly confers the necessary jurisdiction on each coastal State to regulate DSM on its continental shelf in accordance with its own legislation, it offers very little guidance as to how this is to be done. In other words just as there is no comprehensive international legal framework for the regulation of land based mining, precisely how coastal States are to regulate DSM is not specified in international law. Nevertheless, the rights of coastal States are not absolute. In regulating DSM on its continental shelf, a coastal State may be subject to other more generally applicable rules of international law, including those contained in UNCLOS and other international agreements, in particular as regards environmental matters.

One exception to this general principle concerns DSM on the outer continental shelf. While not specifying how this is to be undertaken, article 82 of UNCLOS does determine what is to happen to the proceeds. More specifically this article requires the coastal State to make annual payments or contributions in kind in respect of DSM in the outer continental shelf. Such payments and contributions are to be made through ISA which is then responsible for distributing them to the parties to UNCLOS on the basis of equitable sharing criteria 'taking into account the interests and needs of developing States, particularly the least developed and the land-locked among them'. The obligation to make such payments and contributions starts five years after the start of production at a particular site at a rate of 1% of the value or volume of production at that site. This subsequently increases by annual increment of 1% to a final rate of 7% from the 12th year onwards.

In contrast, coastal State may retain all of the royalties that they can recover from DSM within 200 nm from the baseline. Moreover coastal States are basically free to determine how such royalties are to be structured and set in accordance with their own economic development priorities and legislation.

DSM in the Area

In contrast to the broad and permissive provisions that relate to DSM on the continental shelf, UNCLOS supplemented by the Part XI Agreement sets out a relatively detailed legal framework for DSM in the Area. Part XI of UNCLOS sets out a number of generally applicable principles with regard to the conduct of States in relation to the Area including peace, security international cooperation and mutual understanding, the responsibility to ensure compliance and liability for damage, the use of the Area for exclusively peaceful purposes. The main focus of Part XI, however, is on the exploration and exploitation the resources of the Area. These are defined in article 133 of UNCLOS as 'all solid, liquid or gaseous mineral resources *in situ* in the Area at or beneath the seabed, including polymetallic nodules'. In other words the focus of Part XI is on very much on DSM.

At the core of Part XI is the notion, already mentioned, that the (mineral) resources of the Area are vested in mankind as a whole on whose behalf ISA is to act. The relevant article goes on to provide that such resources are not subject to 'alienation' although the minerals that are recovered from the Area may be be alienated in accordance with Part XI and the rules, regulations and

procedures of ISA. In other words the role of ISA is to act both as trustee of the resources of the Area and as regulator with regard to DSM undertaken there.

Comprising just under 60 articles, Part XI is one of the longer parts of UNCLOS. Additional more detailed provisions on DSM relating to prospecting, exploration and exploitation are contained in Annex III while Annex IV is concerned with the statute of the 'Enterprise' an organ of ISA. Before examining the how Part XI was amended by the Part XI Deep Sea Mining Agreement it is appropriate also to briefly outline other provisions in UNCLOS that may be relevant to DSM.

Protection of the marine environment

The protection and preservation of the marine environment is the subject of Part XII of UNCLOS. Part XI imposes a general obligation on States to protect and preserve the marine environment⁶⁶ and provides both that States are responsible for fulfilling their international obligations concerning this matter and that they bear liability for the consequences of any breach of such obligations.⁶⁷ Most of the focus of Part XII is on the prevention of pollution although article 206 imposes an obligation on States to undertake 'as far as practicable' an assessment where there are reasonable grounds to believe that the potential impacts of planned activities under their jurisdiction and control may cause 'substantial pollution' or 'significant and harmful changes to the marine environment'. In other words this obligation is not very stringent.

As will be seen below the provisions of Part XII are further elaborated in terms of DSM through other legal instruments. Such instruments are potentially more relevant to DSM in areas under national jurisdiction given that the scheme of UNCLOS is to require the issue of the environmental impact of DSM in the Area to be addressed under the Part XI regime.

Research

The issue of marine scientific research is addressed in Part XIII of UNCLOS. Such research, which is not actually defined in UNCLOS, is still a high seas freedom, but it is subject to the prior consent of the coastal state in the case of research on the continental shelf (and in the EEZ). This would include research relating to DSM. As regards marine scientific research in the Area, the relevant provision of Part XIII provides that all States have the right to conduct marine scientific research but only in conformity with the provisions of Part XI.⁶⁸

Article 143, which provides that scientific research in the Area shall be carried out exclusively for peaceful purposes and for the benefit of mankind as a whole, states that States may carry out marine scientific research in the Area and requires States to 'promote international cooperation' through *inter alia* participation in international programs and disseminating research results. The Authority is also entitled to carry out marine scientific research in the Area. It is, however, important to note that UNCLOS distinguishes between marine scientific research and prospecting and exploration activities relating to (mineral) resources that are subject to the prior approval of the Authority (as described in more detail below).

8.2 Part XI Deep Sea Mining Agreement

Background

The background to the development of the Part XI Deep Sea Mining Agreement lies in the rejection by many industrialized countries of the provisions included in Part XI of the final version of UNCLOS. Concerns were in particular expressed by these countries over provisions on mandated

⁶⁶ Article 192.

⁶⁷ Article 235.

⁶⁸ Article 256.

technology transfer, royalties, taxes and other payments as well as the potentially bloated institutional arrangements and the significant role envisaged for the Enterprise as the ISA organ responsible for directly carrying out activities in the Area.

Pending the entry into force of UNCLOS various interim agreements were concluded between States with an interest in DSM. These included the 1984 Provisional Agreement Regarding Deep Sea Mining (entered into by Belgium, France, the Federal Republic of Germany, Italy, Japan, the Netherlands, the UK and the USA) and the 1987 Agreement on the Resolution of Practical Problems with Respect to Deep Seabed Mining Areas (which was entered into by Canada, Belgium, Italy, the Netherlands, and the then Union of Soviet Socialist Republics).

Eventually following lengthy negotiations the Part XI Deep Sea Mining Agreement was concluded on 28 July 1994, paving the way for the entry force of UNCLOS later that year. Although the Part XI Deep Sea Mining Agreement did not alter the basic principle that the resources of the Area are the common heritage of mankind it does not contain detailed production policies, systems of assistance to land-based producers, tax impositions or provisions on the mandatory transfer of technology. Instead it takes a more market oriented approach that combines a reduction in the size of the institutions of ISA, and broader representation in decision-making bodies.

The relationship between the Part XI Deep Sea Mining Agreement and UNCLOS

The Part XI Deep Sea Mining Agreement has a slightly unusual relationship with UNCLOS. Article 2(1) of the Part XI Deep Sea Mining Agreement provides that its provisions and Part XI of UNCLOS are to be 'interpreted and applied together as a single instrument' with the provisions of the Part XI Deep Sea Mining Agreement prevailing in the event of inconsistency. In other words it is necessary to consider both instruments together in order to understand the current legal regime for DSM in the Area.

ISA

With the entry into force of UNCLOS in 1994, ISA came into existence as an international organisation (and thus a body recognized by international law). The members of ISA are *ipso facto* the parties to UNCLOS and therefore include the EU and its Member States.

The governing bodies of ISA are the Assembly and the Council. The Assembly, which comprises one representative from each ISA member, is the supreme organ of ISA responsible for establishing the general policies of the organisation. The Council, which 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 Deep Sea Mining Agreement so as to provide a balanced composition, 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. There is in addition a Legal and Technical Commission comprising 25 suitably qualified members elected for a five year term by the ISA 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 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. The Secretariat also performs the tasks of the Enterprise on an interim basis.

The regulatory regime

The detailed regulatory regime for DSM is set principally in Annex III of UNCLOS which is entitled 'Basic conditions of prospecting, exploration and exploitation'. 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. The regulatory regime is moreover supplemented by a series of rules, regulations and procedures adopted by ISA that together make up the 'Mining Code'. These include the following five regulations:

- 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);
- Decision of the Council of the International Seabed Authority relating to amendments to the Regulations on Prospecting and Exploration for Polymetallic Nodules in the Area and related matters (ISBA/19/C/17);
- 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);
- 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);
- 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. What is to be noted about the regulations adopted to date is that they are concerned with prospecting and exploration. Regulations on exploitation and royalties have yet to be adopted, although work has begun on their development. In other words although much work has been accomplished to date, the legal framework for DSM in the Area is yet to be completed.

Finally it is important to note that in accordance with article 139(1) a State must ensure that activities in the Area carried out by natural or legal persons that possess the nationality of that State or are effectively controlled by nationals of that State must be carried out in conformity with Part XI. Moreover article 4(4) of Annex III of UNCLOS provides that such a sponsoring State or States has the responsibility to ensure, within its legal system that a contractor so sponsored shall carry out activities in the Area in conformity with the terms of its contract and its obligations under UNCLOS. The article goes on to provide, however that a sponsoring State will not, however, be liable for damage caused by any failure of a contractor sponsored by it to comply with its obligations if that State 'has adopted laws and regulations and taken administrative measures which are, within the framework of its legal system, reasonably appropriate for securing compliance by persons under its jurisdiction'.

The obligations of sponsoring States were further examined by the International Tribunal for the Law of the Sea, a specialist international court established under UNCLOS, in its advisory opinion of February 2011 on the 'Responsibilities and obligations of States sponsoring persons and entities with respect to activities in the Area'.⁶⁹

8.3 Convention on Biological Diversity

As noted above, UNCLOS imposes rather general obligations on States to protect the marine environment, including within waters and the seabed subject to their national jurisdiction. The Convention on Biological Diversity (CBD),⁷⁰ to which the EU and the Member States are Contracting Parties, strengthens these obligations.

⁶⁹ 1 February, 2011, Case No. 17.

⁷⁰ 31 ILM (1992), 822.

The jurisdictional scope of the CBD is specified in Article 4. This states:

Subject to the rights of other States, and except as otherwise expressly provided in this Convention, the provisions of this Convention apply, in relation to each Contracting Party:

- (a) in the case of components of biological diversity, in areas within the limits of its national jurisdiction; and
- (b) in the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction.

While article 3 of the CBD expresses the general responsibility of all States to ensure that activities within their jurisdiction or control do not cause damage to the environment of areas beyond national jurisdiction,, the Contracting Parties to the CBD are urged to cooperate with other Contracting Parties directly or where appropriate, through competent international organisations for the conservation and sustainable use of biological diversity.⁷¹

Article 8 of the CBD provides the following specific responsibilities for Contracting Parties in relation to protected areas, ecosystems and natural habitats within national jurisdiction:

- (a) Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;
- (b) Develop, where necessary, guidelines for the selection, establishment and management of protected areas or where special measures need to be taken to conserve biological diversity;
- (c) Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their conservation or sustainable use;
- (d) Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;
- (e) Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas.

Moreover the Contracting Parties are required to prepare and update inventories of biological resources as a basis for planning and decision-making. The CBD also obliges its parties to develop national strategies for the conservation and sustainable use of biological diversity, including the establishment of protected areas. Moreover it requires the Contracting Parties to integrate the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies. The CBD itself envisages that its provisions should be applied with respect to the marine environment consistently with the rights and obligations of States under the law of the sea.⁷²

As seen the CBD's jurisdictional scope is not limited to areas under national jurisdiction. Although it is clearly understood that any measures beyond the limits of national jurisdiction must be carried out within the framework of the UNCLOS legal regime, the CBD has stimulated a recognition of the importance ecosystems and habitats in the marine environment. The CBD is relevant to DSM particularly as regards activities undertaken within areas under national jurisdiction. Coastal States authorizing such activities must ensure that these are in conformity with their obligations under the CBD.

⁷¹ Article 5.

⁷² Article 22(2).

8.4 London Convention

Article 210 of the UNCLOS provides for the legislative powers of (coastal) States with regard to dumping at sea. Article 210 states:

1. States shall adopt laws and regulations to prevent, reduce and control pollution of the marine environment by dumping.
2. States shall take other measures as may be necessary to prevent, reduce and control such pollution.
3. Such laws, regulations and measures shall ensure that dumping is not carried out without the permission of the competent authorities of States....

In other words UNCLOS clearly foresees that any dumping shall not be carried out without the express prior approval of the coastal State, which has the right to permit, regulate and control such dumping.⁷³ UNCLOS grants coastal States the right to enforce generally accepted international rules and standards vis-à-vis foreign vessels: pursuant to Article 216(1) laws and regulations adopted in accordance with Article 210 and applicable international rules and standards established through competent international organisations or diplomatic conferences for the prevention, reduction and control of pollution by dumping shall be enforced by the coastal State with regard to dumping within its EEZ or onto its continental shelf.

At the international level this issue is regulated through the legal regime of the London Convention. The original Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter⁷⁴ (the London Convention) imposed a system with three different categories: dumping of waste of category I was generally prohibited, waste of category II required a prior special permit, for waste of category III a prior general permit was needed. Contracting Parties were required to designate an authority to deal with permits, keep records, and monitor the condition of the sea (Article VI).

The 1996 Protocol to the London Convention⁷⁵ was agreed to further the Convention and to replace it among its parties. As of March 2008 the EU Member States having ratified the Protocol are Belgium, Bulgaria, Denmark, France, Germany, Ireland, Italy, Luxembourg, Slovenia, Spain, Sweden and the United Kingdom. Member States not already listed which are parties to the 1972 Convention are Cyprus, Finland, Greece, Hungary, Malta, the Netherlands, Poland and Portugal.⁷⁶ The Protocol prohibits all at-sea incineration of wastes, waste storage in the seabed, and all other waste dumping, except for a "reverse list" of substances that may be dumped at sea. The London Convention would appear to be potentially relevant to DSM in terms of the disposal of waste in the course of mining activities undertaken within areas under national jurisdiction given that the general scheme of UNCLOS is to confer a full set of regulatory responsibilities on ISA in terms of DSM in the Area. The precise relationship between the London Convention (and any applicable regional seas agreements) and DSM is an issue that will require further analysis.

8.5 Agreements on navigation concluded under the auspices of IMO

As a framework convention, UNCLOS does not itself set out binding rules regarding the safety of navigation but confines itself to stating where the authority to make such rules lies. It does this through the incorporation by reference of the rules made by what it refers to as the "competent

⁷³ Article 210(5).

⁷⁴ London, Mexico City, Moscow and Washington, 29 December 1972; 1046 UNTS 120.

⁷⁵ London, 7 November 1996; (1997) 36 *ILM* 1.

⁷⁶ Taken from the IMO status list spreadsheet www.imo.org/includes/blastDataOnly.asp/data_id%3D22499/status-x.xls

international organization” namely the International Maritime Organisation (IMO).⁷⁷ Aspects of IMO’s overall mandate of potential relevance to DSM include: (i) vessel-source pollution; (ii) maritime safety; and (iii) maritime security.

Within the auspices of IMO, a wide range of binding and non-binding instruments have been adopted. Of these, the most important binding instruments include:

- The Convention on the International Regulations for Preventing Collisions at Sea, London, 20 October 1972 (COLREG 72) In force 15 July 1977, as regularly amended;⁷⁸
- The International Convention for the Prevention of Pollution from Ships, London, 2 November 1973, as modified by the 1978 Protocol (London, 1 June 1978) (MARPOL 73/78) and the 1997 Protocol (London, 26 September 1997) and as regularly amended;⁷⁹
- The International Convention for the Safety of Life at Sea, London, 1 November 1974 (SOLAS 74) as regularly amended;⁸⁰
- The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, London, 1 December 1978 as amended in 1995 and 2010;⁸¹
- The International Convention on the Control of Harmful Anti-fouling Systems on Ships, London, 5 October 2001;⁸²
- The International Convention for the Control and Management of Ships’ Ballast Water and Sediments, London, 13 February 2004 (BWM Convention),⁸³
- The International Convention on Oil Pollution Preparedness, Response and Co-operation, London, 30 November 1990. In force 13 May 1995,⁸⁴
- The Protocol on Preparedness, Response and Co-operation to Pollution Incidents by Hazardous and Noxious Substances, London, 15 March 2000 (2000 HNS Protocol). In force 14 June 2007;⁸⁵
- The International Convention on Civil Liability for Oil Pollution Damage, Brussels, 29 November 1969. In force 19 June 1975;⁸⁶
- The International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, Brussels, 18 December 1971. In force 16 October 1978 and as amended in 1992 and 2003;⁸⁷
- The International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea, London, 3 May 1996. Not in force;⁸⁸
- The International Convention on Civil Liability for Bunker Oil Pollution Damage, London, 23 March 2001. In force 21 November 2008.⁸⁹

All of these instruments, which are legally binding or will be legally binding when they enter into force, have a global scope of application. Moreover they contain a wide range of different types of standard including (i) discharge and emission standards; (ii) construction, design, equipment and manning standards; (iii) navigation standards; (iv) contingency planning and preparedness standards; and (v) liability, compensation and insurance standards.

⁷⁷ Although not named as such, the IMO is universally regarded as the body meant by this phrase.

⁷⁸ 1050 *United Nations Treaty Series* 16.

⁷⁹ 1340 *United Nations Treaty Series* 62.

⁸⁰ 1184 *United Nations Treaty Series* 278.

⁸¹ 1361 *United Nations Treaty Series* 190. In force 28 April 1984, as amended and modified by the 1995 Protocol.

⁸² In force 17 September 2008, IMO Doc. AFS/CONF/26, of 18 October 2001.

⁸³ Not in force, IMO Doc. BWM/CONF/36, of 16 February 2004.

⁸⁴ 30 *International Legal Materials* 733 (1990).

⁸⁵ IMO Doc HNS-OPRC/CONF/11/Rev.1, of 15 March 2000.

⁸⁶ 9 *International Legal Materials* 45.

⁸⁷ 11 *International Legal Materials* 284.

⁸⁸ 35 *International Legal Materials* 1415.

⁸⁹ OJ L 256/7 (2002).

The legal framework for navigational issues created under the auspices of IMO is potentially relevant in terms of the safety of vessels and floating structures used for DSM. More specifically such vessels will likely be subject to the various IMO conventions although they are not subject to a specific regulatory regime of their own.

8.6 Regional agreements

In addition to the international agreements of global application described in the previous paragraphs a number of agreements regarding the sea and its protection and use have been concluded at the regional level and which therefore form part of the regional international law framework with potential relevance to the DSM. These include the Barcelona Convention, which applies to the Mediterranean and Black Seas, the OSPAR Convention which applies to parts of the North Atlantic Ocean and the Noumea Convention which applies to parts of the Pacific Ocean.

The **Barcelona Convention**⁹⁰ was concluded within the framework of the Regional Seas Programme of the United Nations Environment Programme (UNEP), which is intended to foster regional co-operation for the benefit of the marine and coastal environment. The EU and its Mediterranean and Black Sea Member States are party to the Barcelona Convention. The Barcelona Convention is essentially a framework convention. Although it sets out a number of general obligations (in article 4) as well as specific norms relating to certain activities (such as pollution caused by dumping (article 5), pollution from ships (article 6), pollution from land based sources (article 8), and the conservation of biodiversity (article 10) these tend to be somewhat qualified in that the contracting parties are required to take 'appropriate measures', or to undertake measures 'as far as possible'.

Most of the detail of the legal framework created under the auspices of the Barcelona Convention is contained in a series of protocols adopted at diplomatic conferences of the contracting parties in accordance with article 21. Most of the protocols, which require the contracting parties to implement their provisions through national legislation, relate to measures against pollution.

The historical focus of the **OSPAR Convention**⁹¹, and the earlier Oslo and Paris Conventions from which it emerged, has been on pollution prevention. It also requires the Contracting Parties to 'take the necessary measures to protect the maritime area against the adverse effects of human activities so as to safeguard human health and to conserve marine ecosystems and, when practicable, restore marine areas which have been adversely affected'.⁹² In addition, the OSPAR Commission, established pursuant to the OSPAR Convention, may adopt non-binding recommendations and also binding decisions (Articles 10 (3) and 13). There are currently 16 parties to the OSPAR Convention: the coastal States bordering the North-East Atlantic except the Russian Federation, three States (Finland, Luxemburg and Switzerland) that are located upstream on watercourses reaching the OSPAR Maritime Area, and the EU.

The OSPAR Convention contains a set of basic rules and principles which are elaborated in its 5 Annexes and 3 accompanying Appendices. The four Annexes that were adopted together with the Convention deal with pollution from land-based sources (Annex I), pollution by dumping or incineration (Annex II), pollution from offshore sources (Annex III) and the assessment of the quality of the marine environment (Annex IV). Annex V on the Protection and Conservation of Ecosystems and Biological Diversity of the Maritime Area was adopted in 1998, together with Appendix 3

⁹⁰ Convention for the Protection of the Marine Environment and Coastal Regions of the Mediterranean. Originally the Convention for the Protection of the Mediterranean Sea against Pollution, Barcelona, 16 February 1976; 1102 UNTS 27.

⁹¹ Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

⁹² Article 2(1)(a).

containing criteria for identifying human activities for the purpose of Annex V, and entered into force in 2000. The main pillars to guide the implementation of the OSPAR Convention and its Annexes are the six strategies that were reaffirmed and updated in 2003, including the Biological Diversity and Ecosystems Strategy (OSPAR Biodiversity Strategy).⁹³

Annex V expands on the OSPAR Convention in terms of nature conservation provisions. In order to perform their obligations under the OSPAR Convention and the Convention on Biological Diversity, the Contracting Parties are obliged by Article 2 of Annex V:

- to take the necessary measures to protect and conserve the ecosystems and the biological diversity of the maritime area, and to restore, where practicable, marine areas which have been adversely affected; and
- to co-operate in adopting programs and measures for those purposes for the control of the human activities identified by the application of the criteria in Appendix 3 of Annex V.

Measures according to Annex V include the designation and the establishment of marine areas or rather a system of marine areas that need to be protected by means of appropriate programs and measures against the adverse effects of human activities.

The **Noumea Convention**,⁹⁴ which was adopted in 1986, aims to ensure that resource development in the Pacific takes place in harmony with the maintenance of the unique environmental quality of the region and the evolving principles of sustained resource management. The parties to the Noumea Convention are the Cook Islands, Fiji, Federated States of Micronesia, Nauru, Papua New Guinea, Republic of the Marshall Islands, Samoa and the Solomon Islands. The Convention has two Protocols: one on dumping and the other on cooperation in combating oil pollution. It applies to contracting Parties' EEZs and also to areas of the high seas beyond national jurisdiction that are completely enclosed by these EEZs (the 'Convention Area').

The Noumea Convention requires contracting Parties to prevent, reduce and control pollution of the Convention Area, from any source, and to ensure sound environmental management and development of natural resources, using for this purpose the best practicable means at their disposal, and in accordance with their capabilities. Moreover the parties must prevent, reduce and control pollution in the Convention Area caused by discharges from vessels, and resulting directly or indirectly from exploration and exploitation of the seabed and its subsoil.

Again such regional agreements are more likely to be relevant to DSM undertaken in areas under national jurisdiction.

⁹³ Strategies of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic, Chapter I (OSPAR Agreement 2003-21; Summary Record OSPAR 2003, OSPAR 03/17/1-E, Annex 31).

⁹⁴ The Convention for the Protection of Natural Resources and the Environment of the South Pacific Region

9 EU law

As already mentioned, the European Union (EU) and all of the Member States are parties to UNCLOS. Consequently, as recognised by the European Court of Justice (ECJ) its provisions form ‘an integral part’ of the EU legal order.⁹⁵ It is, moreover, now clearly established that EU law applies to maritime areas over which EU Member States have jurisdiction.⁹⁶ In other words EU law will apply to DSM and related activities conducted on the continental shelf of a Member State.

At the outset it is important to note that, unlike marine hydrocarbon extraction, which is subject to the regulatory framework created by the Hydrocarbons Directive⁹⁷, the topic of DSM is not directly addressed in EU law. Instead most of the instruments of EU law that are potentially relevant to DSM are concerned with environmental protection.

9.1 The Environmental Impact Assessment Directive

The Environmental Impact Assessment Directive⁹⁸ requires the environmental consequences of certain public and private projects that are likely to have significant effects on environment by virtue, *inter alia*, of their nature, size or location to be assessed before authorisation. Article 2(1) provides:

Member States shall adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue *inter alia* of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects.

For certain projects listed in Annex I to the directive, an environmental impact assessment (EIA) is obligatory whereas for projects listed in its Annex II, Member State authorities are required to determine through a case-by-case examination or general thresholds or criteria whether the project is to be made subject to an assessment (Article 4(2)(1)). In all cases the criteria of Annex III must be taken into account.

While shore based mining (‘underground mining’) and quarrying activities and large-scale commercial oil and gas extraction are both listed in Annex I, along with a number of maritime activities such as the construction of large trading ports, there is no specific reference in the directive to DSM. Nor is DSM listed in Annex II even though the ‘extraction of minerals by marine or fluvial dredging’ is together with a range of coastal defence works. In other words, unless DSM can be characterised as the extraction of minerals by marine dredging, it does not appear that the directive currently imposes any requirement for EIA for DSM activities in maritime areas subject to the jurisdiction of the Member States.

9.2 Strategic Environmental Assessment Directive

The Strategic Environmental Assessment Directive⁹⁹ (the SEA Directive) requires a formal environmental assessment of certain plans and programmes which are likely to have significant

⁹⁵ Case C-459/03, *Commission v. Ireland*, [2006] ECR I-4635.

⁹⁶ See, for example, Case 61/77 *Commission v Ireland* [1978] ECR 417, paragraphs 45 to 51.

⁹⁷ Directive 94/22/EC of the European Parliament and of the Council of 30 May 1994 on the conditions for granting and using authorizations for the prospection, exploration and production of hydrocarbons (OJ L 79, 29.3.1996).

⁹⁸ Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (OJ L 26, 28.1.2012, p. 1).

effects on the environment. The plans and programme that are subject to strategic environmental assessment (SEA) are defined in Article 2 (a). This provision states ‘plans and programmes’ shall mean plans and programmes, including those co-financed by the European Community, as well as any modifications to them:

- which are subject to preparation and/or adoption by an authority at national, regional or local level or which are prepared by an authority for adoption, through a legislative procedure by Parliament or Government, and
- which are required by legislative, regulatory or administrative provisions.

Authorities which prepare and/or adopt such a plan or programme must prepare a report on its likely significant environmental effects and alternatives, propose mitigation measures, consult environmental authorities and the public, and take the report and the results of the consultation into account during the preparation process and before the plan or programme is adopted. They must also make information available on the plan or programme as adopted and how the environmental assessment was taken into account.

According to the SEA Directive an environmental assessment has to be carried out for plans and programmes which are likely to have significant environmental effects. The SEA Directive applies to plans and programmes which are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism, and which set the framework or future development consent of projects listed in Annexes I and II to the EIA Directive (see below). The SEA Directive also applies to plans and programmes requiring an assessment pursuant to the Habitats Directive.

In other words it would appear that the preparation of comprehensive plans or programs relating to DSM, as well as maritime spatial plans that address the topic of DSM will require a SEA in accordance with the requirements of the SEA Directive. Article 7 of the SEA Directive contains express provisions on transboundary consultation in cases where a proposed plan or programme is likely to have significant effects on the environment in another Member State, or where a Member State likely to be significantly affected so requests.

9.3 The Marine Strategy Framework Directive (MSFD)¹⁰⁰

The MSFD constitutes the environmental pillar of the EU’s Integrated Maritime Policy.¹⁰¹ It requires the Member States to “take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest”.¹⁰²

The MSFD applies to all ‘marine waters’, which are defined in Art. 3(1) to mean the waters, seabed and subsoil that extend from the baseline of the territorial sea to the ‘outermost reach of the area where a Member State has or exercises jurisdiction’. In other words the MSFD applies to the outermost boundary of the continental shelf (including beyond 200 nm as applicable) and/or EEZ.

The Directive does not directly restrict any maritime activities and therefore does not as such restrict or prevent DSM. Nevertheless the directive is potentially relevant to DSM in seabed areas

⁹⁹ Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (*OJ L 197, 21.7.2001, p. 30*).

¹⁰⁰ Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for Community action in the field of marine environmental policy *OJ L 240, 10.7.2004, p. 17*.

¹⁰¹ Recital 3 of the Directive.

¹⁰² Article 1(1).

subject to Member State jurisdiction to the extent that such activities may hinder the achievement of 'good environmental status'.

The definition of "good environmental status" is based on a list of generic qualitative descriptors contained in an Annex to the MSFD, stipulating, for example that biological diversity should be maintained (No. 1), that populations of all commercially exploited fish and shellfish in that Region are within safe biological limits (No. 3), that human-induced eutrophication is minimised (No. 5), or that sea floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected (No.6), that the permanent alteration of hydrographical conditions does not adversely affect marine ecosystems (No. 7), that the properties and quantities of marine litter do not cause harm to the coastal and marine environment (No. 10) and that the introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment (No. 11).

For the purpose of achieving good environmental status, marine strategies are to be developed and implemented in order: to protect and preserve the marine environment, prevent its deterioration, or, where practicable, restore marine ecosystems in areas where they have been adversely affected; and to prevent and reduce inputs in the marine environment with a view to phasing out pollution so as to ensure that there are no significant impacts on or risks to marine biodiversity, marine ecosystems, human health or legitimate uses of the sea.¹⁰³

The procedure for the development of marine strategies is set out in Chapter II of the directive. In outline it requires the Member States to make an initial assessment of their respective marine waters,¹⁰⁴ by reference to various specified criteria and common methodological standards¹⁰⁵, which is then to be used to inform the determination of a set of characteristics for 'good environmental status'¹⁰⁶ which must be notified to the European Commission. The initial assessment is also to be used to establish a comprehensive set of environmental targets¹⁰⁷ and associated indicators to be used to guide progress towards achieving good environmental status. Next each Member State must establish coordinated monitoring programmes for the on-going assessment of environmental status in its marine waters.¹⁰⁸ Following the formal approval by the European Commission of the characteristics for good environmental status, the environmental targets and the monitoring programmes, each Member State must develop, adopt and implement a programme of measures necessary to achieve good environmental status.¹⁰⁹

While substantial progress has been made to date with regard to the implementation of the MSFD, it is important to note that the process is still in a relatively early stage of implementation with the first Member State reports (relating to articles 8, 9 and 10) currently being evaluated by the European Commission.

In implementing their obligations under the MSFD, Member States must take account of the fact that marine waters subject to their sovereignty or jurisdiction form of an integral part of four marine regions namely the Baltic Sea, the North East Atlantic Ocean, the Mediterranean Sea and the Black Sea. Article 4(2) goes on to provide that Member States may, in order to take into account the specificities of a particular area, implement the Directive by reference to subdivisions of the marine regions provided these are defined in a manner compatible with a number of marine sub-regions. In order to achieve coordination so as to ensure a coherent approach across marine regions and sub-

¹⁰³ Article 1(2).

¹⁰⁴ Article 8.

¹⁰⁵ Commission Decision of 1 September 2010 on criteria and methodological standards on good environmental status of marine waters OJ L 232, 2.9.2010, p. 14.

¹⁰⁶ Article 9.

¹⁰⁷ Article 10.

¹⁰⁸ Article 11.

¹⁰⁹ Article 13.

regions, Member States are required to use relevant existing regional cooperation structures including those under Regional Seas Conventions (such as the Barcelona Convention mentioned above). The MSFD clearly states that marine protected areas (MPAs) must be part of the national programmes of measures. Apart from MPAs, the MSFD gives only general indications as to what type of measures must be taken to achieve a good environmental status. Measures proposed for inclusion in programmes of measures include *inter alia*¹¹⁰:

- Input controls: management measures that influence the amount of a human activity that is permitted;
- Management coordination measures: tools to ensure that management is coordinated;
- Spatial and temporal distribution controls: management measures that influence where and when an activity is allowed to occur;
- Mitigation and remediation tools: management tools which guide human activities to restore damaged components of marine ecosystems.

9.4 The Birds Directive and the Habitats Directive

The Birds Directive¹¹¹ and the Habitats Directive¹¹² are *inter alia* the means by which the EU meets its obligations as a party to the Convention on the Conservation of European Wildlife and Natural Habitats¹¹³ (the 'Berne Convention'). The Birds Directive calls for the establishment of Special Protected Areas (SPAs) for birds, while Special Areas of Conservation (SACs) for habitats or species are implemented through the Habitats Directive.

It is now settled law, however, that both directives also apply to areas under the jurisdiction of coastal Member States including the EEZ and continental shelf. The issue of geographical coverage was referred to by the Commission¹¹⁴:

... if a Member State exerts its sovereign rights in an exclusive economic zone of 200 nautical miles (for example, the granting of an operating license for a drilling platform), it thereby considers itself competent to enforce national laws in that area, and consequently the Commission considers in this case that the "Habitats" Directive also applies, in that Community legislation is an integral part of national legislation.

As the Habitats Directive regulates habitats beyond 12 nm offshore (listed in Annex 1 are "reefs" and "submerged sandbanks") and species occurring in the EEZ, its functional jurisdiction should be beyond doubt.

There is also political agreement at EU level that the Directives apply to the EEZ of those EU Member States that have declared EEZs. The Council of Ministers has also encouraged the Member States 'to continue their work towards the full implementation of the Birds and Habitats Directives in their exclusive economic zones'¹¹⁵. As to Member States not having declared an EEZ, following a ruling of the UK High Court, the Habitats Directive was found to apply to the UK Continental Shelf, and the waters above the seabed, up to a limit of 200 nautical miles from the baseline.¹¹⁶

¹¹⁰ See Annex VI dealing with Programmes of measures referred to in Articles 13(1) and 24.

¹¹¹ Council Directive of 2 April 1979 on the conservation of wild birds (79/409/EEC) *OJ L 103, 25.4.1979, p. 1.*

¹¹² Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora *OJ L 206, 22.7.1992, p. 7.*

¹¹³ Berne, 19 September 1979; 1284 UNTS 209.

¹¹⁴ COM (1999) 363 final Communication from the Commission to the Council and the European Parliament "Fisheries Management and Nature Conservation in the Marine Environment" (p10)

¹¹⁵ 2344th Council Meeting, Fisheries, 25 April 2001, Council Conclusions on the integration of environmental concerns and sustainable development into the Common Fisheries Policy, 8077/01, Luxembourg.

¹¹⁶ R v. The Secretary of State for Trade and Industry *ex parte* Greenpeace Limited Case No: CO/1336/1999.

Thus each Member State is required to establish a national list of sites in proportion to the representation within its territory of the natural habitat types and the habitats of species listed in the Directives.

Despite the apparent readiness of Member States to act, however, progress in conserving Europe's marine biodiversity has been rather limited, especially as regards the impact of fisheries. A major constraint for the designation of fully-fledged MPAs has resulted from uncertainty as to who has competence for placing restrictions on commercial fishing activities: the EU or the Member States.

On the one hand Member States are responsible for the protection of sites (i.e. designated under the Birds and Habitats Directives) while on the other hand their ability to regulate fisheries activities has been unclear. The question at stake was if such restrictions may be based on legislation implementing the Habitats-Directive or may only be taken in the context of the CFP, and by whom – either by the Member State unilaterally or by the Council. As the answer to these questions has not been clear for quite some time, there was the urgent need for clarification¹¹⁷. In 2007 the European Commission issued guidelines for the establishment of the Natura 2000 network in the marine environment as well as a paper on the introduction of fisheries measures for marine Natura 2000 sites in order to give guidance to Member State authorities when preparing and requesting fisheries management measures under the CFP. These documents are not, however, of a legally binding nature.

In terms of its requirements, the Habitats Directive requires the establishment of a coherent European ecological network of special areas of conservation (SAC) to be set up under the title 'Natura 2000'. The network is to include: (a) sites hosting the natural habitat types listed in its Annex I; and (b) habitats of the species listed in Annex II, so as enable such habitat types and species habitats to be maintained at a favourable conservation status.

Natura 2000 also includes SPAs established pursuant to the Birds Directive. Each Member State is required to contribute to Natura 2000 in proportion to the representation within its territory of the natural habitat types and the habitats of species. The basic procedure is for each Member State to propose a list of sites to the European Commission, which then establishes a draft list of sites of Community importance. Once the list of sites of Community importance is established the Member States have to designate such sites as SACs and to establish priorities for them.

Member States must also establish the necessary conservation measures for SACs including as necessary management plans and other statutory, administrative or contractual measures. In addition Member States are under a duty to take appropriate steps to avoid the deterioration of national habitats and the habitats of species within SACs as well as the significant disturbance of such species. Moreover plans or projects that may have significant impacts on SACs, even if not directly connected with them, must be subject to an appropriate assessment. Plans or projects with a negative assessment may only be carried out for imperative reasons of overriding public interest, including those of a social or economic nature and provided all compensatory measures are taken to protect the overall coherence of Natura 2000. The potential interaction between this directive and DSM could therefore arise if DSM activities were to negatively impact on a marine SAC.

Member States are required to undertake surveillance of the conservation status of natural habitat types and species. The types of marine habitat listed are:

1. 1170 "reefs", and
2. 1180 "submarine structures made by leaking gases"

¹¹⁷ For a comprehensive analysis as to the legal questions involved, see Owen, D., "Interaction between the EU Common Fisheries Policy and the Habitats and Birds Directives", Institute for European Environmental Policy, 2004.

As regards species conservation Member States must take requisite measures to establish a system of strict protection for a number of animal species listed in Annex IV of the directive which include a number of marine species. It does not appear, on the basis of an initial assessment such species are likely to be affected by DSM.

The Habitats Directive applies to the continental shelf and to any maritime zones claimed by Member States. Basically SACs must be established if they contain various habitat types listed in Annex I or if they are the habitats of the species types listed in Annex II. All of the marine habitat types are located on the seabed and thus already covered by the continental shelf regime. However the water column may provide the habitat of relevant species listed in Annex 2.

9.5 Waste legislation

A feature of DSM, like any kind of mining activity, is the production of waste. The overall legal framework for waste management in the EU is set out in the Waste Framework Directive,¹¹⁸ which is accompanied by additional instruments concerned with different types of waste and disposal methods. The Waste Framework Directive sets out a number of basic concepts and definitions relating to waste management while also setting out basic waste management principles.

The Waste Framework Directive identifies a number of categories of waste that are excluded from its scope, including mining waste covered by the 2006 Mining Waste Directive.¹¹⁹ However it is important to note that the Mining Waste Directive itself does not apply to waste generated as a result of DSM: article 2(2)(b) provides that it does apply to 'waste resulting from the offshore prospecting, extraction and treatment of mineral resources'. In other words mining wastes generated through DSM on the continental shelf/EEZ of a Member State is *prima facie* subject to the Waste Framework Directive. Moreover the Waste Framework Directive expressly lists release of waste to seas/oceans as a category of waste disposal operation for which a permit is required and moreover refers to the London Convention and Protocol, mentioned above, in the recitals. Nevertheless given the manner in which wastes are generated in terms of DSM it is hard to conclude, on the basis of an initial analysis, that this topic is at present either clearly or appropriately regulated in terms of EU law, which is not surprising given that DSM in European waters has yet to commence.

9.6 Maritime spatial planning directive

In April 2014 the European Parliament adopted a Directive on maritime spatial planning. The Directive will require Member States to develop-maritime spatial plans covering the activities taking place in their 'marine waters' as defined in the MSFD and including the water column, seabed and subsoil.

The Directive includes a number of policy objectives for maritime spatial planning (MSP), including securing the EU's energy supply, and also lists a number of maritime activities that that must be taken into consideration, including maritime transport routes, fishing areas and marine protected areas. However, although it does not contain any explicit reference to DSM, this would be expected to be addressed in any assessment of activities taking place within the areas covered by

¹¹⁸ Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (OJ L 312, 22/11/2008, p. 3).

¹¹⁹ Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC (OJ L 102, 11.4.2006, p. 15).

a Maritime Spatial Plan. The potential interactions between DSM and other uses made of marine and coastal resources should also be addressed so that the effective planning for their sustainable development and utilisation can be successfully carried out.

10 National legislation

Before turning to the issue of national legislation relating to DSM it is worth recapping which levels of law apply within the different spatial and jurisdictional contexts listed in the terms of reference.

In outline, international law underpins the entire legal framework for DSM. DSM on the continental shelf of a Member State is subject to the national legislation of the Member State concerned as well as EU law, both of which are informed by international law. Similar observations apply to the overseas countries and territories of EU Member States (OCTs) to the extent that EU law applies a matter this is considered in more detail below.

In the case of countries that are not members of the EU, EU law obviously does not apply.¹²⁰ DSM on the continental shelf of such a country takes place in accordance with the national legislation of that country as guided or informed by international law. Put another way national legislation on DSM should give effect to international law. Otherwise a coastal State is broadly free to regulate, authorise or prohibit DSM in accordance with its own development and environment policies.

As regards DSM in the Area, the basic regime is set out under international law in the form of Part XI of UNCLOS and the Part XI Agreement. However, as noted above, the primary subjects of international law are States and international organisations. While the regime for the Area imposes duties on States as a matter of international law, States must set up appropriate mechanisms to control or regulate activities undertaken in the Area in respect of which they are responsible as States. As observed by ITLOS in its advisory opinion, mentioned above, this implies the adoption of national legislation by States to adopt legislation to regulate such activities.

To return to the question posed in the terms of reference concerning the law applicable in four different spatial and jurisdictional contexts it is important to notice that multiple levels of law apply in each case.

In the case of maritime areas under the jurisdiction of EU Member States DSM must be undertaken in accordance with national law which must in turn give effect to the obligations of the Member States under EU law and international law.

In the case of the maritime areas under the jurisdiction of the OCTs of the Member States in brief, DSM must be undertaken in accordance with the laws of those OCTs, which may or may not be the same as the laws applicable in the Member States with which those OCTs are connected. It is important to note that EU law relevant to DSM does not apply in the OCTs although EU law may shape and influence the applicable laws of those OCTs either because the law of the relevant Member State applies there or because it has influenced the applicable law. The applicable law should also give effect to the requirements of international law even though the OCTs do not have the legal status of States recognised by international law.

In the case of the maritime areas of third countries, EU law obviously does not apply. Instead DSM must be undertaken in accordance with the national laws of those countries, which should in turn give effect to the requirements of international law.

¹²⁰ However certain Member States of the European Free Trade Association (namely Iceland, Liechtenstein and Norway) have must apply elements of EU law in the context of the European Economic Area.

Finally there is the case of DSM undertaken in the Area. Obviously such activity falls to be governed by the specific regime for DSM set out in UNCLOS, the Part XI Deep Sea Mining Agreement and the Mining Code. However, and this is a key point to emphasize, such activities must also take place in accordance with the applicable national legislation of the State that sponsors the person or entity engaged in DSM even if the vessel or structure used is registered in another country. In other words in all four scenarios the applicable legal framework for DSM derives from multiple levels of law.

10.1 Member States

The process of acquiring and analysing the legislation applicable to Member States, OCTs and third countries is now well under way. It is envisaged that the draft final report will contain summaries of the jurisdictions listed below as well as a comparative analysis:

- a. EU Member States: Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, and the United Kingdom;
- b. OCTs: Greenland, New Caledonia and Dependencies, French Polynesia, French Southern and Antarctic Territories, Wallis and Futuna Islands, Mayotte, Saint Pierre and Miquelon, Aruba, Bonaire, Curaçao, Saba, Sint Eustatius, Sint Maarten, Anguilla, Cayman Islands, Falkland Islands, South Georgia and the South Sandwich Islands, Montserrat, Pitcairn, Saint Helena and Dependencies, British Antarctic Territory, British Indian Ocean Territory, Turks and Caicos Islands, British Virgin Islands and Bermuda;
- c. Third countries: Canada, China, Fiji, Japan, Papua New Guinea and the United States of America.

Preliminary summaries from the first four jurisdictions are attached as Annex 1. It is, however, premature to attempt to draw conclusions from these at this time.

11 Preliminary observations

A more complete analysis will be provided in the draft final report. At this stage, however, the following preliminary observations can be made.

First of all, the basic legal framework for DSM, including the issue as to which actor under international law (in other words the relevant coastal State or ISA) has jurisdiction for the purpose of regulating such activities, is set out in UNCLOS as modified by the Part XI Deep Sea Mining Agreement.

In the case of the legal regime for the Area, however, the Mining Code has yet to be completed. In particular regulations on exploitation and the complex issue of royalties remain to be resolved. Moreover sponsoring States need to be able to effectively control the persons and entities whom they sponsor which implies the need for specific legislation on this topic.

As regards DSM in areas under national jurisdiction the coastal State clearly has regulatory jurisdiction in terms of international law and can design and adopt its own legislation accordingly. There are no international standards for DSM as such. While coastal States are subject to a number of obligations in terms of international agreements of global or regional application these tend to be of a rather general nature and the extent to which they may affect DSM is not entirely clear.

As regards EU law, the preliminary analysis suggests that DSM is not subject to a requirement for EIA although there may potentially be important interactions with the MSFD and Habitats Directive. Nor is it yet entirely clear how EU waste management provisions affect DSM. Moreover the topic of DSM is not directly referred to in the proposed MSP directive.

C. Task 6 Environmental analysis

12 Introduction

12.1 Background and overview of the environmental analysis

Although commercial deep sea mining has yet to be developed, a considerable amount of scientific information has been generated on the physical properties of sea-floor massive sulphides, manganese nodules, and cobalt-rich ferromanganese crusts¹²¹. However the habitats, biodiversity, ecosystem structure, and resilience associated with these types of mineral deposits are less well-understood. Sufficient information exists on the drivers of ecosystem structure and faunal distributions to inform environmental policy discussions related to the exploration and exploitation of deep-sea mineral resources. If deep sea mining is developed environmental policies will need to be adjusted as new information, technologies and working practices emerge. This will require an ongoing, collaborative approach involving industry representatives, policy makers, field scientists and subject matter experts, environmental managers, government authorities, international agencies, civil society and the general public.

The three main deep sea mineral deposit types – sea-floor massive sulphides, manganese nodules and cobalt-rich ferromanganese crusts – have been the subject of commercial interest for some time. More recently Japan has announced that certain types of rare earth elements (REEs) have been found in high concentrations at many locations within seafloor muds in the southeast and equatorial Pacific Ocean at about 5000m water depths¹²². To date, these discoveries of Kato et al. (2011) are the only known occurrence of this type of deposit in sediments at a notable scale. Owing to the limited geological and environmental data on REE-rich sediments this summary does not describe the possible environmental considerations specific to them, although many of the issues will be similar as for polymetallic nodules.

This report provides a “state of the latest knowledge” overview of the range of environmental impacts policy makers need to consider when contemplating the issue of extracting metals from the deep sea. If plans are developed for such activities, it will be useful to consider that although environmental management plans are expected to be site-specific, set within a wider regional framework, they will need to accommodate broader themes, such as economic opportunity, legal frameworks, and conservation priorities¹²³.

Finally, it is important to caution that although coastal marine mining in shallow waters (e.g. aggregates, diamond, placer gold) has a relatively long history, no actual commercial scale deep sea mining operation (i.e. beyond 500m water depth) has ever been conducted. Only scientific mineral extraction and limited technological testing has taken place (as early as the 1970s).

The precautionary principle is thus a vital consideration when considering the topic of deep sea mining, in order to avoid repeating destructive practices evident in the deep sea from, for instance, bottom trawling.

¹²¹ For a geographic distribution of the three mineral types, refer to section 4 of this study: Geological Analysis

¹²² Kato et al. 2011

¹²³ Baker and Beaudoin 2013a

12.2 Introduction to the three main sources of deep sea minerals

12.2.1 Sea-floor Massive Sulphides

Description

Sea-floor massive sulphides (SMS) are mineral deposits that form as a result of hydrothermal activity. They may be associated with “black smoker” chimneys, which can form where hydrothermal fluids (in excess of 350° C) are being emitted on the seafloor. Black smokers were first discovered in 1977 at the Galapagos Rift. Since then hydrothermal venting and SMS deposits have been found in all the world’s oceans associated with plate boundaries – mid ocean ridge spreading centres, volcanic arcs and back arc basins. Copper, lead, zinc, and gold are among the valuable metals found in SMS deposits. SMS deposits are the modern analogue of terrestrial massive sulphide deposits found globally in a variety of geological settings.

Sulphide deposits are precipitated as reduced compounds. During mining activities and as a consequence of initial processing on board ship at the sea surface the deposit will be ground into finer particles and oxygenated. This may lead to phase changes in critical elements, some of which may be toxic in low concentrations. The pH of the water may also be changed, and the discharge plume may have a higher temperature than the surrounding water. However, it is not known how quickly these processes will occur and whether they pose environmental risks.

Habitat and Biodiversity

The physical and ecological characteristics of hydrothermal vent systems are unlike that of any other ecosystem or biome on the planet today.

In an environment of elevated temperatures and the complete absence of light hydrothermal vents support food webs based on chemoautotrophic primary production. The distribution of the hydrothermal vents is sporadic¹²⁴ (the spacing between vent sites can be up to hundreds of kilometres), and their existence can be ephemeral.

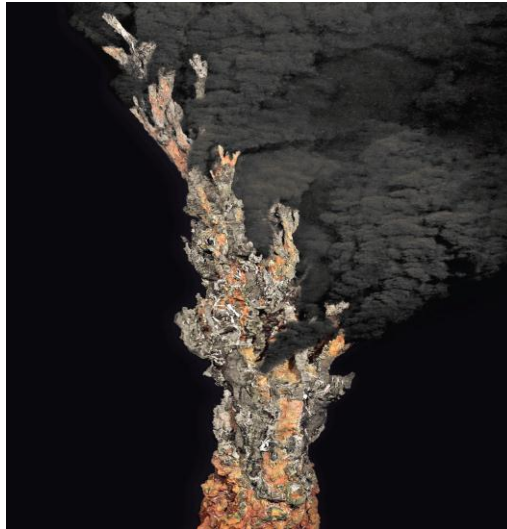
However, at slow spreading ridges, such as the Mid Atlantic Ridge, and ultra-slow spreading ridges, such as the Gakkel Ridge in the Arctic Ocean, where seafloor massive sulphides are more likely to occur, vent systems may persist for extended periods. It is important to appreciate that vent fauna at fast spreading ridges in the Pacific Ocean with high disturbance regimes, may have different life history characteristics to vent fauna on other ridge systems¹²⁵.

Changes in vent fauna may occur in relation to fluid flow (temperature, volumes, and location) and substrate (chimney collapse, eruptive magma events, etc). These dynamics influence the point sources of hydrothermal emissions and also the lifespan of the individual “chimneys” and associated ecosystems¹²⁶.

¹²⁴ Ferrini et al 2008 and Baker 2009

¹²⁵ Boschen et al. 2013

¹²⁶ Baker and Beaudoin, 2013; Johnson et al 2000



The largest black smoker discovered to date (since collapsed) measured almost 45 metres high and occurred on the Juan de Fuca Ridge. Following destruction, chimneys have been measured to grow as fast as 30 centimetres per day. The biggest chimneys are generally found on slow spreading ridges (like the Mid-Atlantic Ridge). On fast spreading ridges like the East Pacific Rise, chimneys are rarely more than 15 metres high. Photomosaic of a 5 metre high chimney in the central Atlantic. Image courtesy of GEOMAR.

Hydrothermal vent ecosystems are important places of biodiversity where the vent-endemic species have adapted to tolerate such challenging conditions. The list of endemic species numbers over 600 and new species are being identified regularly¹²⁷.

The communities of vent-endemic animals vary regionally throughout the global oceans. For example, the eastern Pacific vents are dominated by giant tubeworms, but they do not occur in the Atlantic or Indian Oceans, where varieties of shrimp, anemones, and snails dominate¹²⁸. The current research on the variability of vent communities shows that there may be at least five “biogeographic provinces” for vent-endemic animals, although studies have yet to produce specific boundaries for these areas¹²⁹.

While localised hydrothermal vent ecosystems¹³⁰ are the focus of some commercial activities, such as Nautilus Minerals Inc. within the Exclusive Economic Zone (EEZ) of Papua New Guinea, the largest seafloor massive sulphides are likely to occur at inactive sites on mid ocean ridges. Some contractors to the International Seabed Authority, for instance, have indicated their exploration for seafloor massive sulphides is focussed on inactive sites (e.g. International Seabed Authority, 2011, 2012).

The fauna associated with these areas are more typical of mid ocean ridge rocky fauna, the actual nature of which will depend on depth and the geomorphological / physical oceanographic setting¹³¹. Areas in which massive sulphide deposits will occur may also be a mosaic of rocky surfaces and sedimented areas¹³².

Environmental issues of relevance to seafloor massive sulphides may relate not only to vent fauna, but also attached fauna on rocks, such as corals and sponges, and sediment communities. Benthic communities will include micro-organisms, meiofauna, macrofauna, megafauna, necrophages and

¹²⁷ Desbruyères et al 2006a, Van Dover 2011

¹²⁸ Baker et al. 2010; Boschen et al. 2013

¹²⁹ Van Dover et al 2002; Bachraty et al 2009; Moalic et al 2011; and Rogers et al 2012; Boschen et al. 2013

¹³⁰ Vent ecosystems are highly localized as they are entirely dependent on venting hot fluids. Even going just a few meters away from a source of hot fluids, biodiversity and biomass levels drop very significantly.

¹³¹ Boschen et al. 2013

¹³² e.g. Priede et al. 2013

fish. The existence of a specialised fauna associated with weathered sulphide deposits is at present unknown (Van Dover 2007). In addition, impacts may occur on pelagic ecosystems, including specialised benthic-pelagic organisms, such as swimming sea cucumbers (Billett et al. 1985).

Mining activities at one depth may impact deeper living communities through downslope turbidity currents. Deep-sea fauna are highly specific in their depth ranges owing to the effects of temperature and pressure on their cell wall structure and enzyme systems¹³³. Direct impacts by mining at one depth may therefore have also have a significant effect on very different assemblages of species at greater depths.

12.2.2 Manganese Nodules

Description

Manganese nodules are concretions of iron and manganese hydroxides and occur in a variety of sizes (most are in the range of 5-10 cm in diameter). They are most abundant in the abyssal areas of the ocean (4000 – 6500 m water depth). Manganese, or more accurately polymetallic, nodules contain significant concentrations of nickel, copper, cobalt, manganese and trace metals, such as molybdenum, rare-earth elements, and lithium. The trace metals have industrial importance in many high- and green-technology applications. The abundance of nodules and the concentrations of metals within nodules vary with location. Nodules of commercial interest have been found in the Clarion Clipperton Zone of the equatorial eastern Pacific, around the Cook Islands in the SW Pacific, and in the Central Indian Ocean Basin.

The occurrence of polymetallic nodules has been well known for more than a century, but it was during the 1970s that interest was formed in mining the nodules. This interest did not translate to commercial operations, but in recent times polymetallic nodules have been put back on the agenda as a potential source of minerals. The International Seabed Authority (ISA) presented a model for deposit locations within the Clarion Clipperton Zone (CCZ) and the equatorial north Pacific region, which helped to build momentum for exploration in the area (International Seabed Authority, 2010).

Habitat and Biodiversity

Manganese nodules are found in highly stable environments where particle flux to the seabed is low – they typically occur under low productivity areas within the tropical Pacific and Indian Oceans. Organisms that exist there rely on the gradual downward flux of organic matter from the surface waters above for their survival¹³⁴. However, even in the equatorial Pacific Ocean there is spatial, seasonal and inter-annual variation in the dynamics of surface water productivity and the subsequent flux of organic matter to the seafloor¹³⁵ and this is likely to have a significant effect on the fauna that occur across the vast expanse of the Clarion Clipperton Zone (International Seabed Authority, 2008a,b; 2009).

Although on first glance the abyssal plain areas of the ocean would appear largely unoccupied, research has revealed high species diversity, with organisms living in the fine sediment on the seafloor, on the surface of the sediment, attached and within nodules, and in the overlying water column¹³⁶. The sediment community includes many new species including meiofauna (such as nematode worms and protozoan foraminiferans)¹³⁷, macrofauna (such as polychaete worms and

¹³³ e.g. Billett, 1991; Howell et al. 2002; Carney, 2005; Menot et al. 2010

¹³⁴ Smith and Demopoulos 2003; Smith et al. 2008a

¹³⁵ Wedding et al. 2013

¹³⁶ Snelgrove and Smith 2002

¹³⁷ Nozawa et al 2006; Smith et al 2008b, and Miltjutina et al 2010

isopod crustaceans)¹³⁸, and larger animals (megafauna) such as seastars, and sea cucumbers¹³⁹ and 'giant' protozoan such as komokiaceans and xenophyophores¹⁴⁰.

Almost all of the research into biology assemblages associated with polymetallic nodules to date has been done in the CCZ (a vast area across the Pacific Ocean floor similar in size to the United States of America). Significant faunal change in sediment communities is evident across the CCZ¹⁴¹. Similar assemblages are found in the Indian Ocean, although the species are likely to be different¹⁴². There is a significant problem in achieving a consistent taxonomy of species within an ocean basin, let alone across oceans and this is a significant obstacle to determining the geographic distributions of species that may be impacted by mining.

The fact that life on the deep ocean floor is so diverse has led some researchers to suggest that deep-sea assemblages play significant roles in the ocean processes because of the vast area over which they occur. For example, the great abundance of foraminiferans just by their sheer volume may play a role in carbon cycling, and thus the climate system¹⁴³. Likewise the huge abundance of bacterial microfauna is likely to exert significant control on ecosystem dynamics of the sea-floor, such as the remineralisation of organic matter¹⁴⁴.

12.2.3 Cobalt-rich Ferromanganese Crusts

Description

Similarly to polymetallic nodules, cobalt-rich ferromanganese crusts are formed by the precipitation of manganese and iron from cold seawater. Both nodules and crusts form very slowly growing only a few millimetres every one million years. However, unlike polymetallic nodules, which occur at depths > 4000m, crusts coat the rocky slopes and summits of seamounts (undersea mountains).

Valuable crusts occur on the flat tops of guyots in the western Pacific. There are about 1,200 seamounts and guyots which may be of commercial interest in the western Pacific Ocean¹⁴⁵. Crusts of commercial interest are found principally at water depths between 800 – 2500 m¹⁴⁶. The crusts can be up to 25 cm thick. The crusts have commercially important metals such as cobalt, nickel, tellurium, and rare earth elements¹⁴⁷.

Mining crusts might be inherently difficult to exploit in some cases, given that they are securely attached to the underlying hard substrate and occur in areas of irregular geomorphology. Mining operators will face a challenge to develop technology, which can remove crusts from mountain surfaces with minimal waste rock and its attendant environmental effects¹⁴⁸. There may be problems in removing sediment overburden, and operations near the summits of seamounts have the potential to impact deeper depths through the creation of downslope sediment plumes.

¹³⁸ Glover et al 2002; Brandt et al 2005; and Ebbe et al 2010

¹³⁹ Billett, 1991

¹⁴⁰ Gooday, 1991

¹⁴¹ International Seabed Authority, 2008

¹⁴² Rodrigues et al. 2001

¹⁴³ Lamshead et al 2002; Miljutina et al 2010

¹⁴⁴ Smith and Demopoulos 2003

¹⁴⁵ Clark et al. 2012

¹⁴⁶ Hein et al. 2000, 2009

¹⁴⁷ Hein, 2010

¹⁴⁸ International Seabed Authority, 2002

Habitat and Biodiversity

Ferro-manganese crusts form on bare rock surfaces that are swept clean of sediment by strong currents. The seamounts and guyots with thick crusts are widely distributed, and as such have differing physical conditions – depth of summit, total depth range, steepness of slopes, current speed, substrate, nutrient concentration, etc.¹⁴⁹. Very few seamounts are alike and all possess considerable heterogeneity. The physical heterogeneity leads to great biological variety¹⁵⁰. Surveys carried out at crust sites in the Pacific regions have identified foraminiferans, sponges, corals, squids, echinoderms (sea stars, sea cucumbers, feather stars), crabs, and sea squirts¹⁵¹. Of these large organisms, foraminiferans have been found to be conspicuously abundant and diverse¹⁵².

The isolated nature of many seamounts, although often occurring in groups or chains, led to various hypotheses that seamounts were hotspots of diversity, abundance, biomass and endemism. In many ways these views were built on what was known about island biogeography¹⁵³. Subsequent sampling, however, has challenged these initial thoughts, and today the 'distinctness' of assemblages on seamounts appears unlikely¹⁵⁴. Other sources claim that while many species are shared with other deep-sea habitats such as continental slopes and banks, seamount assemblages may have a different community structure¹⁵⁵. However, seamounts are very poorly sampled and genetic studies of connectivity show a variety of patterns depending on the taxon studied¹⁵⁶.

The large differences between seamounts in terms of the characteristics listed above has made their study difficult and generalisations have been made about seamounts as a whole which probably only apply to a subset, depending also on the biogeographical province in which they occur¹⁵⁷. A major step forward has been made, however, in compiling a relational database of geomorphological, physical oceanographic, and biological characteristics of seamounts, with strict quality control and a measure of confidence in the data¹⁵⁸. These data have highlighted that the degree of knowledge decreases very markedly with increasing depth. The level of knowledge of seamount ecosystems at depths at which cobalt crusts may be mined is extremely limited.

Cobalt crusts may also occur on large ridge like features on the seafloor, such as the Rio Grande Rise off Brazil¹⁵⁹. As for seamounts, recent research on non-hydrothermal vent fauna on the Mid Atlantic Ridge (MAR) in the North Atlantic has shown large-scale affinity of fauna at bathyal depths (c. 200 to 3000m) on the MAR to fauna found on the European and North American continental margins at similar depths¹⁶⁰. It is likely therefore that benthic fauna are widely distributed within any one particular ocean basin, although there may be differences between ocean basins.

ATLANTIS II Red Sea

Building from the geological description of the Atlantis II DEEP deposit provided in Task 4: Geological Analysis, we describe some basic environmental considerations for this occurrence somewhat separately due to its unique status. At an estimated 90 million tonnes in size, Atlantis II DEEP is the biggest known metal-rich sea-floor deposit discovered to date, and it is by far the only

¹⁴⁹ Clark et al. 2010

¹⁵⁰ Pitcher et al. 2007; Consalvey et al. 2010

¹⁵¹ Rogers, 1994; Fukushima 2007; International Seabed Authority, 2011; Schlacher et al. 2013

¹⁵² Mullineaux 1987

¹⁵³ McClain, 2007

¹⁵⁴ McClain, 2007; Rowden et al. 2010

¹⁵⁵ Clark et al. 2012

¹⁵⁶ Shank, 2010; Baco & Cairns, 2012; Bors et al. 2012; O'Hara et al. 2014

¹⁵⁷ McClain, 2007; Clark et al. 2012

¹⁵⁸ Kvile et al. 2013

¹⁵⁹ Perez et al. 2012

¹⁶⁰ Priede et al. 2013

example of a large-scale metalliferous-sediment type deposit. In the 1970s, a pre-pilot test mining study was conducted by a Saudi Arabian company (Preussag A. G.). Using what was described as “conventional floatation” means, they recovered 15,000 m³ of sea floor sediments and brines from four test sites in the Atlantis II basin. They also proceeded to concentrate the recovered material at sea.

Environmental and biological assessment efforts as part of the MESEDA Programme, were completed by 1981 but had never been publicly released. The effort was conducted by scientists from the University of Hamburg and Imperial College of Science and Technology, London School of Mines. In 2010, following the announcement of the joint venture between the mining companies Diamond Fields and Manafa, permission was given to release the report on the Internet.

In its conclusions, the report raises a series of environmental considerations including:

- Sub-surface, deep-water discharge of tailings: The report stresses the importance of sound management and monitoring of tailings discharge in the context of the conservation and protection of marine life in the central Red Sea, adjacent coasts, and adjacent areas that are home to coral reefs.
- The report highlights how planktonic organisms present in all waters in the vicinity of the possible tailings plumes are the most vulnerable life forms that would be affected by heavy metals and chemical processing agents that could be discharged. In addition, subsequent leaching of any tailings (release of zinc, copper, cadmium, mercury, and other toxic elements) would consist of an important ecological stress.
- The report also describes the high level of uncertainty with respect to the in-situ effects of tailings on oceanic plankton. There are noted concerns as to the fate of plankton that may transport certain levels of toxic elements from the area near the mining activity to other biological communities further afield. It was also noted that the addition of volumes of inorganic material into the “detritus-sediment” flow could affect the food supply of deep-water benthic organisms.
- The report notes the how the recruitment of plankton stock from areas to the South would be vital for the replenishment process that would greatly assist the recovery of Central Red Sea deep-water ecosystems. A better understanding of population dynamics is therefore needed as so many unknowns persist that limit the ability to properly manage the conditions for recovery.
- The study noted that the impact of tailings discharge on the benthic environment would include both physical and toxicological effects. They calculated a 1,500 km² area of tailings spread within which areas of intense sedimentation would lead to the creation of an azoic zone. Beyond the area of most intense impact, reduced levels of sedimentation could permit some organisms to survive.
- The study examined the residence life of tailings in the water column and how that residency time will influence the intensity of the toxicological hazard to benthic organisms. Some leaching trials showed notable removal of heavy metals within a period of two-to-three weeks. Such a process would likely reduce the toxicological risk of tailings that might deposit in the overall impacted area and could thus favour survival of benthic organisms and enable better conditions for post-mining recovery.
- The study warned of possible long-term risks associated with bio-accumulation of toxic heavy metals within the trophic levels of the epipelagic and mesopelagic zones. The more wide-spread the distribution of tailings materials the higher the risk of unforeseen, long-term environmental issues.
- The report also highlighted how the potential release of natural high salinity brines into the bottom waters of the Red Sea could be enough to cause localised mortality of organisms if not properly mitigated.

Finally, the study team outlined a series of key recommendations should mining of the deposit be considered:

- Pilot mining operations and environmental assessment should take place for at least a 2 year period in order to identify and measure the full-scale of environmental and social impacts of the specific operations.
- In order to be realistically comparable to actual full scale mining (with respect to relevant environmental monitoring strategies), pilot mining operations should be conducted in a manner well representative of full scale mining.
- For any mining activity, tailings discharge must be restricted to depths beyond 1,100m. It should however be kept in mind that further research may modify this minimum depth level.
- Monitoring plans must include observations of particulate plume development and sedimentation, observation of 'liquid' plume development and its possible extended distribution and observations on potentially toxic substances in relation to ambient concentrations.

A solid baseline understanding of the fate of tailings during full scale mining operations needs to be established in advance in order to plan contingencies and set up emergency response plans. Focused research must be directed to address the needs of a proper environmental monitoring programme that would be implemented during mining. This research needs to include:

- An examination of whether plankton replenishment by species from the Gulf of Aden is a viable process to aid in the recovery of habitats destroyed by mining.
- An examination of the nutrient exchange pathways between the open ocean and coastal regions.
- Studies to distinguish between impacts caused by the mining activity and similar impacts caused by other land-driven natural and man-made sources.

12.3 Purpose of this interim report

The purpose of this interim report is to provide an advanced version of scientifically sound information on key environmental considerations linked to potential EU policy decisions on deep sea mining. This interim report contains near-final content that is ready for comments and feedback that will be used to make final minor adjustments.

13 Approach to environmental analysis

13.1 Approach

The current report focuses, where relevant, on EU specific issues requiring particular policy considerations. However for the most part, environmental considerations related to possible deep sea mining activities are not jurisdiction dependent, save for adherence to regulatory standards. The EU's Marine Strategic Framework Directive thus constitutes an important mechanism for regulating the environmental aspects of potential deep sea mining activities.

Additionally this report builds partially on the efforts of the Pacific Islands Region lead by the Secretariat of the Pacific Commission¹⁶¹. Considering the vast ocean areas under their jurisdiction and limited land space, the Pacific Islands have a particular interest in ensuring the long-term health of the oceans and are thus in the middle of a four-year EU supported exercise to develop sound environmental and economic regulatory frameworks. Many aspects of the knowledge and experience gained with the Pacific are integrated in this summary.

Furthermore, with regard to international waters there are detailed Regulations for the exploration for polymetallic nodules, polymetallic sulphides and cobalt-rich crusts¹⁶²; as well as comprehensive guidance to contractors on the physical, chemical, geological and biological factors to be considered in baseline environmental surveys¹⁶³. The Guidance to Contractors also includes activities, such as test mining, which require the submission of an Environmental Impact Assessment and agreement with the ISA before operations can begin¹⁶⁴.

Key knowledge gaps

The following table provides an overview on the main gaps of knowledge which scientific research can help to understand and develop strategies to in order to minimise risks.

Table 13.1: Key knowledge gaps by deposit type

	Sea floor massive sulphides	Key references
Physical and chemical	<ul style="list-style-type: none"> controls on sub-seabed fluid flows supporting hydrothermal vent regimes loss of habitat of vent systems if mined directly chemical composition and particulate content of waste water released in a discharge plume following initial processing of minerals at the sea surface particle concentration, settling behaviour and dispersal of the operational plume caused by mining. 	Coffey 2008
Biological	<ul style="list-style-type: none"> extent of population connectivity between vent sites, including genetic diversity of vent organisms extent of connectivity, genetic diversity and distributions 	Van Dover 2011 Boschen et al. 2013 Marsh et al 2012

¹⁶¹ In December 2013, GRID-Arendal in support of the Secretariat of the Pacific Commission's Applied Geoscience and Technology Division (SPC/SOPAC) and in partnership with UNEP, an extensive group consisting of the top global experts in the field (including the ISA, academics, industry, governments, NGOs), delivered a broad assessment on the state of the knowledge on deep sea minerals and mining for the Pacific.

¹⁶² International Seabed Authority, 2013a, International Seabed Authority, 2010, International Seabed Authority, 2012

¹⁶³ International Seabed Authority, 2013b

¹⁶⁴ Deep Seas Environmental Solutions Ltd, a member of the Ecorys consortium worked with the ISA Secretariat to produce the revised environmental guidelines adopted by the Authority

	Sea floor massive sulphides	Key references
	<p>of non-vent benthic fauna, such as, but not exclusively, corals and sponges</p> <ul style="list-style-type: none"> • effects of operational and discharge plumes on pelagic ecosystems • effects of mining and plumes on fish and necrophage assemblages • toxicity of operational and discharge mining plumes on benthic and pelagic biota • critical tolerance threshold of benthic fauna to concentration of particulates • downslope ecosystem effects from mining operations • recolonisation rates and recruitment processes at active and non-active vent sites • spatial dynamics of fauna and understanding the drivers governing faunal zonation and micro-distribution patterns at active and non-active vent sites. • modelling of vent and non-vent population dynamics • effect of noise from exploration and mining systems on cetaceans, fish and other organisms 	<p>Erickson et al. 2007 Gollner et al. 2013</p>
	Ferro-manganese nodules	
Physical and chemical	<ul style="list-style-type: none"> • amount and extent of turbidity that will result from the extraction process • loss of nodules as a hard substrate • particle concentration, settling behaviour and dispersal of the operational plume caused by mining • chemical composition and particulate content of waste water released in a discharge plume following initial processing of minerals at the sea surface • compaction of sediment surface • effect of temperature difference of discharge plume relative to ambient seawater • release of nutrient-rich water from deep into surface waters stimulating primary production and ecosystem change • release of cold deep water into warm surface waters or the mesopelagic zone 	
Biological	<ul style="list-style-type: none"> • recolonisation rates at disturbed areas • affects of increased turbidity on communities and individual species • genetic diversity of biota • role of bacteria in the formation of nodules • effects of operational and discharge plumes on pelagic ecosystems • effects of mining and plumes on fish and necrophage assemblages • effects of plumes on seamount and abyssal hill fauna if in the vicinity of operations • smothering effect of resedimentation from operational and discharge plumes 	<p>Tully & Heidelberg 2013 Wu et al 2013 Thiel, H. (2003).</p>

	Sea floor massive sulphides	Key references
	<ul style="list-style-type: none"> • connectivity at the regional scale and whether it is taxon specific • population size and area for protection to maintain reproducing populations • changes in ecosystem functioning and relation to changes in diversity and species composition • modelling of abyssal sediment population dynamics • effect of noise from exploration and mining systems on cetaceans, fish and other organisms 	
	Cobalt rich crusts	
Physical	<ul style="list-style-type: none"> • better understanding of seamount characteristics and interaction of geomorphology, physical oceanography, depth and biogeographic setting in creating habitat heterogeneity and complexity • chemical composition, particle concentration, settling behaviour and dispersal of the operational plume caused by mining • chemical composition and particulate content of waste water released in a discharge plume following initial processing of minerals at the sea surface • creation and nature of downslope turbidity currents and sediment transport of overburden 	<p>Kvile et al. 2013 Clark et al. 2012</p>
Biological	<ul style="list-style-type: none"> • relationship between crustal composition and community composition • effects on biological assemblages and distributions caused by the interaction of geomorphology, physical oceanography, depth and biogeographic setting • effects of downslope sediment transport on deeper benthic assemblages • effects of mining activities on demersal fish populations • toxicity of operational and discharge plumes on biota • effects of operational and discharge plumes on pelagic ecosystems • connectivity between seamounts and at the regional scale and whether connectivity is taxon or life-history specific • better understanding of connectivity between seamounts and other deep-sea habitats such as continental slopes and banks • joint genetic and physical oceanographic modelling studies • population size and area for protection to maintain reproducing populations • changes in ecosystem functioning and relation to changes in diversity and species composition • recolonisation rates and recruitment processes on seamounts effect of noise from exploration and mining systems on cetaceans, fish and other organisms • biodiversity inventory of seamount fauna with good standardised taxonomy and genetic information • combined databases of geological, physical, chemical and biological characteristics of seamounts with data quality control • predictive modelling of seamount population dynamics • understanding of possible cumulative impacts (e.g. fishing and mining in the same region) • critical evaluation of environmental proxies for biological communities • valuation of ecosystem services provided by seamount ecosystems • predictive modelling of ecological risks and mitigation strategies 	<p>Clark et al. 2011b Probert et al. 2007 Pitcher et al. 2007 (several chapters in in Pitcher et al. book) Consalvey et al. 2010 Rowden et al. 2010 Schlacher et al. 2013 Clark et al. 2012 Kvile et al. 2013</p>

13.2 Overview of environmental concerns

While the major impacts from mining will be similar for the three types of mineral deposit considered here, namely:

1. loss of substrate,
2. the effects of mining on the seabed, the operational plume and re-sedimentation and
3. the discharge plume and its effects on pelagic and/or benthic fauna depending on the depth of discharge.

There are also impacts specific to each deposit depending on the geomorphological setting, differing physical conditions, the scale of operations, and the technology used for extraction.

13.2.1 Sea floor massive sulphides

Based on current deep sea exploration technologies (which use “plume sniffing” to locate SMS sites), only active seafloor hydrothermal systems (and/or inactive ones found in proximity to active sites) have been the targets of possible deep sea mining efforts. Therefore the following information is focused on impacts related to these sites.

The mining of SMS will create permanently (human timescale) disturbed areas at the mine site. The geographical extent of the physical disturbance from an individual mine is likely to be less than for comparable land operations.

For example the Solwara 1 site in Papua New Guinea is only 0.112 km²¹⁶⁵. However, the effects of mining are likely to be more extensive through the creation of downslope and lateral operational plumes and from the discharge plume following initial processing at the sea surface. The plumes will include the removal of overlying sediment. The plumes have the potential to affect pelagic communities and downslope benthic assemblages. There is the potential for wide spread toxicity of harmful trace metals in low concentrations. SMS deposits are related to rift valleys, ridge crests and back arcs, each of which has varied topography and thus interaction with the surrounding water. In rift valleys evidence suggests that plumes might be relatively contained to ridge valley areas, where the surrounding ridges can block flows, particularly where hydrothermal plumes don't penetrate above ridge crests. However, more varied situations occur in other SMS areas¹⁶⁶.

The technology currently proposed for extraction involves digging and grinding of the mineralised rock. The mining processes will remove the surface habitat and the mineralised subsurface part of the deposit – at Solwara 1 this is estimated to be down to a depth of 30 m. There is some indication that following the removal of active chimneys at some sites, some regeneration may take place. For example at a Solwara 1 mining test site, active chimneys have been observed to “grow back” on a scale of weeks¹⁶⁷.

Organisms living at active vent sites may have adapted to withstand relatively frequent loss of habitat related to volcanic and seismic activity¹⁶⁸. Thus, they may be able to recover from mining-induced disturbance. Studies have shown how larvae from other vent sites can be transported from tens or even hundreds of km away¹⁶⁹. Other studies have shown how sites can have strong

¹⁶⁵ Coffey 2008

¹⁶⁶ Thurnherr 2004

¹⁶⁷ S. Smith personal communication

¹⁶⁸ Van Dover 2011a

¹⁶⁹ e.g. Millineaux et al. 2010

indications of recovery within a few years¹⁷⁰. However, this may be dependent on whether the sulphide resource is associated with fast-spreading, slow-spreading or ultra-slow spreading ridges (see above). In non-vent areas the deep-sea fauna typically have long generation times and may take decades to hundreds of years to recover. It is important to note that the number of such examples is trivial compared to the diversity of fauna found at such sites.

Apart from the physical destruction of habitat the mining process will also generate increased turbidity related to the extraction/operational plume on the seafloor and from the release of wastewater and fine particulate material (< 8 µm) in a discharge plume following initial on-board processing and dewatering of the ore¹⁷¹. The plumes released by the mining process will travel across the seabed potentially impacting areas adjacent to, and downslope from, the mine site. Particles settling from this plume may smother organisms and/or be toxic to some organisms (due to the presence of sulphides and other chemicals). The plume released into the water column during the transfer of ore to the sea surface and during any pre-processing on board the vessel could have similar effects and may include changes in pH and temperature.

The impact of the discharge plume will depend on the depth at which the plume is released. If the plume is released at the sea surface it could have a major impact on plankton by possibly reducing light penetration, or by stimulating greater growth by the introduction of nitrate, phosphate silicate and other nutrients, and through possible toxic chemical content.

The temperature of the discharge plume at a lower temperature will also have ecosystem effects and may affect local weather (c. Ocean Thermal Energy Conversion – OTEC - environmental effects). If released at mid-water it may also have an impact due to particle load and possibly toxicity. Many gelatinous zooplankton in the mesopelagic and bathypelagic zones filter feed and may be harmed by the increased particle content. Changes in oxygen concentrations may occur if the discharge occurs in and around a mesopelagic oxygen minimum zone. In addition if the temperature of waste water may be considerably higher than the ambient water it is released into, it may rise towards the sea surface and migrate farther afield on deep currents.

Ultimately the optimal conservation zone 'grain size' may differ in relation to the type of venting (rift valley, crest etc.), vent flow rates, surrounding currents and connectivity to other populations¹⁷². Consideration must also be given to near-vent fauna or background fauna. It has long been hypothesised that background fauna among vents benefit from the chemosynthetically produced organic matter, but the scale of this is only beginning to be constrained. A study by Erickson et al. (2009) illustrated that non-vent fauna had considerable portions of their dietary requirements met by chemosynthetic organic carbon sources at locations hundreds of m from active vent sites in the Manus Basin.

13.2.2 Ferromanganese Nodules

Mining polymetallic nodules is expected to occur over very large areas of the abyssal sea floor – the CCZ exploration areas, made available to contractors by the ISA, are initially 75,000 km² (the CCZ itself covers approximately 4.5 million km²). It is estimated the CCZ has 300 billion tonnes of nodules. A single mine site may disturb about 300 km² of seabed area each year. The mining process is likely to rake the nodules from the sediment surface. It is expected that all living things

¹⁷⁰ Tunnicliffe et al. 1997, Shank et al. 1998

¹⁷¹ Coffey 2008

¹⁷² Van Dover 2011

on the sea floor and within the top 50cm of the sediment will be destroyed. The systems used will also compact the sediment surface. Jets of water may be used to wash the nodules creating a plume of very fine sediment which will cover surrounding areas of the abyssal plain,. This increased turbidity may adversely impact the surrounding fauna, including on surrounding seamounts and abyssal hills deep-sea fauna are likely to be poorly adapted to cope with disturbance, as the deep sea is one of the most stable environments on the planet. It may also have a significant effect on gelatinous zooplankton and micronekton in the benthic boundary layer. Mining the nodules will also permanently remove them as a habitat for attached species, such as sponges, sea anemones, komokiaceans and xenophyophores, as they will not regenerate (nodules take millions of years to form).

A numerical simulation study estimated that the finer fractions of re-suspended material from mining activity could remain in the water column for 3-14 years depending on factor such as inter-annual variation in environmental conditions¹⁷³. Two key aspects of this will be the increase in physical presences of fine particles in the water as well as the gradual redistribution of finer particles from the mining area to surrounding areas. These processes will result in altered grain size distributions for the seabed and thus altered habitat structure that would vary with the intensity, method, and duration of mining.

Discharge plume problems will be as described above for polymetallic sulphide mining except that the effects of toxicity are likely to be less, or even negligible. Apart from the visual impact of releasing a discharge plume at the sea surface, ecosystem effects can be expected by introducing cold, nutrient rich and particle-laden water into tropical surface waters. Strict control of water brought to the surface will have to be maintained and the integrity of riser pipes and discharge pipes will require continuous monitoring. In nodule areas the depth of the ocean will be great (4000 to 6000m) increasing options for where a discharge plume might be released. Oxygen Minimum Zones between c. 100 and 1000m are often associated with polymetallic nodule areas, such as the Clarion Clipperton Zone. While these areas are generally impoverished, they may contain unique species, and the remaining metals in the discharge plume may go through phase changes. Deeper discharge in the mesopelagic zone (down to c. 1500m) may affect some species which undertake diurnal vertical migrations. Pelagic biomass typically decreases with increasing depth before increasing in the benthic boundary layer. Options for discharge in the bathypelagic and abyssopelagic zones may need to be considered, although these zones also have their characteristic fauna. However, their abundance will be low and the species are likely to have very wide geographic distributions, at least at the regional scale. There may be a requirement for efficient heat exchangers within the discharge pipeline in order to cool the discharge water. Deep-sea organisms are sensitive to quite small changes in temperature, especially in the abyss where the temperature of the water is only 1 to 2 degrees and very stable. Water brought from deep will also de-gas carbon dioxide at the sea surface, but this even with the large volumes to be re-circulated by mining operations this is likely to be insignificant to natural mixing processes in the ocean.

Abyssal plain communities like those found in the CCZ have been shown to respond to increases in available food supplies within days to weeks spanning increases in sediment community oxygen consumption to changes in macro and megafauna densities¹⁷⁴. Such changes in food supply have also been linked to changes in the size distribution of fauna, or in the energy consumption distribution among animals in various size classes illustrating so called compensatory dynamics¹⁷⁵. However, these changes did not take into account the kind of changes in sediment structure and

¹⁷³ Rolinski et al. 2001

¹⁷⁴ e.g Ruhl et al. 2008

¹⁷⁵ Ruhl et al. 2014

grain size that would result from mining activity. Indeed some fauna may be adversely affect in relation to the 'habitat grain size'. Studies of recovery from experimental mining over periods of up to 7 years suggest that larger fauna such as macro fauna crustaceans may recover more quickly in areas of simulated or test mining than nematodes¹⁷⁶ however, it should be noted that the larger fauna are exceptionally difficult to study owing to their lower diversity
A much longer term study covering 26 years revealed that nematode communities still have reduced density and diversity and differing composition inside experimental areas when compared to areas nearby¹⁷⁷.

13.2.3 Cobalt rich ferromanganese crusts

Mining crusts involves removing the relatively thin layer of ore from the underlying rocky surface. While the technology to undertake this has not been established, it is generally considered that it will involve grinding or scraping the crust off. This is a difficult process due to the lack of uniformity in the thickness of the crust and physical conditions likely at the mine sites: fast currents, steep inclines and rugged geomorphology. However, initial cobalt crust mines are likely just to mine the tops of guyots or the upper flanks of a seamount where slopes are reduced. Removing the crust will destroy all the sessile organisms. It is thought that the marine life on the rocky surfaces may recolonize, but this may occur over very long timescales¹⁷⁸.

Corals on seamounts at depths where mining may occur may be as old as 2300 years¹⁷⁹. As study of trawling recovery on seamounts found that there was little recovery over periods of 5 – 10 years with statistically significant recovery found in only a few taxa¹⁸⁰. As with SMS mining, the sediment plume generated during the extraction process, may also impact surrounding fauna. Waste water extracted from the ore slurry will also be returned to the water column as described above for polymetallic sulphides. Should there be fast currents present, these are likely to quickly disperse this material but it may still impact surrounding fauna.

13.3 Environmental policy and management approaches

13.3.1 Discussion on the EU Marine Strategic Framework Directive (MSFD)

In order to ensure that commercial seabed mining activities have the least possible amount of disruption deemed acceptable on the adjacent ecosystems, internationally agreed definitions need to be developed and adhered to by all stakeholders. The European Commission's Marine Strategy Framework Directive has set up a comprehensive and ecosystem based approach to manage the maritime environment and requires Member States to apply these principles in their maritime strategies (see box 2). This approach could serve as an illustrative example for the possible future management of deep-sea mining activities whether that would be carried out independently or within the context of other regulative measure or policy tools.

Box 2: GES descriptors

¹⁷⁶ Bassau et al. 1995; Radziejewska, 2002

¹⁷⁷ Mijutin et al. 2011

¹⁷⁸ Rowden et al. 2010

¹⁷⁹ Carreiro-Silva et al. 2013

¹⁸⁰ Williams et al. 2010

The European Union adopted the Marine Strategy Framework Directive in 2008 with the aim of achieving a Good Environmental Status (GES) for Europe's marine waters by 2020. Eleven descriptors were identified to define GES. These are:

1. Biodiversity is maintained;
2. Non-indigenous species do not adversely alter the ecosystem;
3. Populations of commercial fish species are healthy;
4. Elements of food webs ensure long-term abundance and reproduction;
5. Eutrophication is minimised;
6. Sea floor integrity ensures the functioning of the ecosystem;
7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem;
8. Concentrations of contaminants have no effects;
9. Contaminants in seafood are within safe levels;
10. Marine litter does not cause harm;
11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

While these criteria were primarily set up to establish a threshold for GES of European shelf seas and coastal waters, all EU operators - throughout their economic activities globally – should follow the same sustainable development principles and environmental imperatives.

In the case of seabed mining, where environmental impacts can only be estimated, owing to the many environmental and biodiversity unknowns, a precautionary approach, including the use of GES descriptors is essential in all commercial activities.

As detailed in the previous chapters there are gaps in knowledge with regard to the physical and bio-chemical properties of the seabed ecosystems. In order to define descriptors for international waters similar to that of the MSFD extensive sets of data and information on the current state of seabed ecosystems would need to be collected. This would allow for the identification of threshold figures (or ranges) that could – using continuous monitoring – alert to any changes resulting from the commercial activities of deep sea mining that could be considered damaging. However not all of the 11 descriptors listed above would be relevant for deep sea environment. The table below provides an overview of the descriptors that could be adapted to monitor changes in deep sea ecosystems.

Table 13.2: Relevance of MSFD descriptors for the deep-sea environment

MSFD descriptors	Deep-sea relevance	Monitoring of spill over impacts
Biodiversity is maintained	Maintaining biodiversity is a key concern in connection with deep-sea mining and can range from the complete eradication of species' habitat to a more limited impact allowing for the re-colonisation of sites	
Non-indigenous species do not adversely alter the ecosystem	Non-indigenous species are unlikely to be introduced as a result of deep sea mining activities.	
Populations of commercial fish species are healthy	While deep-sea mining is not expected to have a direct impact on commercial fish species some spill over impacts could be monitored.	Monitoring of economic impacts of the fishing industries and socio-economic impact on coastal areas
Elements of food webs ensure long-term abundance and reproduction	Depending on the extent of impact on biodiversity, food webs might be affected	

MSFD descriptors	Deep-sea relevance	Monitoring of spill over impacts
Eutrophication is minimised	The lifting of ore and deep water rich in nutrients can lead to eutrophication especially in oligotrophic tropical ocean which is particularly sensitive to nutrient inputs. ¹⁸¹	
Sea floor integrity ensures the functioning of the ecosystem	Monitoring seafloor integrity and ensuring that the physical and bio-chemical properties of the benthic environment are protected is an essential criteria for creating a sustainable marine environment alongside deep-sea mining	
Permanent alteration of hydrographical conditions does not adversely affect the ecosystem	Monitoring of hydrographic conditions especially in connection with the mining of manganese nodules - and the stirring and resettling of sediments - is an important element for ensuring sustainability and for using the most appropriate, site specific technology.	
Concentrations of contaminants have no effects	Measuring the level of contaminants at mining sites (e.g. from vent communities via drifting particles) can indicate long-term environmental impacts	
Contaminants in seafood are within safe levels	Not relevant for deep-sea mining	
Marine litter does not cause harm	Littering from off-shore processing and other activities linked to deep sea mining as well as monitoring of waste management processes are integral to sustainability	
Introduction of energy (including underwater noise) does not adversely affect the ecosystem	Impact of low frequency noise on marine mammals and migration routes of cetacean.	

Once appropriate descriptors monitoring marine areas affected by deep-sea mining have been identified and data has been collected on the current state of the environment it will be essential to establish thresholds within which changes in the environment caused by the activities of deep-sea mining will not threaten sustainability.

The subsequent chapter on desk-based research contains a detailed analysis of the environmental impact of deep sea mining and includes a column highlighting the relevance of GES descriptors for the specific impacts.

13.3.2 General environmental management approaches and principles

¹⁸¹ Mineral Policy Institute (nd): Management of DSM <http://www.mpi.org.au/issues/deep-sea-mining/precautionary-management-of-deep-sea-mining/>

Responsible environmental management involves balancing resource use with maintaining deep-ocean ecosystem processes and biodiversity. Management should therefore include functional linkages between elements of the seabed ecosystems with the subsurface biosphere, the water column, the atmosphere, shelf seas and coastal areas, as well as preserving the full range of goods and services that deep-sea ecosystems provide¹⁸².

Management approaches often focus on a single sector (such as a particular area or human activity) or a single species. However, there is increasing recognition of the importance of an ecosystem approach to management (EAM). The 1992 United Nations Convention on Biological Diversity defined the ecosystem approach as: "Ecosystem and natural habitats management...to meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned." Inherent in EAM is the application of ecological, economic, and social information, and the underlying acceptance that humans are an integral part of many ecosystems. The approach requires integration of information from a wide range of disciplines, across different levels of ecological and socio-economic organization, and on a range of temporal and spatial scales.

A second important concept in the exploitation of any resource is the *precautionary approach*. One of the primary foundations of the precautionary approach results from the work of the Rio Conference, or Earth Summit, in 1992. Principle 15 of the Rio Declaration states: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."¹⁸³

A management method that is frequently applied in support of the precautionary approach is termed adaptive management. This style of management attempts to reduce uncertainties over time in a structured process of "learning by doing"¹⁸⁴. Management actions continue to be informed and adapted as more is learned about the ecosystem at the same time as it is being exploited and managed. An integral part of the process involves managers having the flexibility to make rapid management decisions to ensure that conservation objectives are being met.

In the context of DSM the precautionary approach can also be applied through Marine Spatial Planning (MSP), which is a tool used increasingly by countries to manage multiple uses of marine space. MSP determines what activities can be undertaken where, manages conflicts among competing marine activities, and reduces environmental impact by analysing current and anticipated uses of the ocean. It is a practical way to balance demands for development with conservation goals. The principal output of MSP is a comprehensive spatial management plan for a marine area or ecosystem.

Example for Marine Spatial Planning from Solwara I

The draft Environmental Management plan developed by Nautilus Minerals for the Solwara 1 mine includes a representative no-mine reserve area approximately two km upstream from the mine site. Research has shown that the active sites at the mine site and the reserve area share the same biomass-dominant species and generally similar indices of diversity and community structures. This

¹⁸² Armstrong et al 2010

¹⁸³ UNCED 1992; see also DSM Project Information Brochure 13 available at www.sopac.org/dsm, for discussion on the Precautionary Approach as it relates to DSM

¹⁸⁴ Walters and Hilborn 1978

makes the reserve area a suitable control site that can be a source of recruitment of organisms to mined areas¹⁸⁵.

In the Clarion Clipperton Zone where impacts will occur over much greater areas, the International Seabed Authority has introduced a network of Areas of Potential Environmental Interest (APEI) as part of a regional environmental management plan¹⁸⁶. More recently MacMillan-Lawler et al¹⁸⁷ utilised the new global seafloor geomorphology map¹⁸⁸ to examine the geomorphic feature representativeness of global MPAs as a proxy for biodiversity – a technique that may be useful in assessing and developing APEIs.

Dinard workshop¹⁸⁹

In response to potential pressures on hydrothermal vent ecosystems from the initiation of DSM (and other activities such as fishing, biotechnology exploration, tourism etc.) a group of experts met in Dinard to formulate general guidelines for the conservation of vent ecosystems (as well as cold water seeps). They developed a set of design principles for the comprehensive management of active vent environments that could be used in systematic marine spatial planning.

The Dinard Guidelines are provided to policy makers, environmental managers, and other relevant parties and stakeholders with the aim of guiding the sustainable use of chemosynthetic resources. They state:

Spatial Design of Chemosynthetic Ecological Reserves (CERs)¹⁹⁰

- Identify chemosynthetic sites that meet the Convention on Biodiversity criteria for Ecologically and Biologically Significant Areas (EBSAs) or are otherwise of particular scientific, historical, or cultural importance for priority consideration for protection.
- Define the regional framework for protection of biodiversity. Natural management units (biogeographic provinces and bioregions within these) form the ecological framework within which CERs should be established for the protection of chemosynthetic ecosystems.
- Establish the expected distribution patterns of chemosynthetic habitats to provide a spatial framework for capturing representativity.
- Establish CERs and design replicated networks of CERs within bioregions, using guidelines for size and spacing that ensure connectivity and that take into account the pattern of distribution of chemosynthetic habitats, which may vary from semi-continuous to widely dispersed.
- Define human uses and the levels of protection for each CER to achieve the conservation goal.

Management Strategies for Chemosynthetic Ecological Reserves

- Use a two-level approach for establishing CERs: (1) select CER sites of extraordinary stand-alone value; 2) fill in the “gaps” to establish networks of CERs that, combined, will contribute to the network-level conservation goals while taking into account the spatial demands of human activities.
- Use adaptive management strategies to account for uncertainty and new knowledge.

¹⁸⁵ Coffey 2008

¹⁸⁶ Smith et al. 2008; International Seabed Authority 2008b; 2009; 2012c and <http://www.globaloceancommission.org/policies/deep-seabed-mining/>

¹⁸⁷ unpublished conference proceedings, 2013

¹⁸⁸ Harris et al 2014

¹⁸⁹ The workshop took place in 2010 in Dinard, France. The aim of the workshop was to formulate general guidelines for the conservation of vent and seep ecosystems at regional and global scales and to establish a research agenda aimed at improving existing plans for the spatial management of vent and seep ecosystems <http://www.isa.org.jm/files/documents/EN/Pubs/TS9/index.html#/1/>

¹⁹⁰ Source: Van Dover, et al., 2011b

- Establish CERs in a manner that is consultative and transparent.
- Governance of CERs should be within existing governance regimes wherever possible.
- Where CERs include activities with the potential to cause significant adverse impacts, Environmental Impact Assessments (EIAs) should be required for these activities and should follow best practices.
- Establish monitoring strategies to assess the impacts of cumulative activities in space and time relative to the conservation goal and objectives.
- Use a set of prescriptive criteria, established before multi-use activities begin, to trigger closer monitoring or cessation of activities that jeopardize the conservation goal within a bioregion

These examples show that there is interest from stakeholders to develop an integrated approach to manage the use of marine areas and open discussions with regard to the identification of marine protected areas and the externalities that might arise as a consequence for the countries. However, there is no international initiative that would facilitate a comprehensive approach and set guidelines for the selected areas with regards to marine spatial planning.

13.4 Spill-over impacts affecting ecosystem services

The ecosystem services which exist in these potential deep sea mining sites may include habitats that are important for local and/or commercial fisheries, scientific research opportunities (especially apparent in the case of hydrothermal systems which offer the chance to study the evolution and adaptation of life under extreme conditions and possibly even the origins of life on Earth) and potentially valuable genetic resources and yet to be discovered chemical compounds. It is important that nations fully consider both the economic benefits and potential environmental costs of deep-sea mineral extraction and opportunity costs such as those arising from the displacement of other potential uses of the ocean. Notably, some of the external costs might involve the loss of non-market values, such as the existence of a unique ecosystem or species.

In principle, destruction of ecosystems associated with deep-sea minerals might involve the loss of 'existence values', or 'bequest values', or there may be future-use values of which we are currently unaware (also known as 'option values'). In practice, passive and option values (existence and bequest values) are likely to increase for three reasons:

- 1) people will become more aware of these habitats, especially the specific habitats where mining is proposed;
- 2) any future mining activity will decrease the number of available mining sites, and thereby potentially increase their value; and
- 3) potential non-extractive uses of deep sea habitats including medicinal applications, bio-engineering, or even tourism may become relevant.

Given that current passive and option values for these habitats are exceedingly small, as mining operations and associated research expands, these values are only likely to grow as we learn more about these habitats. Consequently, in addition to prudent management there needs to be a programme of scientific research, dissemination of results, and on-going public consultation¹⁹¹.

Disturbing large areas of seabed may also have impacts on regulating ecosystem services of which (with respect to the deep oceans) we currently have limited knowledge of. A global economic valuation of ocean ecosystem services is currently in the planning phase under the auspices of UNEP's TEEB (The Economics of Ecosystems and Biodiversity) effort. This valuation approach applied to deep ocean systems could help provide a better understanding of the importance and

¹⁹¹ UNEP et al., 2012

value of such ecosystems even if distant from human habitation and/or direct use.

14 Desk-based research

14.1 Findings

Deep-sea mining will directly impact habitats, resulting in the removal of fauna and seabed rock and sediments. Because this is a known outcome, environmental management plans that guide seabed mineral extraction should aim to strike a balance between economic opportunity associated with resource revenue, conservation objectives, and the environmental impacts described herein. Consideration of the lessons learned from terrestrial mining, particularly those that address conservation and minimum impact objectives, may aid in developing sound policy.

14.1.1 Overview of Environmental Impacts

As outlined by Clark and Smith¹⁹² environmental impacts from deep-sea mining can generally be divided into four categories:

- *impact from dislodging minerals* which includes the physical removal of organisms, rock and sediment;
- *impact from a sediment plume* that generally accompanies mining activities and can potentially have a spatial extent larger than the mining footprint itself (depending on ocean currents, the amount of sediment removed and the technology used);
- *impact from the dewatering process* which delivers contaminated and potentially highly turbid seawater into the water column; and
- *impact from the operation of the mining equipment*. This includes noise and light (although very little is known about their effects on deep sea organisms), oil spills and leaks from hydraulic equipment, sewage and other contaminants from the ore carriers and support vessels.

Combined, these impacts reach organisms at the mine site and beyond. In addition to potential impacts from normal operations, natural hazards, such as extreme weather events, volcanic activity, etc., will also need to be considered in the management plans. These impacts may include those that are more generally associated with the presence of marine vessels and primarily occur at the surface. They may be the inadvertent introduction of invasive species along with noise and air pollution generated by ships, fluid leaks and discharges from vessels and equipment, and vibrations. More specific to mining is the introduction of light into seabed environments that are normally light-deprived. Light is known to be either a source of attraction or a deterrent to some fish species, which may or may not alter their normal behaviours for feeding and reproduction, leaving a noticeable impact on that local population.

From a non-ecosystem perspective, there are other impacts to consider. The presence of mining vessels will necessitate site closures before, during, and potentially after mining activities. Such restrictions may extend beyond the mining site to the shipping routes. This may displace or disrupt fisheries and have an effect on revenue.

There are also impacts to the water column that merit consideration. Impacts to the water column are generally caused when the mined material is lifted from the sea-bed to the mining vessel at surface level, when there are routine discharges and also spills from the vessel, and during the

¹⁹² Clark and Smith (2013 a, b)

release that takes place when the ore is dewatered. When the mined material is lifted, the amount of material that escapes back into the water column will be dependent on the lifting system itself and whether or not it is a fully- or partially-enclosed mechanism. There is also likely to be a physical impact to any fish or other organisms present in the water column at the time when equipment is in use. This may result in direct, perhaps fatal, strikes with the organisms or displace them. These impacts however are not likely to affect a full population, but rather the local population found at that mining site. A sound management plan for site selection will include criteria for looking at the nursery and spawning grounds of fish in the vicinity and for avoiding mining activities during ecologically important times. Dewatering in the water column (versus as near to the seabed as possible) may have a clouding effect, or an impact that restricts the normal amount of light penetration through the water column. This may result in localized impacts to primary productivity and potentially reduce oxygen levels – again however, these impacts while not insignificant are not thought to impair a full animal population.

An additional consideration for the impact of dewatering and the water column is that the released seawater will be different in composition from when it was collected with the ore. It is now likely to contain trace amounts of toxic metals or chemicals that will be emitted into water where those materials were not previously present, and this may have an impact on biodiversity. Additionally, when dewatering is done at the surface, the released seawater may have different characteristics than the surrounding seawater into which it is discharged, such as different levels of salinity or temperature. Again, this may have impacts to localized biodiversity. In this instance, modelling may be used to estimate the impact of discharge water.

14.1.2 Steps of the Mining Process that Impact the Environment

Extracting the ore involves basic processes that are common to all three mineral types. As described by Clark and Smith¹⁹³ they are:

Table 3: Basic mining processes

Process	Description
Disaggregation	Crushing and grinding techniques will generally be used for removing both SMS deposits and crusts. Manganese nodules will be “vacuumed” up from the sea floor.
Lifting	The ore is pumped up to the collection vessel in a seawater-slurry via a lifting system. At present it is generally considered that this will be done using a closed system – the riser and lifting system (RALS). However the continuous line bucket system (CLB) has also been proposed for nodule collection. The CLB operates like a conveyor belt transporting the nodules in buckets from the seafloor to the surface.
Dewatering	Once on-board the excess water is removed from the slurry and returned to the water column at a predetermined depth.

¹⁹³ ibid

A cautionary approach will need to be taken when designing controls for the technology, equipment, and techniques for deep sea mining (Hoagland et al., 2010). The technology used in these processes can significantly influence the extent of the environmental impact. Currently technology and tools are not fully adapted to deep sea conditions and require further development, however some of the technologies such as hydrolics, and cutting, crushing, and drilling are being adapted from the offshore petroleum and tunnelling industries. Pumping and riser systems as well as the vessels and watering systems specifically developed for deep sea environment are being patented¹⁹⁴.

14.2 Environmental Impacts Unique to Mineral Type

The impacts that are unique to sea-floor massive sulphides, manganese nodules, or ferromanganese crusts are considered here. Risks and impacts to biodiversity and physical habitat will need to be evaluated according to the extent to which they will occur, both in duration and distance from the mine site. Table 2a, b and c below summarize the potential impacts of mining activities relevant to each deposit type.

¹⁹⁴ <http://www.google.com/patents/CA2735901C?cl=en>

Table 14.1 Nodule mining impacts: Area licensed to each operator - 75,000 sq. km

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Removal of nodules, complete disturbance of seabed and its compaction	Long term. Probably tens to hundreds of years for a non-compacted surface layer to reform; millions of years for nodules to reform	Between 120 (Petersen) and 600 (Sharma) km ² per year per operator. ISA consider 3-10 operators at any one time. Therefore 360-6000 km ² per year	Destruction of habitat and associated organisms	Likely to be extremely slow. For the substrate - may take tens to hundreds of years or even longer in heavily mined areas. For the nodule faunas will take millions of years.	1. Biodiversity is maintained
Sediment laden plumes near seabed containing particle load	During mining activity	Spread will depend on mining process and local currents. Could be tens of kilometres beyond licensed area boundaries	Smothering of seabed animals. Will affect suspension feeders on other nodules in the licensed area and on any seamounts in the vicinity of mining operations	Likely to be slow especially in areas heavily impacted by plume fallout. Elsewhere may take tens of years	5. Eutrophication is minimised 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Sediment laden plumes in water column	During mining activity	Spread will depend on local currents, grain size of material and volume of material released plus length of time of release. The depth at which the plume is released may also determine its spread. Potential areas affected could be very large – thousands of square kilometres	If plumes are released in the photic zone (c200 metres) they will cause a reduction in light penetration and in temperature. These are likely to reduce plankton growth with knock-on impacts to whole food chain. Sediment load likely to affect feeding of gelatinous zooplankton. High nutrient load from deep waters introduced into oligotrophic waters may stimulate primary production and of different species than those	Recovery will be rapid once activity ceases	1. Biodiversity is maintained 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
			normally occurring in the area.		
Size and ecosystem function fractionated impact on life	Shifts in sediment grain size distribution	Depending on position relative to mining and/or sediment plume impacts, sediments may change in their grain size towards sandier or finer composition	This changes the habitat in terms of the sizes of life that will either be benefited or be impacted negatively	These effects may be long lasting as background sedimentation rates are low.	1. Biodiversity is maintained
Noise	During mining activity	Low frequency noise could travel up to 600 km and have strong impacts on marine mammals within 15 km but locations of mining may be away from cetacean migration routes	Masking effects on marine mammals	Recovery will be immediate once activity ceases	12. Introduction of energy (including underwater noise) does not adversely affect the ecosystem
Potential loss of ship or pollution from ships	During mining activity		Pollution of surface waters		8. Concentrations of contaminants have no effects 10. Marine litter does not cause harm
Tailing disposal on land/sea	Long term	Potentially hundreds of km ²			5. Eutrophication is minimised; 6. Sea floor integrity ensures the functioning of the ecosystem; 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem; 8. Concentrations of contaminants have no effects; 10. Marine litter does not cause harm;

Table 14.2 Impacts of SMS mining - Are of each mine site – 0.1km² for Solwara 1 but could be larger

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Mining of seabed, with removal of habitat	On active vent sites may be some years beyond the mining phase. On off-axis vent sites may be hundreds of years to due deposition of toxic chemicals	Area of mining maybe c300 m diameter (based on proposed Solwara 1 mine, Papua New Guinea). However several adjacent locations may be mined sequentially giving rise to a mined area of some km ²	Destruction of habitat and associated organisms by initial mining and pollution of the environment by chemical toxins. This will have a greater impact in off-axis sites	On active vent sites maybe relatively short term (months to years). On off-axis vent sites likely to be of longer term - probably tens to hundreds of years	1. Biodiversity is maintained
Sediment laden plumes near seabed containing particle load and potentially chemical toxins	During mining activity and for many years beyond due to the chemical toxins	Spread will depend on mining process and local currents. Could be kilometres beyond mined area boundaries	Smothering of seabed animals by the particulates especially proximal to the mined area. Potential poisoning of animals in all areas affected by the plume due to the chemical toxins	Recovery from the particulates will probably take a few years. In the off-axis vents recovery from chemical pollution may take tens to hundreds of years	5. Eutrophication is minimised 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Sediment laden plumes in water column containing particle load and chemical toxins	During mining activity	Spread will depend on local currents, grain size of material and volume of material released plus length of time of release. Potential areas affected could be very large – thousands of square kilometres.	If plumes are released in the photic zone (c200 metres) they will cause a reduction in light penetration and in temperature. These are likely to reduce plankton growth with knock-on impacts to whole food chain. Sediment load likely to affect feeding of gelatinous zooplankton. High nutrient load from deep waters introduced into oligotrophic waters may stimulate primary production	Recovery will be rapid once activity ceases	1. Biodiversity is maintained 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
			and of different species than those normally occurring in the area. Toxins in the plumes could cause loss of organisms at all levels in the food chain and could impact commercial fish stocks		
Size and ecosystem function fractionated impact on life	Shifts in sediment grain size distribution. May also include changes in fine scale (biologically relevant) bathymetry	Depending on position relative to mining and/or sediment plume impacts, sediments may change in their grain size towards sandier or finer composition. Shifts at SMS sites likely larger than nodule mining sites	This changes the habitat in terms of the sizes of life that will either be benefited or be impacted negatively	These effects may be long lasting as background sedimentation rates are low.	1. Biodiversity is maintained
Noise	During mining activity	Low frequency noise could travel up to 600 km and have strong impacts on marine mammals within 15 km (Steiner, 2009)	Masking effects on marine mammals	Recovery will be immediate once activity ceases	12. Introduction of energy (including underwater noise) does not adversely affect the ecosystem
Tailing disposal on land/sea	Long term				5. Eutrophication is minimised; 6. Sea floor integrity ensures the functioning of the ecosystem; 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem; 8. Concentrations of contaminants have no effects;

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
					10. Marine litter does not cause harm;

Table 14.3: Impacts of cobalt-crust mining

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
Removal of crusts	Long term. Probably hundreds to thousands of years		Destruction of habitat of attached epifauna	Likely to be very slow (tens to hundreds of years).	1. Biodiversity is maintained
Sediment laden plumes near seabed containing particle load	During mining activity	Spread will depend on mining process and local currents. Could be tens of kilometres beyond licensed area boundaries. Plumes are likely to flow down the seamount flanks	Smothering of seabed animals	Likely to be very slow (tens to hundreds of years) if epifaunal organisms are impacted on bare rock surfaces	5. Eutrophication is minimised 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
Sediment laden plumes in water column	During mining activity	Spread will depend on local currents, grain size of material and volume of material released plus length of time of release. Potential areas affected could be very large – thousands of square kilometres	If plumes are released in the photic zone (c200 metres) they will cause a reduction in light penetration and in temperature. These are likely to reduce plankton growth with knock-on impacts to whole food chain. Sediment load likely to affect feeding of gelatinous zooplankton. High nutrient load from deep waters introduced into oligotrophic waters	Recovery will be rapid once activity ceases	1. Biodiversity is maintained 6. Sea floor integrity ensures the functioning of the ecosystem 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery	Relevance for GES descriptor
			may stimulate primary production and of different species than those normally occurring in the area.		
Size and ecosystem function fractionated impact on life	Shifts in sediment grain size distribution. May also include changes in fine scale (biologically relevant) bathymetry	Depending on position relative to mining and/or sediment plume impacts, sediments may change in their grain size towards sandier or finer composition. Shifts at crust sites likely larger than nodule mining sites	This changes the habitat in terms of the sizes of life that will either be benefited or be impacted negatively	These effects may be long lasting as background sedimentation rates are low.	1. Biodiversity is maintained
Noise	During mining activity	Low frequency noise could travel up to 600 km and have strong impacts on marine mammals within 15 km	Masking effects on marine mammals	Recovery will be immediate once activity ceases	12. Introduction of energy (including underwater noise) does not adversely affect the ecosystem
Tailing disposal on land/sea	Long term				5. Eutrophication is minimised; 6. Sea floor integrity ensures the functioning of the ecosystem; 7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem; 8. Concentrations of contaminants have no effects; 10. Marine litter does not cause harm;

Table 14.4 Land-based metal mining, Area of each mine – up to 26 km² (Hull Rust mine, USA)

Impact	Length of impact	Potential impacted area	Nature of impact	Potential for recovery
Open cast mining with removal of habitat and dumping of spoil	Long-term but with potential for remediation of spoil deposits		Loss of habitat in wilderness areas or farm land in developed areas	
Pollution of groundwater	Long term			
Pollution of surface water (streams, rivers and possibly coastal waters)	Long term			
Tailing disposal	Long term but with potential for remediation			

Impacts to biodiversity

Biodiversity is the area where information and knowledge is rather limited due to the sheer size of the area (spatial coverage) that would need to be analysed in order to come to a comprehensive understanding on the functioning of the ecosystem units at various locations. Although there has been considerable study on vent communities associated with active vents, new discoveries are made at every new visit to these environments, and it is likely that there are many species yet-to-be-discovered. Our knowledge of species composition and biodiversity at even the most carefully studied active vent systems is incomplete. This is also probably true at non-active vents site, that have received little attention in comparison.

Box 5: Research in Seafloor Biodiversity

There have been a number of research projects coordinated on the national as well as the international level aimed at mapping seabed ecosystems. Mapping seabed habitats around the coast of New South Wales has been going on for several years involving a large number of stakeholders.^{195,196} This project has focused on an area of approximately a 1,300km coastline and 5.6 km offshore area and has been on-going since 2002.

Other initiatives include the ChEss project of the Census of Marine Life (2002–2010) which helped co-ordinate international research in exploring for and characterising deep-sea chemosynthetic ecosystem sites¹⁹⁷.

Active vent sites create a unique ecosystem with organisms that are suited to survive in the steep chemical and thermal gradients. Such communities include, for example, barnacles, snails, mussels, crabs, tubeworms, shrimps, and various fish. The species at these sites are vent-endemic – occurring nowhere else. There often appears to be a low diversity of complex multi-cellular organisms despite the high biomass present within fauna colonising vent sites and typically 50 percent of the species present are extremely rare, represented by no more than five individuals in collections of tens of thousands of specimens¹⁹⁸. As these communities are localized to vent systems (with a mix of dominant and rare species), even small-scale mining activities can result in a significant impact to these species – including possible extinctions of the rare species.

Though there remains much to learn and discover about vent-endemic species, they are thought to be highly adaptable– based on the harsh conditions they exist in - and may possess the ability to re-colonize relatively quickly following an event that is detrimental to their habitat. The natural disturbance regimes at vent sites can be intense with observed changes in warm water flows on annual or sub-annual timescales¹⁹⁹. The dynamic and erratic nature of vent systems fosters resiliency against change and consequently organisms may be able to recover quickly following wipe-out events. In addition because active vents are sparsely distributed across the sea-floor, successful species must be specially adapted for dispersal, able to colonize these discrete locations. Thus, species found at active vent sites must be tolerant of natural variability and so may be able to apply that tolerance against disturbances from mining activities.

¹⁹⁵ http://www.sydneycoastalcouncils.com.au/sites/default/files/bob_creese.pdf

¹⁹⁶ <http://www.hcr.cma.nsw.gov.au/uploads/res/Research/marinemappinginnsw.pdf>

¹⁹⁷ German et al., 2011

¹⁹⁸ German et al., 2011

¹⁹⁹ Van Dover et al., 2012

It should be noted that the organisms found on non-active vent sites are somewhat different in nature – they are non-chemosynthetic life forms, very slow growing, and their loss would require decades for recovery. However, because these organisms are not endemic and are also found outside of deposit sites, their loss should be taken into the context of the wider pool of the species as not significantly detrimental.



Giant tubeworms along the East Pacific Rise. *Photo courtesy of IFREMER.*

It is generally expected that the impact to biodiversity will vary according to the site and also by species. For example, at active sites, it is likely that because the species are naturally adaptive and resilient, they may recolonize in a relatively short period of just a few years, whereas at dormant sites any potential re-colonization may take more than a 10-year period (Van Dover et al., 2011a; Williams et al., 2011).

Impacts to the sea-floor

As massive sulphide mining requires the removal of seafloor surface, it is likely that the actual shape and texture of the seafloor will be subject to change following the mining activity.

In addition if there is unconsolidated sediment (as is the case at Solwara 1) this will be moved during the mining process. At Solwara 1 there is approximately 130,000 m³ of unconsolidated sediment. If the commercial scale mining would be launched, the operators plan to move this sediment, using an ROV, to a tip site on the outer edge of the Solwara site²⁰⁰. As during this process the sediment will not be moved higher increases in temperature or oxidation are not expected even though suspended sediment plumes may be created²⁰¹.

When considering the impacts to the sea-floor as a result of mining for massive sulphide deposits, it is useful to distinguish between *active vent sites* and *dormant vent sites*. The mining process is not expected to diminish the natural venting. Therefore it is expected that active venting fields will remain, chimney structures will reform, and the underlying hydrothermal energy that sustains life in these environments will still exist for the potential re-establishment of vent-dependent and associated communities. However the same is not necessarily true for inactive venting sites. Inactive vents that are removed during mining will possibly not re-form. It is also worth noting that mining activities along the sea floor may potentially change the distribution of venting sites. For example: the internal function of the venting system will not be altered, but if one venting site is removed then the internal venting system may re-route, resulting in a new chimney at a different location²⁰².

²⁰⁰ Coffey 2008

²⁰¹ Hunter and Taylor, 2013

²⁰² Van Dover et al., 2011a

Further away from the vent sites there are also other biota that reside on the sea-floor. These species are often filter feeders, such as deep-water corals and sponges that require a sediment-free current to supply their nutrients. During mining, sediment on the seabed is disturbed and the presence of particulate matter can alter food supply. Large amounts of disturbed sediment can also have a smothering effect on certain seafloor residents²⁰³. Each of these impacts is going to be contingent upon the actual amount of sediment present, the footprint of the mining site, and the technology used.

Impacts in the water column

The act of grinding sulphide deposits in the presence of toxic seawater will create toxic chemicals²⁰⁴. Whilst vent communities may be tolerant of some levels of toxicity this will not be the case for organisms located away from the vent areas, and these are likely to be heavily impacted by the transfer of the toxins in plumes. The spatial distribution of the plumes will depend on the mining activity and the strength of bottom currents.

The discharge from dewatering will contain some fine sediment and may contain elevated levels of dissolved metals. Ingestion of this contaminated water by organisms creates potential for some bioaccumulation through the food chain via uptake by plankton and subsequent predation by small fish and crustaceans and larger fish²⁰⁵.

14.2.2 Manganese Nodules

Impacts to biodiversity

There is much less information about communities in the abyssal oceans than other more accessible areas. However it has been noted from studies done in the nodule fields of the CCZ that animal communities differ between those found on nodule surfaces and those found in the surrounding sediments. Generally the sediment dwelling communities are more diverse and abundant than the “nodule communities”²⁰⁶.

An investigation into the abundance, composition and spatial distribution of megafauna was undertaken in the CCZ using seafloor photographs. Analysis of over 11,000 bottom photographs revealed 32 taxonomic groups, including sponges, sea urchins, ophiuroids, actinians and holothurians. The highest density, up to 222 individuals per hectare were glass sponges (Hexactinellida) belonging to a group of sessile suspension feeders. The spatial distribution of megafauna was found to vary with the nodule coverage, indicating that the nodules provide a habitat for sessile organisms like sponges. In areas where nodules were absent the deposit feeders like holothurians dominated²⁰⁷. During the mining operation these animals may be able to shift positions but sessile marine life, including animals living on the nodules will be destroyed by the mining activities.

Because the sea-floor habitats in abyssal regions are physically stable, especially compared to those along ocean ridges where massive sulphide deposits are located, the organisms found there are not well suited to changes in their environment. They exhibit low rates of re-colonization and are therefore likely to be severely impacted by nodule mining activity²⁰⁸.

²⁰³ Rogers, 1999

²⁰⁴ ICES 1992

²⁰⁵ Coffey 2008

²⁰⁶ Clark and Smith 2013b

²⁰⁷ Stoyanova 2012

²⁰⁸ Baker and Beaudoin, 2013c

It is anticipated that the loss of biodiversity across a wide area will have detrimental effects. Experiments carried out in both the Peru basin and the CCZ show that even though (after several years) mobile species may return, the sessile species do not recover²⁰⁹.

Impacts to the sea-floor

Removing manganese nodules from the seabed may involve a variety of methods including suction, digging or scraping, although suction appears to be the leading candidate at present. Because the nodules are partially or completely buried in the top 20 cm of the seabed sediment, their removal also involves removal or sifting of sediment and destruction of the fauna found there. The mining process may also compact the seabed perhaps making it more difficult for recolonization.

Impacts in the water column

When nodules are removed, it is likely that seabed sediments and seawater will mix, causing a release of particles and chemicals into the ambient seawater. These newly introduced particles and chemicals may have an effect on local biodiversity and may spread to wider areas if carried by currents as plumes.

Various organisms residing on the sea-floor rely on a clear flow of water to deliver their nutrients. These certain sessile species may be impacted if their food supply is altered due to the increased presence of sediment in the current.

14.2.3 Cobalt-rich Ferromanganese Crusts

Impacts on biodiversity

Removing ferromanganese crusts is anticipated to be more difficult than removing sulphide deposits or manganese nodules, because crusts are formed typically along (often steep) slopes of seamounts. Technology, therefore, needs to be developed that will strip away crusts while minimizing rock waste on areas where the geomorphology may be highly variable. However, initial licences issued by the International Seabed Authority are targeted at the tops of guyots in the western Pacific Ocean where thick cobalt crusts have been formed as the seamounts gradually sink deeper and where the geology is relatively 'benign'.²¹⁰

Mining process will have a negative impact on biodiversity. The substrate on which fauna are attached will be removed, overlying sediment may be cleared, and waste rock tailings dumped. Downslope and lateral operational plumes may be created and there will be discharge plumes at mesopelagic depths. Many seamounts have been impacted already by bottom trawling and it is evident from impact studies on fishing activities that seamount biota are particularly sensitive to human disturbances²¹¹. Recovery may take decades to centuries²¹².

As with sulphide deposits and manganese nodules, some mobile marine life may be able to move out of the path of mining equipment, but sessile fauna will be removed completely.

²⁰⁹ Kaneko et al., 1997; International Seabed Authority 1999; Thiel et al., 2001; Bluhm 2001

²¹⁰ International Seabed Authority 2013 c, d

²¹¹ Koslow, 2001; Clark et al. 2010

²¹² Williams et al. 2010

A wide variety of fauna are associated with seamounts including sponges, corals, crustaceans, echinoderms and fish.²¹³ However, as Kvile et al. (2013) highlight great care is required in making any generalisations about fauna because seamounts are so variable in their characteristics. Faunal abundances are generally higher on the top and shallow flanks of seamounts where currents are stronger and where food inputs greater, including benthic-pelagic coupling through the diurnal vertical migration of mesopelagic micronekton. While seamounts in any one area may have similar species drawn from a regional species pool, species will differ significantly depending on the depth at which they occur, particularly on upper slopes. This is because the cell membrane structures and enzyme systems of individual species are adapted to particular temperature and pressure regimes, and their distributions also vary depending on the local geomorphological setting, current regime and food supply. The degree of turnover of species with increasing distance between seamounts appears to be related to depth²¹⁴.

Structural organisms residing on crusted sea mounts, such as cold water corals, are long-lived and provide habitat to other organisms such as fish and other invertebrates. Their removal would have a significant impact on diversity in the local environment. Site tests in the offshore areas of New Zealand and Australia show that recovery of species at crusts sites requires extremely long periods of time. In areas where a moratorium on deep-sea fishing has been introduced there has been no re-colonisation even after 10 years²¹⁵.

Species differences may occur in assemblages giving either on or outside crust substrates²¹⁶. However, previous indications that some fauna may have higher or lower abundances on crusts is still an open question. Apparent differences between crust and non-crust areas (presumably at the same depth) have been suggested to occur owing to the high level metal content of the seabed in areas with crusts.

Benthic species on seamounts are often dominated by suspension feeders such as corals and sponges. They will be highly susceptible to sedimentation from mining plumes by wither clogging feeding processes or smothering early life history stages²¹⁷. Any spatial management plan for mining and conservation areas would therefore have to consider particularly downstream effects of mining activities.

Impacts on the Sea-floor

Mining for ferromanganese nodules may potentially initiate changes in seawater quality through the release of chemicals from the seabed and the processed minerals. To-date there has been limited research about the chemical impacts and toxicity as results of deep-sea mining, so it is premature to predict what the full impact may be²¹⁸.

It is worth noting that because ferromanganese crusts form on slopes that are generally free of sediment the impact from sediment plumes will be limited in scope, compared to other forms of deep sea mining. However, plumes may travel downslope or laterally and impact non-mined areas by smothering sessile organisms.

²¹³ e.g. Pitcher et al. 2007; Conalvey et al. 2010; International Seabed Authority, 2011; Schlacher et al. 2013

²¹⁴ Schlacher et al. 2013

²¹⁵ Williams et al. 2010

²¹⁶ Schlacher et al. 2013

²¹⁷ ibid

²¹⁸ Zhou 2007

14.3 Comparison with land-based mining

Introduction

Generally, the rate of finding new, high-quality land-based mineral deposits is in decline²¹⁹, yet the demand continues to increase. This decreasing supply however pushes miners towards recovering lesser-grade deposits, which return lesser yields and increase production costs such as mining equipment and fuel prices. A decreasing supply also drives mining operators towards more “remote and challenging environments” which is likely to have certain environmental and social impacts.

Additionally, for some countries including many in the EU that have limited land-based resources or have difficulties accessing them, deep-sea mining could present a new opportunity to diversify resource streams and ensure provided it is a financially viable alternative. However in addition to financial feasibility of such projects environmental, social, and economic factors would also need to be considered.

Deep-sea mining is a new industry with many unknowns, but there are lessons which can be learned from onshore mining and offshore oil and gas extraction. These industries share the need to manage physical habitat destruction, the potential loss of biodiversity and the dispersal of toxic waste. The technology required for deep-sea mining is still evolving and must be able to operate at great depth and subject to the variations in wind, waves and currents. These difficult conditions will require expert management and maintenance of equipment to ensure that accidents do not occur.

It has been proposed by some that the ecological footprint of a deep sea mine in comparison to an equivalent land-based operation would be considerably smaller²²⁰. At present, there is insufficient information to totally substantiate this claim. For SMS in particular this is at least theoretically conceivable considering the incredible volume of waste rock and overburden that need to be displaced for land-based operations to access the ore. Table 5 contrasts the environmental impact of land-based mining with potential impacts from marine mining.

However despite whether marine mining has a higher or lower footprint than land based mining, a country or region’s total ecological footprint (with respect to activities of “land” transformation”) is cumulative and cannot be separated activity by activity. So whether the mining activity affects the forest biome or the ocean biome, it affects the biocapacity of the country and region as a whole due to the interconnected nature of ecosystems. As we have described earlier, many aspects of the proposed deep sea mining approaches include many of the same steps used in conventional mining. Countries and regions with already limited biocapacity would simply be adding to their overall “ecological debt” if some trade offs are not at least considered. Deciding on such trade offs is by no means straight forward. It is unknown whether a deep sea mine can replace a new land based mine, or if the resource streams for specific metals may be diverted from ecologically (and many times socially costly) land based operations to deep sea efforts that may potentially be less ecologically costly. In all cases countries would need to evaluate independently - taking into consideration the market and environmental conditions of the individual minerals - whether the economic and environmental footprint of deep-sea mining would be smaller or larger than that of land-based mining.

However if policy is designed in a holistic, cross-sectoral manner based on resource frugality (i.e. reduced total consumption), replacement of ecologically high cost activities for lower ones, and the integration of economic progress within a framework of nature-based performance, it may indeed

²¹⁹ Paterson 2003; SNL Metals and Mining 2013

²²⁰ e.g. Scott 2006

be possible for mineral extraction activities to be a corner stone of an ecologically sustainable and socially inclusive “blue economy”.

Table 14.5: Comparison of land based and deep sea mine sites²²¹

	Land based mines	Marine mines
Parameters	Volcanogenic Massive Sulphides	Seafloor Massive Sulphides
Land disturbance	Large area of disturbance both at the mine (open cut and underground). Some disturbance associated with infrastructure such as roads, concentrator, smelter. Mine life can be measured in decades.	Limited spatial extent but destruction of site-specific habitats, limited and reusable infrastructure. Short mine life.
Waste generation	Large amounts of waste including waste rock, tailings, effluent (potential for acid mine drainage), air pollution, potential oil/chemical spills.	No or little overburden, limited tailings (in comparison to land based deposits), waste-water plumes which have the potential to transport toxic substances, limited air pollution from vessels, potential oil/chemical spills.
Biodiversity loss	Total biodiversity loss over a large spatial scale at open cut mines.	Total biodiversity loss at sites of extraction and areas immediately adjacent.
Rehabilitation potential	Major changes to landscape and hydrological regime, but good potential for general rehabilitation over decades to centuries.	Major changes to seafloor topography but on limited spatial scale. In theory, potential of development of healthy (but potentially different) communities over years to decades.
Energy use and GHG emissions	GHG emission via transport and cement production, air pollution, high energy use (depending on the extraction technique energy costs can account for 10-12% of all costs)	Off-shore processing of the minerals and transportation by air or water could contribute to a reduction of GHG emissions and additionally reduce the environmental and social impacts caused by the infrastructural developments linked to road transportations and building of on-shore processing plants.
	Manganese	Manganese nodules
Land disturbance	Large area of disturbance both at the mine (open cut and underground). Some disturbance associated with	Large area of disturbance of benthic layer at mined areas and potentially areas adjacent. Potentially short mine life.

²²¹ The actual amalgamated environmental impacts of the operations including processing and transportation would have to be compared and evaluated on a case-by-case basis

	infrastructure such as roads, concentrator, smelter. Mine life can be measured in decades.	
Waste generation	Large amounts of waste including waste rock, tailings, effluent, air pollution, potential oil/chemical spills.	No overburden, limited tailings (in comparison to land based deposits), some waste-water discharged as a plume which may disperse considerable distance, limited air pollution, potential oil/chemical spills.
Biodiversity loss	Total biodiversity loss over a large spatial scale at open cut mines.	Total biodiversity loss at sites of extraction and potentially areas immediately adjacent.
Rehabilitation potential	Major changes to landscape and hydrological regime, but good potential for general rehabilitation over decades to centuries.	Although changes to the seafloor morphology may be limited, current scientific evidence indicates that there is likely to be very poor rehabilitation potential within human time scales.
Energy use and GHG emissions	GHG emission via transport and cement production, air pollution	Off-shore processing of the minerals and transportation by air or water using offshore bases could contribute to a reduction of GHG emissions and additionally reduce the environmental and social impacts caused by the infrastructural developments linked to road transportations.
	Rare Earth Elements	Cobalt rich crusts
Land disturbance	Moderate area of disturbance both at the mine. Some disturbance associated with infrastructure such as roads, concentrator, smelter. Mine life can be measured in decades.	Spatial area of a commercial mine is currently undefined, but could be significant and on a larger spatial scale than on land mining.
Waste generation	Large amounts of waste including waste rock, tailings, effluent, air pollution, potential oil/chemical spills.	No overburden, the limited tailings dealt with on land, some waste-water discharged as a plume, which may spread considerable distance, limited air pollution.
Biodiversity loss	Total biodiversity loss over a large spatial scale at open cut mines.	Total biodiversity loss at sites of extraction and potentially areas immediately adjacent.
Rehabilitation potential	Major changes to landscape and hydrological regime, but good potential for general rehabilitation over years to decades.	Major changes to substrate, slow recovery over tens to hundreds of years. May never fully recover in some areas of altered substrate.

Energy use and GHG emissions	GHG emission via transport and cement production, air pollution	Off-shore processing of the minerals and transportation by air or water using offshore bases could contribute to a reduction of GHG emissions and additionally reduce the environmental and social impacts caused by the infrastructural developments linked to road transportations.
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15 Roadmap to identify operational targets for Good Environmental Status

15.1 Overview

A Good Environmental Status (GES) of marine waters means that the various uses made of the marine resources are conducted at a sustainable level, ensuring their continuity for future generations (European Commission 2014). The European Commission has set up 11 descriptors to monitor the state of the marine waters in Europe ranging from biodiversity, through eutrophication and contamination to energy uses.

Operational targets and good environmental status

*Operational targets or operational objectives define the necessary steps that would need to be taken in order to fulfil objectives of an organisation. Within the context of this project operational targets include those activities that would be required from the European Union (or other policy making organisations) to ensure that the good environmental status of those marine areas where seabed mining operations take place are preserved and **sustainable use of these marine waters are guaranteed. It is essential that the sequence of activities leading to the operational objectives reinforce one another and provide added value individually as well as collectively. Furthermore, communication and dissemination tools such as stakeholder consultation are vital to ascertain that implementing policies behind GES are not seen as restrictive and do not facilitate circumvention via international consortiums or other means. Moreover, facilitation of an international industry-wide voluntary commitment on adhering to practices linked to good environmental status and sustainable use of marine waters could contribute to transparency of operations and environmental impacts.***

Based on the key environmental impacts identified earlier in the project there are aims to propose a sequence of activities (roadmap) that could result in setting up operational targets of GES²²² for marine waters where seabed mining activities take place. In order to identify viable activities for operational targets it is important to be aware of the operations involved with seabed mining as well as their environmental impacts and the status of the environment at various geographical locations.

The roadmap builds upon current limitations in knowledge specifically with regard to biodiversity in benthic environments and consequently includes activities such as data gathering and transparency in reporting as well as the establishment of conservation areas where mining activity should be prohibited.

The purpose of this roadmap is to steer commercial mining practices in such a way as to meet the ecological objectives and achieve good environmental status for the relevant marine areas. Additionally the roadmap can facilitate discussion and research into sustainable seabed mining practices as well as the coordination of activities of the different stakeholders.

In addition to the development of GES in the MSFD framework, there are also a number of other indicator variables that are becoming accepted for issues related to climate change (Essential Climate Variables). The Group on Earth Observation has several communities of practices which are examining such variables and how to implement them globally. The Biodiversity Observation

²²² Based on Member States' agreement

Network (GEO – BON) has developed a set of Essential Biodiversity Variables (EBVs) that are widely accepted as being valuable for tracking change (Pereira et al. 2013). These include genetic diversity indicators, the abundance and distribution of various taxa, habitat and the timing of change. Data from such variables can directly into GES indicators and would form the foundation that would underpin provision of information on environmental and ecological change.

15.2 Methodology

A preliminary draft for the roadmap which was presented in a proposal submitted to the European Commission. This draft (seen in the below figure) includes the identification of the individual steps necessary for setting operational targets, a brief analysis of costs and benefits, and recommendations for their implementation e.g. types of policy measures.

Table 6: Proposed template for preliminary roadmap on operational targets for GES

Step 1: Gathering raw data on deposits and ecology
Description:
Cost and benefit estimation:
Recommendations for implementation:
Step 2: Transparency of information exchange
Description:
Cost and benefit estimation:
Recommendations for implementation:
Step 3: Common indicators for technology assessment
Description:
Cost and benefit estimation:
Recommendations for implementation:

In order to establish the validity of the steps proposed for the roadmap, stakeholders have been contacted and literary sources consulted as to gather an understanding of the different practices that would be expected to take place once commercial deep-sea mining is operational. Information on the supply chain, deep sea mining processes, and applicable international legislations is crucial for the operational objectives to be effective and relevant. Once activities associated with significant environmental impact are identified policies, objectives, and operational targets can be developed to ensure that these operations are carried out under specified conditions assuring that the desired environmental objectives are achieved.



Consequently the sequence of activities proposed below are a translation of the relevant environmental, social values, high level policy objectives, and standing legislation into a form of practical steps that have a direct impact on the management of deep-sea mining operations. The activities are:

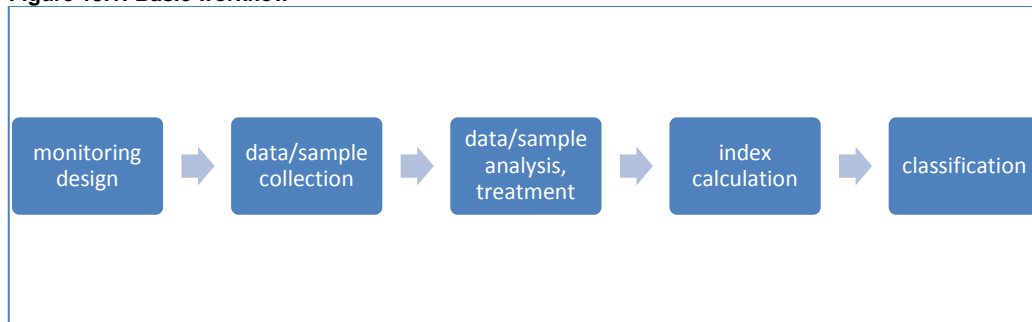
- outcome-focused and describe the expected response from sea-bed mining operators;
- measurable by qualitative or quantitative indicators; and
- timescaled, providing a sequence.

GES workflow

Indicators can take several forms from the interpretation of limited variables such as a toxin and potential responses in a model organism to complex multi-metrics such as those for fishes or primary productivity.

In the case of marine primary productivity they can include data on the amount of pigments and composition of phytoplankton. For fish, this can include variables such as species composition, relative abundance, make up of 90% of density or biomass, indicator or model species, and functional guild abundances. GES indices process generally takes the form as illustrated below.

Figure 15.1: Basic workflow



Classification takes into account prior knowledge about variation in the indicator setting and translates the information to policy relevant a context such as ‘undisturbed conditions’ to ‘evidence for severe changes’. The road map to creating a set of indicators thus necessarily involves consideration of each of these steps.

15.3 Roadmap to establish operational targets for GES

The following steps are foreseen as elements to establish valid and adaptable operational targets for GES for the marine environment where deep sea mining activities take place.

The term adaptable is viewed as an essential quality for the below steps as new information, data, and experiences linked to first time commercial operations are expected to feed invaluable information on the actual environmental impacts. Consequently the below proposed sequence of activities remain “dynamic “and subject to change.

Step 1: Gathering raw data on deposits and ecology

Description: A comprehensive benthic survey would need to be carried out over extensive areas prior to awarding extraction licenses for deep-sea mining. These benthic surveys would include mapping of:

- habitats,
- water quality,
- composition of the minerals to be mined, and
- embedded geological structure.

Benthic habitat maps can be derived from aerial imagery, underwater photos, acoustic surveys, and data gathered from sediment samples. The resulting digital map could be viewed using geographic information system tools.

Information on the mineral deposits and the benthic ecosystems impacted would be one of the most dynamic elements of the roadmap. It is the one area where the extent of unknowns is unclear. This would require the use of advanced technology that maps and records migration.

Cost and benefit estimation: Depending on the method of implementation it is likely that a significant portion of the costs would be borne by the companies carrying out deep-sea mining.

Costs: To be developed (information from survey companies for specific areas).

Technology:

- Survey management
- Analysis of acoustic data
- High definition video and stills photography
- Remotely Operated Vehicle (ROV) surveys
- Seabed sampling (grab sampling, box coring, trawling)
- Single beam echo sounder capabilities (dredge monitoring, beach profiling, monitoring of disposal sites etc.)
- Identification of seabed biotopes
- Physio-chemical analysis
- Taxonomic identification

Recommendations for implementation:

In order to ensure consistency in data collection a regulative measure would need to be applied which requires companies operating within Member State continental shelf areas to carry out benthic surveys and share the information in a public domain.

In the case of ABNJ it is likely that an international initiative would need to be launched with similar mechanism where the ISA could host the information in a domain accessible for the public.

Potential risks might arise if activities taking place in continental shelf areas of countries which do not impose the requirement for preliminary benthic survey and information exchange. A highly desirable outcome would be an international agreement on compulsory benthic survey for deep-sea mining operators.

Such an international agreement could also contribute to ensure harmonisation with regard to the methodology of information collection.

Step 2: Streamlining data management

Description: Access to data and information are a fundamental element not only for establishing GES but also for managing large scale mining operations. It is expected that individual stakeholders – mining companies as well as national authorities - would collect data on the benthic environment as well as associated impacts of the operations; however it is essential that a broad overview of data including statistics and forecasts is gathered and regularly updated on the European as well as the international level.

Streamlining data management would allow the creation of a single data repository with online access. Such a database would allow exporting and importing of maps and aerial views for the different sites and could be customised and configured in such a way that information marked as confidential would not be displayed for all viewers. Further consolidation of data with the International Seabed Authority would create a transparent system that includes information on stakeholder involvement (details of the mining companies), sites of the operation, and exploration and extraction licenses.

Step 2: Streamlining data management

Types of information:

- benthic survey
- stakeholder involvement per operation
- sites of operation
- size and access to deposits
- exploration and extraction licences
- future extraction potential etc .

Cost and benefit estimation: To be developed

Recommendations for implementation:

Depending on the level of data consolidation, maintaining and updating such a site would fall into the competences of the European Commission. With regard to the data collection, in order to have a complete overview stakeholders would be required to report and can be obliged by regulatory measures or can be encouraged by voluntary intra-industry schemes such as certification or quality control initiatives.

Step 3: identifying common indicators for technology assessment

Description: A critical element of the roadmap will be to establish indicators in order to assess the sustainability of the deep sea mining operations. These indicators will be essential in determining - based on the impacts of the technology used and the benthic environment - whether a specific marine area can be considered to have Good Environmental Status. Sustainable technology has the characteristics of minimising negative environmental impact and can include methods and processes as well as physical infrastructure.

Two main types of indicators could be used:

- technology indicators; and
- environmental indicators.

Technology indicators would comprise of an assessment on the following criterion:

- performance of the system (state and types of tools and machines used in deep-sea mining operations);
- adaptability of technology to the changing benthic and pelagic conditions;
- safety of the system (safety score);
- reliability of the system (mean time between failures); and
- social impacts of technology.

Environmental indicators would comprise of an assessment on the following criterion:

- resource usage for building and operation;
- waste management (waste water, solid waste etc.);
- pollution (air, water, land); and
- impact on density and species composition at benthic and pelagic zones;
- impact on sediment composition
- presence of alien or non-indigenous species

The indicators developed from the above criterion can build on benthic and pelagic indicator models already adopted (e.g. ECASA toolbox) taking into consideration that none of the existing indicators have been 'tried and tested' yet.

Cost and benefit estimation:

The development and regular update of a comprehensive list of indicators would fall into the competences of the European Commission and the relevant international organisations (ISA).

Recommendations for implementation:

Following the selection of the indicators a European level regulatory requirement would need to be established or current regulatory requirements would need to be amended (e.g. MSDF) in such a way that

Step 3: identifying common indicators for technology assessment

deep sea mining activities taking place in marine areas belonging to the continental shelves of Member States would be required to provide information on the fulfilment of the above indicators.

In the case of ABNJ and for marine waters belonging to the continental shelves of third countries a wider international agreement would need to be reached in order to establish a common set of indicators for operational activities.

Step 4: establishing qualitative descriptors

Description: Based upon the current state of the relevant maritime areas a set of qualitative descriptors setting out the key targets for sustainability would need to be established. These qualitative descriptors will describe the state of the marine environment once the relevant indicators have been met. Prevention would be one of the essential roles of these qualitative descriptors as it is nearly impossible to take measures to remove or reduce the impact on the natural system once an invasive species has established itself (Van Hoey et al., 2010).

Therefore, an early warning system adapted to the specific maritime area should be developed including detection, diagnosis, quick screening, risk assessment, identification of proper response, reporting to the competent authority and an authority response (Van Hoey et al., 2010).

Cost and benefit estimation:

To be developed.

Periodic monitoring and assessment of the status of the environment with regard to the descriptors would fall within the competences of national regulatory bodies.

Recommendations for implementation:

Determining and evaluating qualitative descriptors would require a joint effort of national and international regulatory bodies, research centres, NGOs, and other stakeholders. Based on these qualitative descriptors strategic objectives can be derived with regard to the long-term environmental status of the marine waters to prevent adverse effects of deep sea mining and to safeguard human health and ecosystems.

The environmental status set out in the qualitative descriptors can be measured by third party assessment, reporting or self-certification.

Step 5: reporting

Description:

Reporting requirements within the mechanisms of a GES would be twofold; on the one hand reporting would be required from stakeholders engaged in deep-sea mining operations. On the other hand national authorities and international bodies would be also be required to share consolidated as well as disaggregated information on environmental impacts, and protective and preventive measures taken. Environmental impact reporting or environmental statements from individual stakeholders would include:

- The identification of the state of the specific marine environment prior to deep sea mining operations (based on surveys as described under step 1);
- The description of the technological tools and practices;
- An assessment of the operations based on the technology and environmental indicators (as described under step 3)
- As assessment of the marine environment during the operations of deep sea mining, including preventive measures taken to minimise the impact of invasive species (as described under step 4)

Environmental impact reporting or environmental statements from national and international regulatory bodies would include:

- Consolidated information on the state of the marine environments prior to deep sea mining operations of all relevant stakeholders under licence from the ISA (based on surveys as described under steps 1 and 2);

Step 5: reporting
<ul style="list-style-type: none"> • An assessment of the operations based on the technology and environmental indicators (as described under step 3) • As assessment of the marine environment during the operations of deep sea mining, including preventive measures taken to minimise the impact of invasive species (as described under step 4) • Updated independent audit reports on the technological tools, practices and environmental impacts of the deep-sea mining operations (as described under step 6).
<p>Cost and benefit estimation:</p> <p>To be developed</p>
<p>Recommendations for implementation:</p> <p>The content and frequency of reporting requirements can be set by European regulatory provisions making it obligatory for Member States or individual companies. Alternatively individual stakeholders can be encouraged to report on the impacts of their activities via voluntary measures such as quality control or certification schemes. In the case of ABNJ and for marine waters belonging to the continental shelves of third countries a wider international agreement would need to be reached in order to establish reporting requirements.</p>

Step 6: ensuring independent assessment of practices/measuring environmental impact
<p>Description: Independent assessment of the operational practices serves the purpose of verifying the compliance of completed or on-going deep-sea mining activities with the relevant provisions of legislative elements, environmental policies, indicators and qualitative descriptors.</p> <p>Third party environmental audit reports reinforce transparency, reliability and social accountability of the stakeholders. Moreover, target setting and external reporting facilitate environmental improvement through public disclosure of targets and results. It can also contribute to the reduction of corporate risks and broaden the range of investors. Furthermore it can improve the list of preferred suppliers for buyers with green procurement policies.²²³</p> <p>In order to achieve comparability and transparency of operations a generally accepted standard for environmental reporting (whether third party or self-evaluation) would need to be developed.</p>
<p>Cost and benefit estimation:</p> <p>Third party audit schemes would be developed by certification bodies and relevant costs would be levied onto the individual stakeholders carrying out the operations.</p>
<p>Recommendations for implementation:</p> <p>Regulative measures can be imposed to make third party audit schemes compulsory once extraction licenses have been granted. Alternatively environmental reporting and third party auditing can also be prerequisites of obtaining extraction licenses. In the latter case implementation of provisions would fall into the competences of the ISA and national authorities responsible for granting licences of operation.</p>

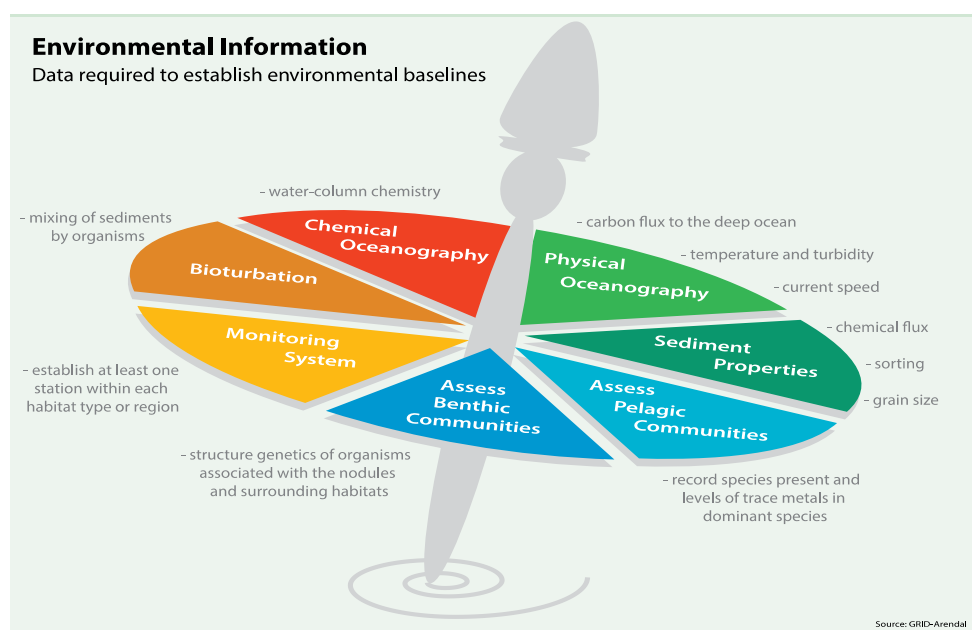
Once basic environmental impacts are identified and a roadmap prepared to measure operational targets, the next step will be to monitor the operations. In order to establish monitoring criteria tools will be assessed that are currently available for the review and monitoring of the environmental impacts.

²²³ Association of Chartered Certified Accountants (nd)

16 Review and inventory of monitoring techniques

Seabed mapping and monitoring techniques are a cost-effective way to carry out wide-scale surveys and can be used to identify seabed (or sub-seabed) features of conservation, resource, or scientific interest²²⁴. Seabed mining operators in international waters are obliged to satisfy best environmental practices and to provide the regulatory authority with reporting/monitoring information confirming that best practices are being applied²²⁵. Within jurisdictional areas of particular countries relevant national provisions also apply.

Relevant regulatory authorities are responsible for the verification of the monitoring measures and that the mining operator is adhering to the best environmental practices. In order to achieve this baseline surveys will be needed prior to mining activities. Additionally, mapping of pre-mining conditions such as seabed sediments, habitats, and water column features are necessary in order to identify any physical impacts. Once measurements have been carried out on the physical properties of the specific areas a minimum threshold needs to be set with regard to the environmental impacts, such as impacts on the sediment, species, pollution, waste generation practices etc. within which activities can be considered to fulfil best environmental practices.



Example of environmental baseline data required under the ISA Mining Code's regulations on prospecting and exploration within the Area. GRID Arendal 2013 in Lodge et al 2013).

16.1 Inventory of monitoring techniques

Oceanographic tools have evolved over the last century to include a wide array of platforms and sensors that can now measure a range of marine variables in manual, semi-autonomous or autonomous ways. These can range from making measurements by shipboard sampling systems to releasing robotic equipment which then reports back to shore via satellite for its full service lifetime, several years in some cases. Platforms can range from satellites, to ships to specialised

²²⁴ Boyd et al. 2006

²²⁵ International Seabed Authority 2011a

deep-sea vehicles. Likewise oceanographic tools range from thermometers to sensors capable of conducting molecular genetic analyses *in situ* and reporting data back to shore, fully autonomous and in real time. Sampling for the complete range of known body size is now possible through various sampling and processing approaches including varied sieve and water filter sizes.

Satellites can see the 'skin' of the ocean and have proved very valuable insights into the spatial variation in temperature, salinity, sea surface height, and even bathymetric features through their gravimetric influence on sea surface height. In a seafloor mining context such imaging could provide useful indications of the distribution of potentially sediment laden plumes at the sea surface. Although there have been great advances in autonomous systems, ships remain a vital platform for oceanography and marine survey work. The greatest recent change in the way ships are used is that a greater portion of sea time is now going into deploying and servicing a wide range of systems that are able to collect data autonomously in one way or another. Additionally the use of remotely operated vehicles (ROVs) and hybrid systems has also increased. Thus the capability of any single research cruise has greatly increased, with much more being possible in a given number of days on station. Ship dependant equipment includes ROVs, which are tethered to a ship, as well as conductivity temperature and depth (CTDs) recording systems, which also have a suite of biogeochemical sensors and sample bottles. These CTD rosettes can take samples at discrete depths in the water column, and can also come specially fitted for examining trace metals such as iron. Another wire deployed tool is a standalone pump system (SAPS) for filtering water *in situ*. There are also multiple tools for sediment sampling including box cores, multiple coring systems such as the Bowers and Connely megacore system, which are widely regarded as being able to return the least disturbed sediment samples possible without an ROV or specialised lander.

Capabilities for buoys, moorings and lander systems have improved in recent years with a vast array of sensors now deployable to deep ocean depths, many of which can operate for a year or more without service²²⁶. These can operate as standalone or delayed mode systems where data is returned whenever the systems are serviced. However, there have been important advances in telecommunication methods such that there are now many examples of systems that can telemeter data acoustically from the deep seafloor to near surface, and then by wire to a surface buoy that can send and receive satellite messages.

Seafloor cable systems have also increased in their use and reliability and have much greater capability in terms of power available for sensors and telecommunication bandwidth, as well as real time data feed. The added capacity of bandwidth can allow for images and other large format data to be readily relayed. And some sensors such as video and active acoustics can use relatively larger amounts of power depending on how frequently those are running²²⁷. These systems can operate either from bespoke cables which connect to a junction box, which either can go to shore via another cable or connect to an acoustic to satellite relay system as mentioned above. Cabled systems are also required for applications where time synchronisation and real-time alerting are needed, such as for monitoring of geophysical motion in relation to geo-hazards. Junction boxes and sensors can also be added to existing and even disused seafloor telecommunication cables as has been done with the H2O and ALOHA cabled system projects in the northeast Pacific Ocean.

Tools such as buoys and moorings do not require constant monitoring and can be serviced once a year. Data recording devices can also be recovered and serviced by divers. Some of the sensors allow for the electronic transmission of data while others store information in which case divers need to download the data.

²²⁶ see Ruhl et al. 2010 and 2011 for more detail including examples and vendor details

²²⁷ Priede et al. 2003, Barnes et al. 2008, Favali et al. 2009

Box 16.1: Monitoring tools proposed by Nautilus Minerals²²⁸

In its Environmental Impact Statement for the Solwara I project, Nautilus Minerals has listed some of the monitoring tools it aims to deploy in order to ensure sustainable operations. The following list is a selection of the proposed tools and methodology:

- Place time-lapse cameras on the seafloor to observe selected vents
- Repeat temperature mapping of mine area at appropriate intervals, at least annually
- Video and map active chimneys in areas after Seafloor Mining Tool (SMT) (i.e., mining) activity.
- Obtain long-term temperature monitoring in selected vents using thermistors.
- Complete a centre-line transect imaging survey at Solwara 1 and South Su after three to six months, and thereafter six-monthly or at an appropriate frequency to be determined.
- Photo mosaic/video pass (frequency as above).
- Visual analysis of species, density and abundance from video transects.
- Use settlement collectors to obtain settling animals
- Using ROV and scoops (opportunistically and/or during routine monitoring), transport samples of densest clumps of snails in path of mining and relocate to adjacent areas (initially).
- Video observation of plumes generated by SMT activities (including mining, sediment removal and competent waste material side casting) during operation.
- Establish sedimentation traps at the selected/control sites to monitor natural/mine-induced settlement.
- Particle size analysis annually.
- Video redeposition of sediments on mine areas and changes to topography of mined areas.
- Core samples for grain size analysis (annually).
- Hydrophone monitoring of sound characteristics of MSV, Riser and Lift System and SMT operations.
- Record any observations of marine mammals in the vicinity of operations during life of mine.
- Deploy a current meter (ADCP) for continuous recording at a fixed site for ocean currents and plume predictions.

According to the information on the website of Nautilus Minerals, further details of the proposed monitoring programs, including descriptions of the methods, locations and frequency of monitoring, will be included in the detailed Environmental Management Plan ("EMP") which will be submitted to the government of PNG for approval prior to project commissioning.

Several research projects have conducted research and development activities around ocean observatory science and technology including the European Seas Observatory Network (ESONET), EuroSITES, European Multi-disciplinary Seafloor and water column Observatory (EMSO) project, and the Fixed Point Open Ocean Observatory (FixO³) project. The EMSO project has also sought to form a European Research Infrastructure Consortium, which is a legal instrument created by the EC to facilitate more effective operation of research infrastructures. It is expected that the EMSO-ERIC will be operational by 2015. Moreover, this organisation can act as a clearing house for knowledge on ocean observatories for European industrial interests.

Ocean data buoys now have a track record for recording and relaying data from open ocean sites globally (see OceanSITES). These can carry a large payload of sensors and power systems. Power can come from batteries, solar, wind and even on-board diesel generators or wave energy. One of the key advantages to buoy systems is that it allows for the direct measurement of atmospheric conditions and how they relate to sea surface conditions over time including the transfer of heat, wind and wave energy, and primary production which drive marine food webs, even for most deep-

²²⁸ Coffey (2008): Environmental Impact Statement, Nautilus Minerals, Solwara I.
<http://www.cares.nautilusminerals.com/assets/documents/main%20document%20text.pdf>

sea life²²⁹. Measurements at this interface can, importantly, help when trying to differentiate potential human impacts from naturally occurring seasonal or inter-annual variation²³⁰.

Telecommunications can come via two-way links to satellites for relaying data and taking software upgrades and new instructions to instruments, as well as links to systems down mooring lines or acoustically.

Moorings can have a surface expression (buoy), but deep water moors often avoid surface waters as this reduces risk due to weather damage and vandalism. Moorings can be recalled by acoustic release, timed release, corrosive release, or some combination depending on the application and acceptable levels of risk. They can serve to fix instruments or packages of instruments at certain depths in the water column over time at fixed points. Thus they are very useful in creating time series data for various water column features like profiles of water mass structure, biogeochemical fluxes including the transfer of energy primary production to deeper depths as a particulate rain of 'marine snow'. They can also easily hold sensors for the measurement of suspended particle load and current profiles. Here too, these data allow for understanding of not only impact related variables such as particulates and their fluxes, but also provide information on the natural variation in particular organic carbon fluxes, for example.

Seafloor landers are another long-used platform for marine research and survey work. They can carry a wide range of payloads including current meters, seismometers and other geophysical devices, cameras which can measure animal activity and diversity²³¹ and sedimentation dynamics²³², animal and seafloor community respiration measurement equipment²³³, and complex experimental systems²³⁴. Lander systems can also carry baited cameras and current meter systems that can calculate the densities and biodiversity of fishes and invertebrates.

The last decade has seen the maturation of several advanced platforms including unmanned surface vehicles (USVs), wave gliders, buoyancy gliders, autonomous underwater vehicles (AUVs) with long range and/or endurance, AUV docking stations, and benthic rovers. All of these systems can now be deployed for months at a time and collected data over a pre-programmed range of depths or spatial settings. USVs have which can station keep or survey an area cyclically. Because these can carry relatively large payloads as well as solar and/or wind harvesting equipment, they can have long endurance for a wide range of variables. Examples of USVs from commercial vendors are now available. Wave gliders gather wave energy and have limited navigation capability that includes station keeping capability. One wave glider has done a trans-Pacific crossing providing an important demonstration of endurance. Buoyancy gliders now have broad uptake in the oceanography community and can hold a limited number of compact sensors including examples for optical backscatter (turbidity), fluorescence, nutrients and oxygen.

A wide range of AUVs are now available from several commercial vendors. These often have a modular payload. AUVs that can dive to abyssal depths remain relatively rare, though, with only a few commercial and research organisations designing, building and using these globally²³⁵. Multiple research and development laboratories have now developed AUVs with long range and high endurance²³⁶. The Autosub LR, for example, has expected range of 6000 km or endurance of up to

²²⁹ e.g. Smith et al. 2009, Hartman et al. 2010, Billett et al. 2010

²³⁰ e.g. Vardaro et al. 2013

²³¹ e.g. Vardaro et al. 2009

²³² e.g. Smith et al. 2014

²³³ Bailey et al., Smith et al. 1999

²³⁴ Sweetman et al

²³⁵ Wynn et al. 2014

²³⁶ e.g. the TETHYS vehicle at the Monterey Bay Aquarium Research Institute [MBARI], and the Autosub Long Range [LR] at the National Oceanography Centre, UK

6 months²³⁷. This long range capability stands to provide a step change in monitoring capability and cost effectiveness. It can reduce the dependency on costly ship time and improve spatiotemporal sampling. These systems can act as virtual mooring infrastructures providing repeat profiles of the entire water column over time, or they can conduct ocean data sections over ocean basin scales. Moreover, because of the endurance and ability for satellite telecommunication, they can do so without the need for additional complexity added by docking stations for data and power exchange.

Benthic rovers have also become more common with multiple research labs now working on next generation rovers. These have capability to make measurements of seafloor oxygen consumption and similar variables on timescales of days²³⁸. These can also carry a range of cameras and other sensors and in many ways these can operate as mobile lander systems, where the rover can move to new locations in time series.

There are a broad range of sensors now available, with miniaturisation and improvements in reliability and cost effectiveness changing rapidly. This is driven, in part, by requirements to get sensors on to gliders and AUVs where space and power are at a premium and there are rarely chances to fix failed sensors. Conductivity, temperature and fluorescence sensors have been available in compact systems for many years. Chemical electrode based sensors have also long been used in oceanography and include oxygen sensors. These electrode systems are now often surpassed in performance by optode systems, where foils exposed to seawater are illuminated and a subsequent response by the foil is then quantified. These optodes have now been adapted for a variety of purposes. Similarly infrared light-based methods have also improved, with systems now able to detect nutrients and CO₂ now commercially available. There are now also sensors in development which use microfluidics or 'lab-on-chip' systems. These allow for reagent based techniques to be deployed *in situ* with better efficacy including those for nutrients.

A major advance in acoustic and optical imaging is currently happening. Acoustic current meter technology is also mature with several variants of 2D or 3D acoustic current meters now available. There are now several efforts to better process such data to get more value added data such as those values that can be inferred from backscatter. The rendering of detailed 3D surfaces from acoustic data is also improving with vertical faces now imaged for habitat composition.

With the maturation of digital cameras, platforms and semantic image processing, the use optical images is set to make a step change in the coming years. Photographs and photogrammetric methods have long been useful in oceanography, marine survey and ecological research. These systems can image life and habitats across a wide range of scales. In the water column, the challenge of scale measures has been overcome through the use of structured light cameras, where the imaged volume is known. Examples include the *In situ* Ichthyoplankton Imaging System (ISIS²³⁹) and Underwater Vision Profiler (UVP), or via 3D systems where the size and location of objects can be determined. Holographic imaging systems have been developed and commercialised that can image marine algae cells and smaller zooplankton (e.g. LISST-Holo). Macro and mega plankton imaging systems have also been developed and commercialised, including the UVP. HD video has also been used successfully to map plankton²⁴⁰.

Benthic imaging has benefited from HD video and digital camera development. The pair of digital still cameras with advanced AUV technology as brought a step change in capability for mapping large areas of the seafloor photographically. For example, an area with sides of about 10 km² was

²³⁷ Wynn et al. 2014

²³⁸ e.g. Sherman et al. 2009

²³⁹ Cowen and Guigand, 2008

²⁴⁰ Robison et al. 2005

mapped with the Autosub6000 AUV at the Porcupine Abyssal Plain²⁴¹. The system was able to photograph 160 km of track line with mm scale pixel resolution in a lattice layout. This has allowed for research at a more landscape scale than has been possible in the marine sector previously, where continuous surveys are generally limited to a few km. Newly commercialised 4k cameras (a.k.a Super-Hi Vision, 7680x4320 pixels) have also been adapted for deep sea use, such as those used in the HADES project²⁴². Importantly, there are detailed and well accepted best practices for analysing data from images that are embodied in point transect and line transect theories²⁴³.

Molecular sensors have been maturing with at least one system having been commercialised, the Environmental Sample Processor (ESP), developed at MBARI. The ESP is capable of taking water samples to 4000 m depth, decompressing the sample in its housing, and running a complex set of molecular probe analyses via real time DNA, RNA, molecular marker reactions including q-PCR. The results are then imaged using Fluorescent *In Situ* Hybridisation (FISH), and phytotoxin quantification. These images can then be sent back to shore in real time via ocean observatory telecommunication systems such as seafloor cables or cable-buoy-satellite relay.

Given the range of available platforms and sensors, it is now possible to mount much more comprehensive monitoring programmes that can help eliminate doubt as to the sources of variation, be they human or natural. Best practices should include the appropriate sensor or sampler for the target variable, size class or fauna character as well as stratified random sampling with sufficient replication for observed variation. These strata can be made up of factors such as habitat type, time of year or other known features and if adequate samples are taken across each strata, then each can be systematically examined in EIA and other analyses including statistical methods.

The curation of data and samples for areas of seabed mining by any researchers or contractors is especially important considering the rarity of such samples globally and the need to cross reference specimens which may not be taxonomically described, but occur at sites being examined by more than one contractor. Thus, the curation of samples should include entry of sample collection details into taxonomic database systems. In the oil and gas sector this is often handled at a national level. However, given that many areas are outside of national jurisdiction, a coherent data-basing and voucher specimen system is advisable. Likewise, because there is relatively little data available (with suitable metadata) for deep-sea systems generally, the more data that can be made openly available, the better able scientist and surveyors will be at understanding potential and real impact. While there are no doubt commercially sensitive data in industrial applications, much if it can be released without economic detriment to industrial interests.

16.2 Analysis and reporting

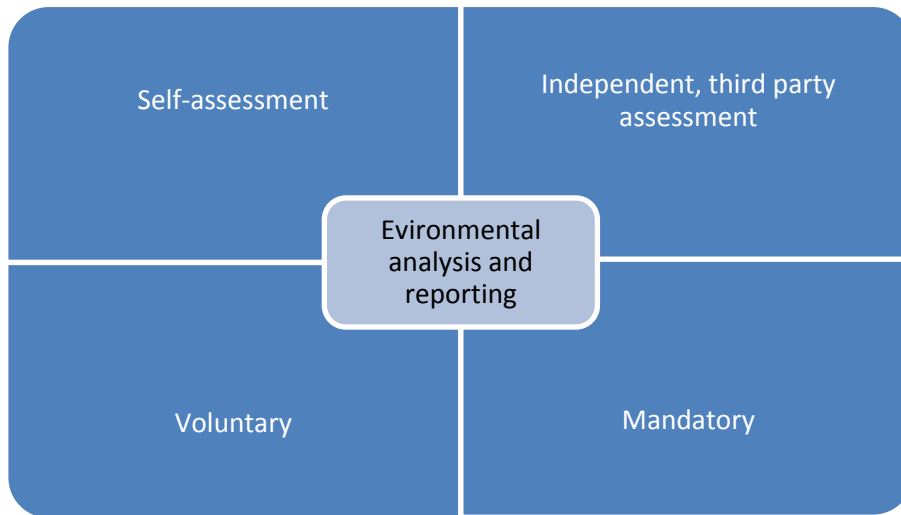
Once an on-site survey has been carried out findings can be further analysed and reported. There are again multiple ways to evaluate the findings ranging from a basic assessment against criteria and environmental performance to more in-depth analysis of the conditions taking into consideration social and economic spill-over impacts.

Environmental impacts can be assessed and reported by the operators (self-assessment) or independent third parties. Moreover, the analysis and reporting activities can be mandatory or voluntary.

²⁴¹ Wynn et al. 2014

²⁴² <http://www.who.edu/hades>

²⁴³ Buckland et al. 1993



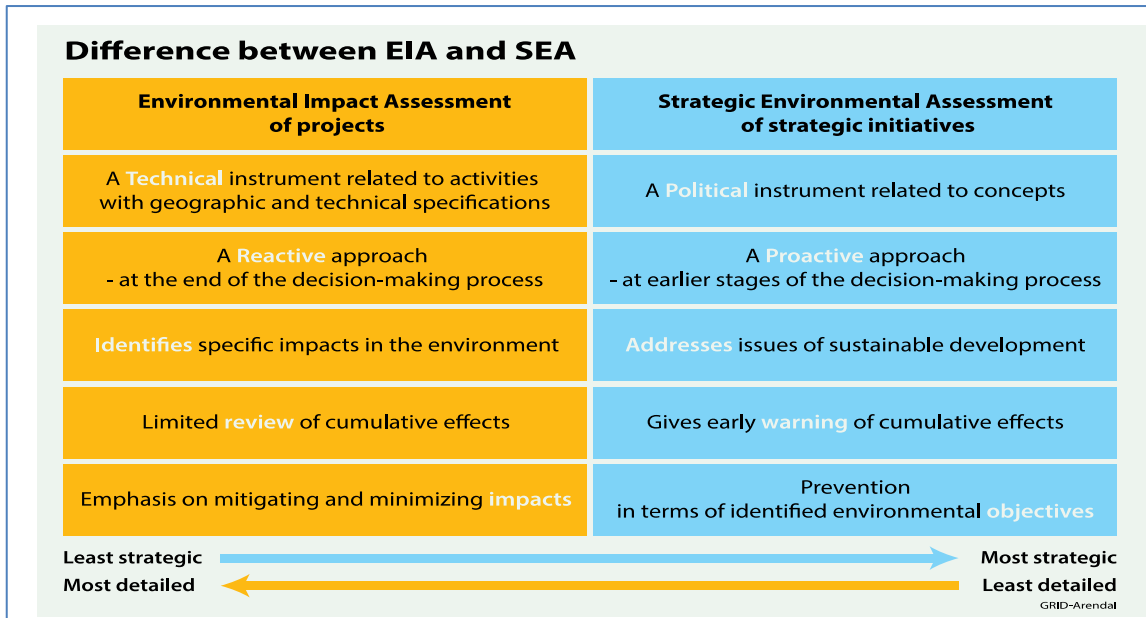
The following are some of the methods for analysis and Reporting on environmental performance:

- Strategic Environmental Assessment (SEA);
- Environmental Impact Assessments (EIA);
- Self-reporting or third party assessment based on National and international legislative framework;
- Setting environmental performance targets; and
- Voluntary or mandatory quality control or certification scheme (ecological-technological).

In the case of both SEA and EIA the analysis takes into consideration a wider set of impacts and looks at a longer time frame than an annually audited environmental performance or certification would do. Assessment tools based on a set targets – either defined by legislation or independent environmental performance targets – can be rather restrictive and focus on impacts recorded at a given time without providing an on-going review of impacts along the value chain.

The following figure illustrates the differences that could exist between EIAs and SEAs.

Figure 16.1: Differences between EIA and SEA



Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) as part of the decision making process (GRID Arendal 2013 in Pendleton et al 2013).

Quality control schemes which can be linked to certification look at a broad range of activities through the supply chain and in addition to identifying harmful activities they also provide assistance in improving the environmental performance of companies. Certification schemes can be further divided according to their target. Some certification schemes set a baseline standard against which they measure the performance of companies. In other cases certification schemes can set more stringent requirements to identify top performers or premium standard.

17 Next Steps

17.1 Workshop

Findings of Task 6 will be discussed at the international environmental workshop to be held on the 30 of April in Brussels. The workshop will provide an opportunity to discuss the Task results and validate its findings in light of on-going exploration work. The organisation of the event will allow for an active participation in the form of interactive discussions, exchange of information, and feedback from the attendees.

The day prior (on the 29th April) the technology workshop will be organised at the same location and it is expected that a number of participants will stay on to attend the environmental session.

Participants

Experts in deep sea mining and environmental protection have been invited from all parts of the world. While a limited attendance is planned we expect that in addition to the 30-35 invitees who have been directly approached, a number of attendees will possibly join from the technology workshop as well as approach us via information gained from the Maritime Forum website. The international workshop is expected to feed further information as thematic sessions are organised on the topics of:

- Land-based mining contrast;
- Current gaps of knowledge;
- Threats and mitigation measures;
- Good practices and,
- Policy perspectives e.g criteria for operational targets on Good Environmental Status.

Agenda

10.00 - 11.00	REGISTRATION
11.00-11.30	Welcome and Introduction to the study (Presenter RJM)
11.30 -12.00	Findings of the environmental analysis (Presenter Yannick Beaudoin)
12.00-12.30	Land-based mining vs. Seabed mining: environmental perspective (Presenter Yannick Beaudoin and Mike Buxton from TU Delft)
12.30 -13.00	Moderated discussion on: filling gaps of knowledge (Presenter Phil Weaver)
13.00-14.30	LUNCH
14.30- 15.00	Moderated discussion on: threats and mitigation measures (Presenter Allison Bredbenner- Eszter Kantor)
15.00-15.30	Moderated discussion on: good practices (Presenter Mike Buxton and Sven Petersen)
15.30 -16.00	COFFEE/TEA BREAK
16.00-16.30	Interactive discussion on: policy perspectives (Presenter Allison Bredbenner - Eszter Kantor)

16.30 - 16.45	Closing session- Emerging key findings from the workshop (Presenter Yannick Beaudoin)
16.45	END OF MEETING
16.45 - 18.00	Wrap-up cocktail

17.2 Final report

Within the current structure of the report findings will be further developed, analysed, and contrasted with the opinions of stakeholder. Findings will be also drawn in from other tasks of the study to provide an all-encompassing view and a complete free-standing report on environmental issues with regard to the current status and the environmental aspects for deep-sea mining activities.

Furthermore, the draft final report will include feedback from stakeholder via an analysis of on-site interviews and/or questionnaires which will be handed out at the international workshop.

The draft final report is to be submitted until the 28 June. Following the receipt of comments and suggestions by the Commission a final report is going to be compiled and submitted until the 28 August 2014.

D. Progress on other tasks

18 Task 2. Economic analysis

18.1 Aim

The economic analysis aims to present an overview on the economic viability – including associated costs and benefits- of possible deep sea mining projects. The task very much builds on inputs from other tasks regarding typical mining operations and technologies and associated cost pattern (task 3), availability and composition of deposits (task 4), but also legal requirements (e.g. regarding licensing and royalties) which may have a cost impact.

An important part of this analysis is the commodity market analysis for the major commodities that are expected to be mined from the deep sea, as this is a major driving force behind deep sea mining and will have a direct impact on its financial feasibility. It will also address possible implications on world market prices caused by a new source of supply will be addressed (will deep sea mining develop into a typical boom-bust industry?).

18.2 Activities

The activities under this task include:

- a) Assessment of relevant commodity markets (workings, pricing)
- b) identifying and drawing up criteria to determine economic viability;
- c) producing a simple economic model to assess the profitability of deep sea mining operations;
- d) preparing three case studies (one for each type of mining) to assess possible future consequences of commercial operations;
- e) indicating scenarios where seabed mining could become strategically important for Europe; contrasting the costs and economic implications of seabed mining with alternative methods for obtaining the minerals including some variables of land-based mining and recycling;
- f) Assessing potential implications on commodity prices of an increased supply of minerals/metals from deep sea mining.

Tasks b, c, and d are related to the development of an economic model that is able to test the financial feasibility of deep sea mining. To be able to assess the relative attractiveness of deep sea mining vis-à-vis other alternative supply sources a comparison is made with land-based mining and recycling (task e). This will not only address costs characteristics but also is expected to entail other criteria including strategic criteria and availability of reserves. This directly links to the commodity market analysis which is addressing tasks a and f.

In the period leading up to this interim report, main focus has been put at developing the structure of the economic model and a first analysis of the commodity market, including a “trial analysis” for one particular commodity (silver) to illustrate the type of analysis that is expected to be produced.

18.3 Commodity markets – first results

18.3.1 Introduction

The development of demand and supply for commodities is one of the main components in determining the economic viability of deep sea mining. Under this task we address the expected global demand for the various types of minerals (separately addressing the category of rare earth

elements), the working of commodity markets and resulting prices for minerals and metals that are mined in the deep sea. This will not only address the resulting prices (including existing forecasts and historic volatility) but also create an understanding of the underlying drivers and the possible implications of price volatility on the development of deep-sea mining (stable growth vs. boom and bust). The potential responses of land-based mining will also be addressed, notably if these are restricted to a limited number of players (e.g. China) possibly in regulated market (state involvement in land-based mining). This task also includes the assessment of the potential implications on commodity prices of an increased supply of minerals/metals from deep sea mining. The issues covered can be related to the criteria for critical raw materials as defined by the European Commission (2010), namely economic importance and supply risk²⁴⁴.

This task puts deep-sea mining quantities and costs into perspective with the markets of mined minerals. It thus provides an overview of these markets, along three major points:

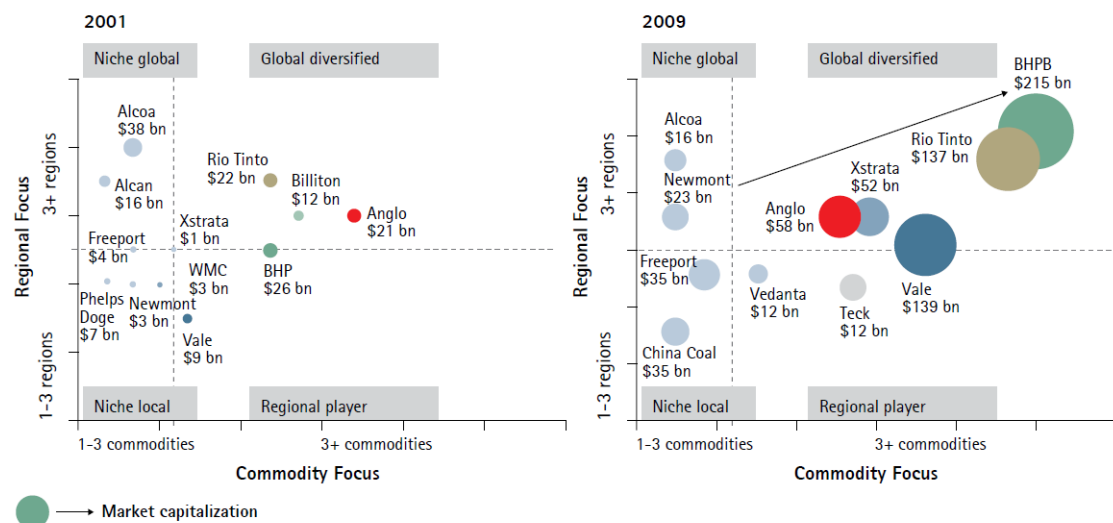
- first, it gives an overview of the overall markets of mined minerals, discussing recent developments, main actors, and market structure;
- second, it selects materials relevant in the DSM context and groups them according to their market characteristics;
- thirdly, for each selected material, it gives an overview of the market and a future outlook of accessibility and prices.

18.3.2 Major trends at commodity markets

The current status of commodity markets has been shaped by a remarkable demand surge in the early 2000s, which changed the business as a whole. Until around 2000, miners expected a long-term slow decline in demand and prices, and concentrated on cost-cutting measures and efficiency at mine level. The years before 2000 were also characterised by a development towards privatisation and vertical disintegration.

The remarkable increase in demand for mining products since around 2004 – mainly due to growth in emerging and developing countries, notably China – has changed the picture profoundly. While profitability increased with the rising prices, it was difficult for the supply side to serve demand in volume terms, and miners increasingly turned to mines with lower ore quality which had become profitable; the main objective of mining companies shifted from performance of individual mines to global performance and expansion.

Figure 18.1 Global and commodity expansion between 2001 and 2009



²⁴⁴ See also European Commission (2013): Raw materials, sustainable supply in the EU, available at <http://ec.europa.eu/enterprise/policies/raw-materials/sustainable-supply/>

Source: Accenture (2011): Global Operating Models for Mining Companies. Adding value beyond the individual assets. Mining Executive Series, available at:

http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture_Mining_Global_Operating_Models_POV_FINAL.pdf

This shift of focus meant a change in the organisation of the industry which witnessed a phase of mergers as well as new entrants. While some national or commodity-specific champions emerged, the dominant business model turned out to be that of a globally active, diversified, large player. Figure 18.1 shows the impressive overall growth (measured in market capitalisation) in the industry over the first decade of the 2000s, with global giants showing the most pronounced increases.

While the most recent years in general confirm this picture – the largest growth in 2012 was observed for BHP Billiton, Rio Tinto, Xstrata, Grupo Mexico, and Inner Mongolia Baotou Steel Rare Earth High Tech: “three diversified, one copper, and one rare earth producer”²⁴⁵ – 2012 also was a year in which profits started to drop significantly. Decreasing productivity, volatile commodity prices, and increased state involvement have affected the performance and outlook of industry negatively.

Three points are relevant in the context of DSM to take away from this description of market developments:

- Expectations for the future follow from past experiences. Currently, most expect demand to stay high in general. However, supply is already turning to less profitable sites. In the (near) future there is rather an issue of increasing production costs rather than oversupply;
- Overall demand changes are mainly due to general worldwide economic development and resource use of fast-growing economies;
- Things can change very quickly. The fundamental increase in demand observed from 2004 was apparently not anticipated by market players, which shows that some areas of unpredictability remain.

18.3.3 Market structure

As indicated above commodity markets are increasingly dominated by a number of major companies. Actors can be classified by size into categories ranging from global giants to juniors. While accounting only for a small share of active companies, the global and senior companies dominate the market and are vertically integrated, with production facilities including mining, smelting and refining. In 2008 the “majors” represent about 83% of the total value of all non-fuel minerals production, whilst the remaining 17% is accounted for by about 1000 medium sized and small companies.²⁴⁶ Looking at the trends described above, these numbers are likely to have further developed in favour of the global giants.

The still large number of junior companies often specialise in exploration. “If juniors find a deposit, it is usually sold to a major mining company, capable of raising the necessary capital, experience and competence to invest in actual production.”²⁴⁷ Nevertheless, junior exploration companies require capital for their activities as well, meaning that exploration is highly dependent on shareholder / venture capital and thus on the general financial markets environment.

²⁴⁵ PwC (2013): Mine. A confidence crisis. Review of global trends in the mining industry – 2013. Available at http://www.pwc.com/en_GX/gx/mining/publications/assets/pwc-mine-a-confidence-crisis.pdf

²⁴⁶ European Commission (2008), Commission Staff Working Document accompanying the Communication from the Commission to the European Parliament and the Council: The Raw Materials Initiative – Meeting our Critical Needs for Growth and Jobs in Europe

²⁴⁷ European Commission (2008), Commission Staff Working Document accompanying the Communication from the Commission to the European Parliament and the Council: The Raw Materials Initiative – Meeting our Critical Needs for Growth and Jobs in Europe

Table 18.1 Overview of the formal mining industry

Company category	Approx. asset base	Approx. number of companies	Comment
Global	Exceeds US\$10 billion	50	Global and senior companies which have access to the largest portion of available capital
Seniors	US\$3 – US\$10 billion	100	
Intermediates	US\$1 – US\$3 billion	350	Companies often on a growth path to become seniors
Juniors (producers)	US\$500 million – US\$1 billion	1,500	Companies which often have one mine
Juniors (exploration)	US\$5 – US\$500 million	2,500	Volatile and share market dependent; they are finders, not producers and their focus is on their exploration activities
Junior – juniors	Below US\$5 million	1,500	Focus is on accessing venture capital and enhancing their stock price

Source: ICMM (2012)

Vertical integration has been a hot topic in the last years.²⁴⁸ Still perceived as complex and risky, integration has mainly happened in an upstream direction (such as zinc smelters acquiring zinc mines). The underlying rationale is security of supply in a market with long-term increasing demand and insecure supply – decreasing mine grades and slowly reacting exploration together with a certain bargaining power of the relatively few suppliers confronted with large demand.

A study by the World Bank (2011)²⁴⁹ highlights that state control has in mining has increased mainly due to the growth of Chinese (state-controlled) operations. Among the top 40 mining companies in 2012 measured by market capitalisation, there are a number of Chinese state-owned ones: apart from some large coal mining companies, these include Inner Mongolia Baotou Steel Rare-Earth Hi-Tech Co., Jianxi Copper Company Limited, or Zijin Mining Group Company Ltd. (China's largest gold producer).²⁵⁰ But also in other emerging economies there is a growing interest in state-controlled mining in other emerging economies, especially in Latin America (Venezuela, Ecuador, Bolivia) as well as industrialised countries such as Finland; in Poland, the state continues to be the largest shareholder of the biggest copper mining company. In many African countries, state control is described to be characterised by large uncertainty over the state's aims and actions²⁵¹ State control is higher in refining than in mining, which is attributed to the higher value added in this sector.²⁵²

To some extent this is also related by what is called “resource nationalism” in a recent study of PwC (2013)²⁵³ which is highlighted as one of the industry's most important risks in 2012, manifesting itself in:

- increasing resource taxes (such as in Australia, Canada, India, Brazil, the USA, Ghana, Zambia);

²⁴⁸ See for the upstream integration: PwC (2011): Mine 2011: The game has changed. Review of global trends in the mining industry, available at http://www.pwc.com/en_GX/qx/mining/pdf/mine-2011-game-has-changed.pdf

²⁴⁹ World Bank (2011): Overview of State Ownership in the Global Minerals Industry – Long Term Trends and Future. Extractive Industries for Development Series no. 20. Available at <http://siteresources.worldbank.org/INTOGMC/Resources/GlobalMiningIndustry-Overview.pdf>

²⁵⁰ See PwC (2013): Mine. A confidence crisis. Review of global trends in the mining industry – 2013. Available at http://www.pwc.com/en_GX/qx/mining/publications/assets/pwc-mine-a-confidence-crisis.pdf

²⁵¹ In this case however, where mining is dominated by small-scale activities and illegal trading, more “control” of the state would rather be beneficial for market functioning (see section on ASM).

²⁵² As noted above, this shows that the primary interest of states is to secure rents rather than to control the primary supply, except in cases where a country has a monopoly.

²⁵³ PwC (2013): Mine. A confidence crisis. Review of global trends in the mining industry – 2013. Available at http://www.pwc.com/en_GX/qx/mining/publications/assets/pwc-mine-a-confidence-crisis.pdf

- the attempt to control and profit from activities downstream the value chain by direct laws or by export restrictions of unrefined products (such as in India, Indonesia, Brazil, South Africa, the DRC);
- implementing local ownership requirements, requiring a certain percentage of the mine being locally owned (such as in Indonesia, Russia, Mongolia, Zimbabwe).

From the perspective of DSM, two conclusions on state control are relevant:

- State control is an issue for supply risk of certain minerals, especially those which are currently produced by mainly one country – such as rare earths in China, or cobalt in the DRC (although in the case of the DRC, armed conflict is more of an issue than increasing or unclear state control). For such materials, DSM can be a game changer by diversifying supply;
- The changing nature of state control may be an important issue to consider for deep sea miners entering contracts with states: they need to keep in mind that the taxes and royalties to pay may increase, or that engaging in downstream activities may not always be easily possible without granting the state some control over it.

18.3.4 Commodities relevant to deep sea mining

The commodities which are expected to be mined in deep sea mining operations do not only depend on the composition of the deposits but also on the concentrations in which they are found and the ease with which they can be extracted from the deposits. Major commodities are expected to be as follows:

- Polymetallic sulfides - Cu, Zn, Au, Ag, Pb; with traces of Co, As, Sb, Se, Cd, In, Ga, Ge, Sn, Ti, Hg, some of which are desirable to have and some of which are harmful
- Nodules - Mn, Co, Ni and Cu; with Fe and traces of LREE (La, Ce, Nd, Sm, Tb), V, Y, Li, Te, PGE (Pt)
- Crusts - Mn, Co, Fe and Ni; with less Cu and traces of Mo, Y, Te, LREE, Pb, PGE (Pt), Hf, Th, U, Ti, Ba, Zr, Nb, W

Most of the trace elements are present in very low concentrations but might be of economic interest if the volume of processed material is large enough. For many of the elements, there is currently insufficient knowledge of their abundance and distribution to be able to comment with any degree of confidence. In most cases the metallurgy (deposition, mineralogy, quality, etc.) is completely unknown. New research is required on this aspect.

Based on their market characteristics, the minerals relevant in DSM can be grouped into five main types and one extra category.

Table 18.2 Suggested market grouping of materials

Type	Examples relevant in DSM	Price mechanism, transparency
Precious metals	Gold, silver	Well established and transparent markets. Prices especially for gold often not clearly linked to demand and supply
Base metals	Copper, nickel, zinc	Prices linked to varying supply and industrial demand, traded at London Metal Exchange (LME)
Minor metals / by-products	Cobalt, molybdenum, manganese, thallium	Often mined as a by-product and thus lower price elasticity of supply; smaller quantities than

Type	Examples relevant in DSM	Price mechanism, transparency
		base metals; most not traded at LME (exception: cobalt, molybdenum)
Mineral sands and rare earths	Titanium mineral concentrates, rare earths (light, heavy)	Occur frequently, but in low concentrations. Not publicly traded, but mostly directly via long-term or yearly to quarterly contracts
Steel raw materials	Cobalt, manganese, molybdenum, nickel, zinc (, titanium metal)	Demand heavily influenced by steel industry

Source: Ecorys based on <http://metals.about.com/od/investing/a/Metal-Markets.htm>, Dunbar (2012), <http://www.infomine.com/investment/industrial-minerals/>

Clearly there are some overlaps between these categories – particularly, rare earths could also be classified as minor metals, and all steel raw materials appear in other categories as well – but this grouping is useful to quickly identify market forces at play. Steel raw materials are good to keep in mind because of the major forces influencing their demand.

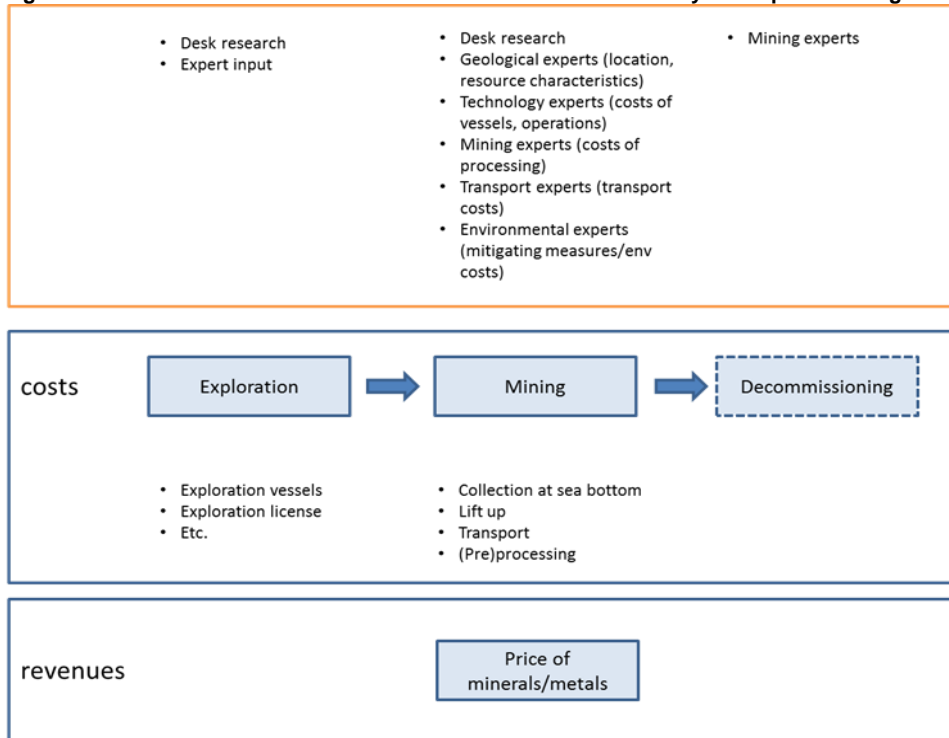
18.3.5 Example of specific commodity market - Silver

In Annex xx an example is presented of a more detailed analysis for a specific commodity market, viz. silver. For the major commodities that will be traded as a result of deep sea mining operations a similar analysis will be performed.

18.4 Economic model – first results

Based on the value chain components of deep sea mining the components of an economic model can be determined. The scheme shown on figure 2.4 depicts the main elements that are expected to determine the economic viability of deep sea mining. It also gives an impression on the sources of information that will be used to establish what are essential parameters and the approximate values for these parameters.

Figure 18.2: Main elements to determine the economic viability of deep sea mining



The structure follows the stages and processes that are relevant for deep sea mining by looking at a life cycle approach, not only including the mining and processing operation itself but also including the exploration stage (and if relevant decommissioning stage).

The DSM economic model that is designed as part of this study assesses the feasibility of deep sea mining projects. The assigned model calculates the internal rate of return (IRR) taking into account the complete DSM trajectory, from exploration and extraction from the seabed to revenues from mined commodities. The model can be governed by non-experts by simply changing input variables in the “cockpit”. In the cockpit all main inputs can be adjusted and outputs are presented. The cockpits provides the possibility to design the project by adding ROVs or mining vessels in project years of choice and is also able e.g. to include specific labour costs and personnel for all offshore operations.

At this stage the model is further expanded with an exploration module and data collection activities are underway to be able to create realistic assumptions regarding input values. The model will be further elaborated based on the outputs of the other tasks.

Once the functioning parameters of the model have been established and agreed upon with the Commission services, three case studies will be prepared – for all three main mining operation types – to establish possible scenarios for future large-scale mining operations. The location of the case studies (where mining takes place) will closely follow trends that can be observed in currently existing license and prospective license areas.

In these case studies the economic feasibility will be calculated under three different commodity price scenarios, which will be based on existing commodity price forecasts. Based on this various additional sensitivity and break-even analysis can be applied determining the necessary conditions for the commercial viability of deep sea mining operations. These break-even analyses can be applied on all elements of the economic model as indicated above, and can also be used to

determine the most critical parameters. Specific break-even analyses will be carried out on resource characteristics and commodity prices.

Finally this task will develop scenarios where seabed mining could become strategically important for Europe. This contains two elements:

- A comparative analysis of the costs and economic implications of seabed mining with alternative methods for obtaining the minerals including land-based mining and recycling;
- A qualitative review of other strategic criteria which may determine demand for deep sea mining.

This will be the result of a cross-over between the commodity analysis and the economic costing analysis.

19 Task 4 Geological analysis

19.1 Aim

The aim of the geological analysis is to establish an overview of the location and geological controls of deep-sea marine mineral deposits. These include manganese nodules occurring on the seabed of the abyssal plains, cobalt-rich ferromanganese crusts that are associated with the flanks of old volcanic seamounts, and massive sulphides that form in volcanically active areas along mid-ocean ridges and at submarine volcanoes related to subduction zones.

19.2 Activities

Within the time period covered by this progress report activities focused on gathering of site specific data (GEOMAR) and the building of GIS-readable regional geological feature catalogue (GRID-Arendal) as described in activity a). The remaining activities will be part of the next reports.

Original Activities

- a) Comprehensive overview of world wide sites that have been subject to surveys for the three main types of mining activities:
 - a. Including abyssal plains, oceanic ridges and seamounts;
 - b. Indicating the availability of the surveys and the interoperability of the data;
- b) Suggestions for prioritising future mapping and sampling efforts;
- c) Visualisation of findings by creating map layers showing:
 - a. Likely mineral deposits;
 - b. Surveyed mineral deposits;
 - c. Seabed mining projects;
 - d. Economic viability of the projects (based on criteria identified under Task 2; and
- d) Delivering the maps in a form suitable for integration into the EMODnet and for public viewing.

19.3 First Results

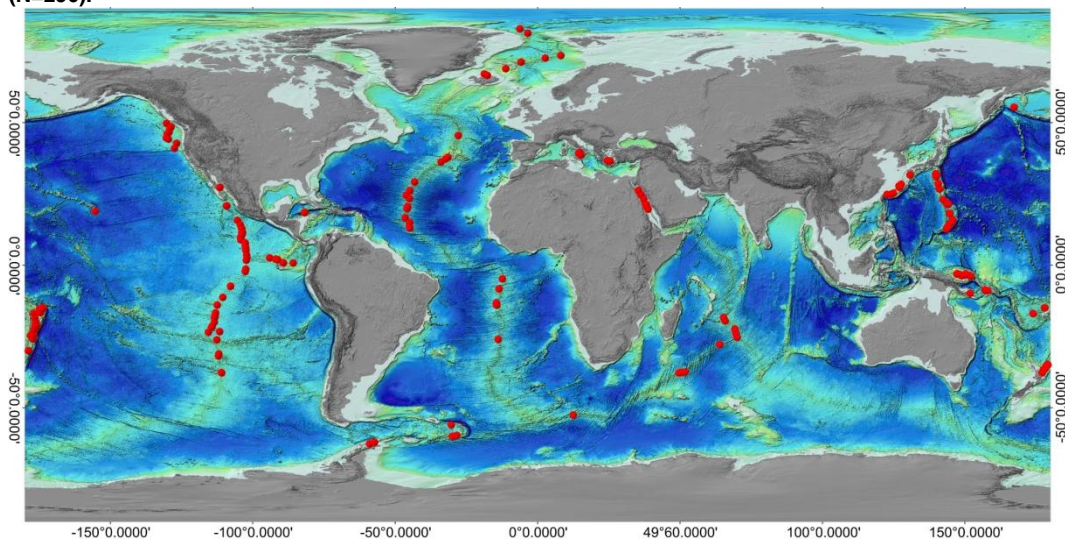
Site-specific Information on Marine Mineral Resources

The project team used the InterRidge vents database version 2.1 for seafloor massive sulphides (Beaulieu et al., 2013) that covers discoveries up to 2010 and updated this list with new information from recent publications. Since the InterRidge database contains numerous entries of low-temperature hydrothermal emanations that are not of economic interest, we used only those sites that have indications of sulphides present in their descriptions (N=296; Fig. 1.1 and 1.2). Information about metal grades and tonnage and geological information is currently being added from those sources.

Figure 19.1 Example of the information collected from public sources and scientific publications.

No	name	deposit type	T _{max} (°C)	depth	tectonic setting	volc. setting	ore type, grade	size estimate	outcrop area(m ²)	legislation	references
16	Solitaire Field	small mounds, chim. (<5m tall), clear fluids	296	2630	MOR (4.0)	talus on bottom of rift valley	PMS, Cu-rich	very small	50x 50m (hydr. Venting)	EEZ - Mauritius	Nakamura et al., 2012
17	Sonne Sulfide Field, MESO zone	large mound	inactive	2845	MOR (4.5)		PMS, Cu-rich	medium-sized	--	ISA	Herzig & Plüger (1988), Halbach et al. (1995, 1998), Münch et al. (1999)
18	Edmond Site	large sulfide talus, chim., sedim.	382	3290	MOR (4.6), off-axis	rift valley wall	PMS, high grade	medium-sized	100x 90m expl. area	ISA	Van Dover et al., 2001; Von Damm et al., 2001 AGU; Kumagai et al 2008
19	Kairei Vent Field	large sulfide talus, chim., sedim.	360	2450	MOR (4.8), off-axis	rift valley wall	PMS	medium-sized	--	ISA	Hashimoto et al. (2001; Kumagai et al., 2008; Nakamura et al., 2009
20	Mount Jourdanne	small MS, chim.	inactive	2940	MOR (1.4)	rift valley floor	PMS	very small	<100m	ISA	Fujimoto et al., 1999; Münch et al. (2001)
21	SWIR 51.7°E	MS dredged; abun. fauna	active	1595	MOR (1.4)	rift valley	PMS	--	--	ISA - Chinese EL	Tao et al., 2012, Tao et al., 2009
22	SWIR 50°28'E	MS, chim., sedim.	inactive	1739	MOR (1.4)	thick crust, no axial valley	PMS, cpy, py, sph, nat Cu	--	~200x125 m	ISA - Chinese EL	InterRidge mail #54 in 2009; Tao et al., 2012
23	49°39' Dragon Site	large mound, chim. >5m tall	active	2760	MOR (1.4), ridge offset	high in transform fault	PMS, py/mc, sph (cpy core)	medium-sized	~200x125 m (S zone)	ISA - Chinese EL	Tao et al 2011; Tao et al., 2012
24	12°30'E, SWIR	ox. Sulfides	inactive	3730	MOR (0.8)	rift valley wall	PMS, oxid. sulfides	--	--	ISA	Bach et al., 2002

Figure 19.2: Location of seafloor massive sulphide occurrences investigated for this report (N=296).



Factors influencing SMS formation (properties of the deposits)

Part of the project is the compilation of relevant site-specific data on the various known mineral occurrences based largely on scientific literature. This information includes data on their distribution as well as geological information relevant for their economic potential such as their water depth, host rocks and the contained resources (type of metals, metal grade, distribution, tonnage, number of analyses, methods used for analyses, etc.).

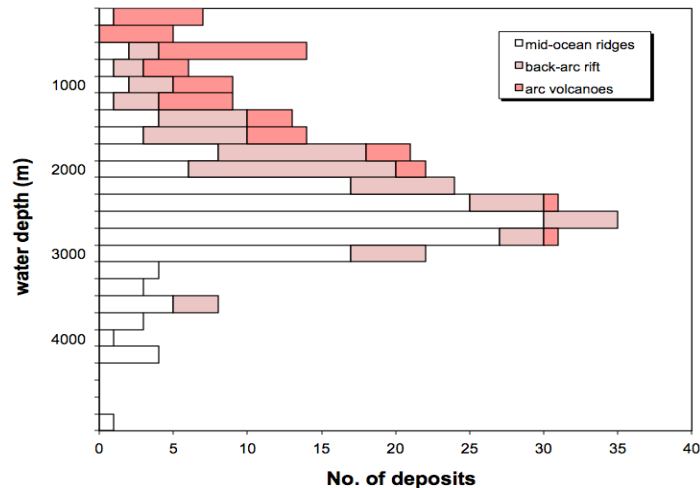
Tectonic Setting

The tectonic setting is closely connected to the composition (and metal-content) of the source rock, where hydrothermal circulation takes place. At mid-ocean ridges, the composition of the source rock is relatively homogenous “MORB” (mid-ocean ridge basalt). MORBs are divided into N-MORB (“normal”) and E-MORB (“enriched”). These values refer to the amount of incompatible/compatible elements in the host rock. The presence of enriched MORB influences the concentration of, for instance, Ba in the ores. Another difference that is known to influence the metal contents and grades of massive sulphides on the sea floor is the amount of sediment cover on top of the MORBs. In general, ridges with sediment cover are large (efficient trapping of metal-bearing fluids), have lower than average metal-grades, higher Zn and Pb than sites on un-sedimented ridges. This is due to the metal-content being diluted by abundant non-ore material. However, sediments and or volcanoclastics create an efficient cap for hydrothermal fluids therefore helping in forming large occurrences.

At volcanic arcs and back-arcs, especially of the western Pacific, the source rock is more variable than at MORs. This variation is directly reflected in the composition of the massive sulphides, which are often higher in copper and gold grade. Here, the subducting slab, a piece of old-seafloor composed of volcanic and magmatic rocks and sediment, influences the systems at arcs and back-arcs. Additionally, in such a tectonic setting metals are interpreted to be enriched via direct magmatic input of metals and volatiles into the hydrothermal system.

Water depth is often closely tied to the tectonic setting (Fig. 1.3) and also an important factor influencing the exploitability and metallogeny of seafloor massive sulphide deposits. The majority of mid-ocean ridge (MOR) sites are distributed at 2-3 km depth, whereas arc sites are generally situated at shallower water depths. Back-arc rifts are found at a wide variety of water depths. Water depth (pressure) influences the boiling temperature of hydrothermal fluids and thus the metallogeny of the deposits. Deposits situated at great water depth are difficult and expensive to exploit, but deposits that occur at shallow water depths (< 1000 meter) are characterized by low confining pressure that causes the mineralizing fluids to boil before reaching the seafloor. This boiling causes precipitation of the metals of interest below the seafloor and results therefore in low metal grades in the deposit at the seafloor. Such deposits will have little economic interest.

Figure 19.3: Depth distribution of occurrences investigated for this progress report (N=290).



From the figure above, we conclude that the majority of mid-ocean ridge (MOR) sites are distributed at 2-3 km depth, whereas arc sites are generally situated at shallower water depths. Back-arc rifts are found at a wide variety of water depths. Water depth (pressure) influences the boiling temperature of hydrothermal fluids and thus the metallogeny of the deposits.

Size and shape of SMS deposits

Based on our review, the size of a sea floor massive sulphide (SMS) deposit varies from a few tonnes to >15 million tons (Mt) of ore material, however, reliable size estimate are very rare since drilling information is needed to accurately infer the tonnage of massive sulphide occurrences. This information is only present for very few sites (Table 1.1). For most occurrences information on their size relies on visual estimates of the surface area that is covered by hydrothermal precipitates. By far most seafloor sulphide occurrences are small! The exception to this are the brine pool deposits in the Red Sea, including the Atlantis II Deep, by far the largest metal deposit (90 Mt) on the modern seafloor. Here, the ore material is deposited as unconsolidated metal-bearing muds instead of massive sulphide.

The main styles of deposits are sulphate and sulphide chimneys and mounds. Individual chimneys can vary in size from only a few centimetres to up to 45m. It is important to note, that up to 90% of the metals carried by the fluids through chimneys is eventually lost to seawater where it is dispersed as a plume. Chimneys collapse with time and create sulphide accumulation at the site of hydrothermal activity (talus) that can form a substantial part of a sulphide deposit. Chimney formation may be focused, forming larger structures, or distributed over larger area, for example along a fissure, thereby often forming smaller chimneys. Sulphate and sulphide mounds may also grow by inflation as more material is accumulated to the core of the mound. Such mounds are often zoned, with the surface being more Cu- and Zn-rich than the core (e.g., TAG, Middle Valley, PacManus, Palinuro which have all been drilled). This information is vital for any global or site-specific resource estimates that are based on surface samples only. Those results will likely not be representative for the deposits as a whole. Sub-seafloor accumulations such as those at Middle Valley on the Juan de Fuca Ridge, where massive sulfide accumulations occur beneath a sediment cover and much less is known about this type of deposit growth on the modern ocean floor. In these systems hot fluids do not vent to the seafloor, instead cooling and precipitation is confined to the pore space of sediments or volcanoclastics. Such systems are difficult to find but clearly more efficient in retaining the metal sulphides within proximity to the vent site and they have the potential to form very large deposits. Many volcanic massive sulphide (VMS) deposits mined on land are inferred to have formed in this type of “sealed” environment.

Reliable estimates of the total sulphide accumulation in submarine sulphide deposits are only possible in a few cases where drilling has provided information on deposit thickness. Drilling results from the large TAG mound, which measures 200 m in diameter and 45 m in height, indicate 2.7 million tonnes of massive sulphide averaging 2% Cu plus 1.2 million tonnes of stockwork at 1% Cu. During Ocean Drilling Program (ODP) Leg 139, drilling at Middle Valley, on the Juan de Fuca Ridge, intersected massive sulphide accumulations and subsequent drilling of the Bent Hill and ODP mounds at Middle Valley during Leg 169 confirmed a total tonnage of between 10 and 15 million tonnes. Data from extensive commercial drilling of the Solwara 1 deposit near Papua New Guinea has been used to estimate a deposit size of 2.3 million tonnes. Current mining scenarios are working with an annual tonnage of sulphide ore of approx. 2 million tonnes. There are only few deposits of this size known from the modern seafloor, but some have been found in most of the settings where seafloor hydrothermal activity occurs, including the mid-ocean ridges (Galapagos, TAG, Alvin Zone, Krasnov, and Semyenov sites), sedimented ridges (Middle Valley), intraoceanic back-arc basins (North Fiji Basin), volcanic arcs (Myojin Knoll), and rifted arcs in transitional or epicontinental environments (JADE, Solwara 1). However, only few deposits in the largest size class (top 10%) are thought to exceed 2 million tonnes in size. It should be noted that the size estimates for many of the supposedly large deposits along the Mid-Atlantic Ridge are not based on drilling results. For our purpose of defining economically interesting deposits those with accumulations of less than 1 million tonnes are considered small.

Table 19.1 Seafloor Sulphide Occurrences for which size information is available based on drilling information.

Deposit	Location	Size	drilling tool / vessel	Reference
Atlantis II	Red Sea	90 Mt	coring	Nawab, 1984
TAG	Mid-Atlantic Ridge	4 Mt	ODP-drill ship	Hannington et al., 1998
Middle Valley	Juan de Fuca Ridge	10–15 Mt	ODP-drill ship	Zierenberg et al., 1998
PacManus	Bismark Sea	small	ODP-drill ship	Binns et al., 2002
PacManus	Bismark Sea	small	lander-type	Petersen et al., 2005
Solwara 1	Bismark Sea	2.3 Mt	ROV-based	Lipton et al., 2012
Suiyo	Izu-Bonin Arc	small	lander-type	Marumo et al., 2008
Iheya North	Okinawa Trough	small	IODP-drill ship	Takai et al., 2012

Fryer , Pika	Mariana Trough	small	lander-type	Kakegawa et al., 2008
Logatchev	Mid-Atlantic Ridge	small	lander-type	Petersen et al., 2009

The largest deposits currently known are all at least 100,000 years old, implying that sustained hydrothermal venting over long periods is required to produce significant accumulations of massive sulphide at the seafloor. The growth rate for the main massive sulphide lens (2.7 million tonnes) at the TAG site on the Mid-Atlantic Ridge is about 500 to 1,000 tonnes/yr. Similar growth rates have been estimated for other large deposits on the Mid-Atlantic Ridge (Logatchev, Ashadze, and Krasnov), based on the maximum ages and estimated tonnages of the deposits.

The relatively smaller sizes of most deposits discovered so far are related to the short-lived nature of their heat sources, which include narrow dike injections along the axial zones of the ridges. This is confirmed by age dating indicating that hydrothermal discharge at fast spreading centres is episodic on time scales of only 10 to 100 years. Therefore most sulphide occurrences along the fast-spreading ridges will likely be uneconomic. By contrast, the protracted history of hydrothermal venting at sites like TAG on the slow-spreading mid-atlantic ridge is a consequence of deep-seated magmatic activity followed by long periods of cooling and release of heat from depth. These deposits are situated in stable structural environments with relatively slow rates of spreading, far from the axis of the ridge. On sedimented ridges, such as Middle Valley on the Juan de Fuca Ridge, long-term heat retention due to a thick impermeable sediment cover may also contribute to the large sizes of such deposits.

The construction of the database with site-specific information for manganese nodules and Co-rich ferromanganese crusts is the next step and will be finished by the end of April 2014.

Regional scale geological information

The global geomorphological features that are important to the mineral commodities, such as the location of plate boundaries, ridge axis, seamounts and guyots, hadal basins, and plateaus etc. have all been compiled by our project partner at GRID Arendal. From this georeferenced data we will later export the resource information into suitable formats such as kml-files for use with Google Earth® or those for EMODnet.

Figure 19.2 Example of a geomorphic feature map of the North Pacific Ocean based on data compiled by GRID-Arendal (from Harris et al., 2014).

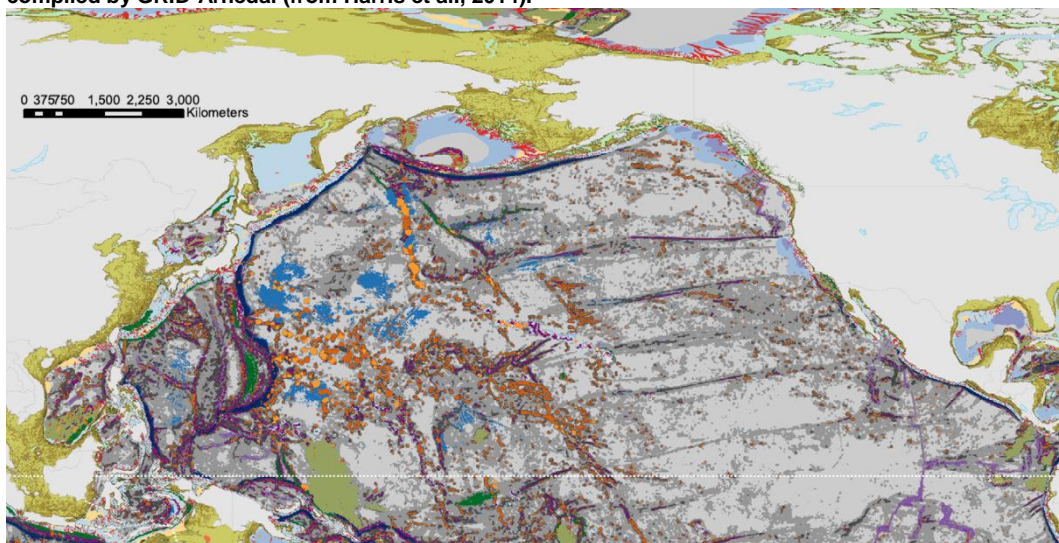


Table 19.2 Progress in activities under task 4 and data collection methodology

Task 4- Geological analysis	data availability	data collection method	Progress
Site-specific information on mineral occurrences worldwide	Partially available for sulphides; needs to be collected from publications and reports; especially for nodules and crusts	entries into database	sulphide data collected; transformation of information into database in progress (80% done) site-specific information on ferromanganese crust and manganese nodules (0 % done)
Regional geological information on seabed typology (abyssal plains, oceanic ridges and seamounts; age of the crusts) for the relevant areas of deposits	good; from public databases	transformation to GIS	done by GRID-Arendal (finished)
other information (like MPA's) and availability to create the map layers for integration into EMODnet	Partially available;	digitizing from existing reports	data partially available (30 % done)

20 Task 5 Projects analysis

20.1 Introduction

Table 15.1 and table 15.2 give an overview of the current marine exploration and mining licenses for each of the three identified mineral types (polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts). Exploration licenses involve the identification, delineation and evaluation of deep sea mineral resources. Mining licenses allow the extraction of minerals from the sea floor. The table presented can be characterised as work in progress since not all projects are identified yet.

Marine exploration or mining licenses can be issued by either the International Seabed Authority (ISA) or by national governments, depending on where the project is located. National governments issue the licenses for activities that take place within the Exclusive Economic Zone (EEZ) of a country. The EEZ comprises the area up to 200 nautical miles from the territorial sea baseline. Within its EEZ, a coastal state has exclusive sovereign rights for the purposes of exploring and exploiting, conserving, and managing the natural resources (living or non-living) of the water column, seabed, and subsoil. The national governments also issue the licenses for the Continental Shelf. The Continental Shelf (as defined by UNCLOS) is the sea floor that extends beyond the territorial sea up to 200 nautical miles from the territorial sea baseline or beyond that to the outer edge of the continental margin. Within its continental shelf, a coastal state has sovereign rights for the purposes of exploring and exploiting mineral and other non-living resources of the seabed and subsoil, together with sedentary living organisms²⁵⁴.

The seabed and subsoil beyond the limits of national jurisdiction (i.e., all of the seabed that lies beyond each country's continental shelf) is known as the Area. The Area and its mineral resources are declared by UNCLOS to be "the common heritage of mankind." The seabed minerals of the Area are managed on behalf of all by the International Seabed Authority (ISA), an institutional body established under UNCLOS. No country may claim or declare sovereign rights or try to appropriate any part of the Area or its resources. But any UNCLOS member country is eligible to undertake seabed mineral activities in the Area, subject to the rules of UNCLOS and the ISA.

This means that exploration or mining activities in the Area may only be carried out under a contract with the International Seabed Authority. Contracts are approved by ISA's executive council, on the recommendation of the Legal and Technical Commission²⁵⁵.

²⁵⁴ Source: SPC (2013). Deep Sea Minerals: Deep Sea Minerals and the Green Economy. Baker, E., and Beaudoin, Y. (Eds.) Vol. 2, Secretariat of the Pacific Community.

²⁵⁵ Source: SPC (2013). Deep Sea Minerals: Deep Sea Minerals and the Green Economy. Baker, E., and Beaudoin, Y. (Eds.) Vol. 2, Secretariat of the Pacific Community.

Table 20.1 Overview of current deep sea exploration licenses issued by the ISA for polymetallic nodules, polymetallic sulphides and cobalt- rich ferromanganese crusts.

Contractor		Date of entry into force of contract	Date of expiry of contract	Sponsoring State	General location of the exploration area under contract	Type	Area (km ²)
1	Interoceanmetal Joint Organization	29-mrt-01	28-mrt-16	Bulgaria, Cuba, Czech Republic, Poland, Russian Federation and Slovakia	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
2	Yuzhmorgeologiya	29-mrt-01	28-mrt-16	Russian Federation	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
3	Government of the Republic of Korea	27-apr-01	26-apr-16		Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
4	China Ocean Mineral Resources Research and Development Association	22-mei-01	21-mei-16	China	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
5	Deep Ocean Resources Development Co. Ltd.	20-jun-01	19-jun-16	Japan	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
6	Institut français de recherche pour l'exploitation de la mer	20-jun-01	19-jun-16	France	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
7	Government of India	25-mrt-02	24-mrt-17		Indian Ocean	polymetallic nodules	150.000
8	Federal Institute for Geosciences and Natural Resources of Germany	19-jul-06	18-jul-21	Germany	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
9	Nauru Ocean Resources Inc. (NORI)	22-jul-11	21-jul-26	Nauru	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
10	Tonga Offshore Mining Limited	11-jan-12	10-jan-27	Tonga	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
11	UK Seabed Resources Ltd.	8-feb-13	7-feb-28	United Kingdom of Great Britain and Northern Ireland	Clarion-Clipperton Fracture Zone	polymetallic nodules	58.000

	Contractor	Date of entry into force of contract	Date of expiry of contract	Sponsoring State	General location of the exploration area under contract	Type	Area (km ²)
12	G-TEC Sea Mineral Resources NV	14-jan-13	13-jan-28	Belgium	Clarion-Clipperton Fracture Zone	polymetallic nodules	160.000
13	China Ocean Mineral Resources Research and Development Association	18-nov-11	17-nov-26	China	Southwest Indian Ridge	polymetallic sulphides	10.000
14	Government of the Russian Federation	29-okt-12	28-okt-27	Russian Federation	Mid-Atlantic Ridge	polymetallic sulphides	10.000
15	Japan Oil, Gas and Metals National Corporation (JOGMEC)	27-jan-14	26-jan-29	Japan	Western Pacific Ocean	cobalt-rich ferromanganese crusts	
16	Government of the Republic of Korea	To be signed			Mid-Indian Ridge	polymetallic sulphides	
17	Institut français de recherche pour l'exploitation de la mer	To be signed		France	Mid-Atlantic Ridge	polymetallic sulphides	
18	Marawa Research and Exploration Ltd.	To be signed		Kiribati	Clarion-Clipperton Fracture Zone	polymetallic nodules	75.000
19	China Ocean Mineral Resources Research and Development Association (COMRA)	To be signed		China	Western Pacific	cobalt-rich ferromanganese crusts	

Source: ISA

Table 20.2 Overview of current deep sea exploration licenses issued by national governments for polymetallic nodules, polymetallic sulphides and cobalt- rich ferromanganese crusts.

Note: table is still under construction

	Contractor	Date of entry into force of contract	Date of expiry of contract	General location of the exploration area under contract	Type	License	Area (km2)
20	Diamond Fields International	2010		Deep Sea II project, Red Sea	SMS	Mining	
Pacific Islands							
21	Nautilus Minerals	2010	2030	Solwara 1 project, Manus Basin; Papua New Guinea	SMS	Mining	59
22	Nautilus Minerals Inc			Papua New Guinea (except Solwara 1)	SMS	Exploration	107.917
23	Neptune Minerals			Papua New Guinea	SMS	Exploration	
24	Nautilus Minerals Inc	?		Solomon Sea & New Ireland Ard	SMS	Exploration	
25	Nautilus Minerals Inc	?		Solomon Islands	SMS	Exploration	
26	Neptune Minerals			Solomon Islands		Exploration	
27	Nautilus Minerals Inc	?		Kingdom of Tonga	SMS	Exploration	
28	Neptune Minerals			Kingdom of Tonga	SMS	Exploration	
29	Korean Institute of Ocean Science and Technology (KIOST)			Kingdom of Tonga	SMS	Exploration	
30	Nautilus Minerals			Kingdom of Tonga		Exploration	
31	Nautilus Minerals Inc	?		Fiji	SMS	Exploration	60.000
32	Neptune Minerals			Fiji	SMS	Exploration	
33	Korean Institute of Ocean Science and Technology (KIOST)			Fiji	SMS	Exploration	
34	Nautilus Minerals Inc	?		Vanuatu	SMS	Exploration	
35	Neptune Minerals			Vanuatu	SMS	Exploration	914 ??
36	Neptune Minerals			Federated States of Micronesia	SMS	Exploration	
Japan							
37	Japan Oil, Gas & Metals National Corp			Izu & Ogasawara Island Chain & SW	SMS & CRCs	Exploration	

	Contractor	Date of entry into force of contract	Date of expiry of contract	General location of the exploration area under contract	Type	License	Area (km2)
	(JOGMEC)			Okinawa Islands, Japan			
38	Neptune Minerals			Japan		Exploration	
New Zealand							
39	Chatham Rock Phosphate New Zealand	25-feb-10	24-feb-14	Canterbury , New Zealand (permit 50270)	Rock Phosphate	Exploration	4.726
40	Nautilus Minerals Inc			Bay of Plenty, New Zealand (Permit Number 39348)		Exploration	52.820
41	Neptune Resources			Gisborne, New Zealand (permit Number 53828)		Exploration	3.448

20.2 Issued exploration and mining licenses

Licenses issued by ISA

At the time of writing the ISA has issued only exploration licenses and no mining licenses. Between 2001 and 2013, the ISA approved 19 applications for exploration contracts in the Area of which:

- seventeen concern the exploration of polymetallic sulphides and two the exploration of cobalt-rich ferromanganese crusts.;
- twelve of the exploration sites are located in the Clarion-Clipperton Fracture Zone (CCZ). This area is located in international waters of the Pacific Ocean (see figure below). The remaining licenses issued by the ISA are located in the Indian Ocean (3), the Atlantic Ocean (2) and the northwestern Pacific Ocean (2).

Figure 20.1 Location of the Clarion-Clipperton Fracture Zone (CCZ)



The (exploration) contracts issued by ISA allow companies to conduct exploration activities for a period of 15 years, reporting on their programs of activities annually. Contracts by ISA may be awarded to States Parties (signatories of UNCLOS), state enterprises sponsored by States Parties, or to natural or juridical persons having the nationality of States Parties and sponsored by States Parties. This element of sponsorship is fundamental to the international regime, as it is designed to ensure that a State Party to UNCLOS ultimately has international responsibility for the activities of contractors with the International Seabed Authority. As private entities, they are not directly bound by UNCLOS²⁵⁶.

Additional applications have been made to the ISA for exploration contracts by India, Russia, Singapore, UK, Brazil, Germany and the Cook Islands – which will be decided at this ISA's 20th annual session in July 2014. So by the end of 2014 there could be 25 ISA contracts in place (Source: According to an interview).

Licenses issued by national governments

National governments have until now issued two deep sea marine mining licenses: one by the government of Papua New Guinea (Solwara 1 project in the Bismarck Sea) and one by the governments of both Saudi Arabia and Sudan (Atalantis II project in the Red Sea). All the other issued deep sea licenses by national governments concern exploration licenses²⁵⁷.

For some countries/regions we have found information regarding the deep sea marine licenses, for other (like China, Russia, USA and Canada) this information is not yet available.

²⁵⁶ Source: SPC (2013). Deep Sea Minerals: Deep Sea Minerals and the Green Economy. Baker, E., and Beaudoin, Y. (Eds.) Vol. 2, Secretariat of the Pacific Community

²⁵⁷ Other mining licenses have been issued but these cannot be characterized as deep sea mining licenses since the depth of these locations does not exceed the 500 meters. This is for example the case for Sandpiper Marine Phosphate project of the coast of Namibia (depth of 180-300 meters) and the location Chatham Rise within the EEZ zone of New Zealand (depth of 350-450 meters).

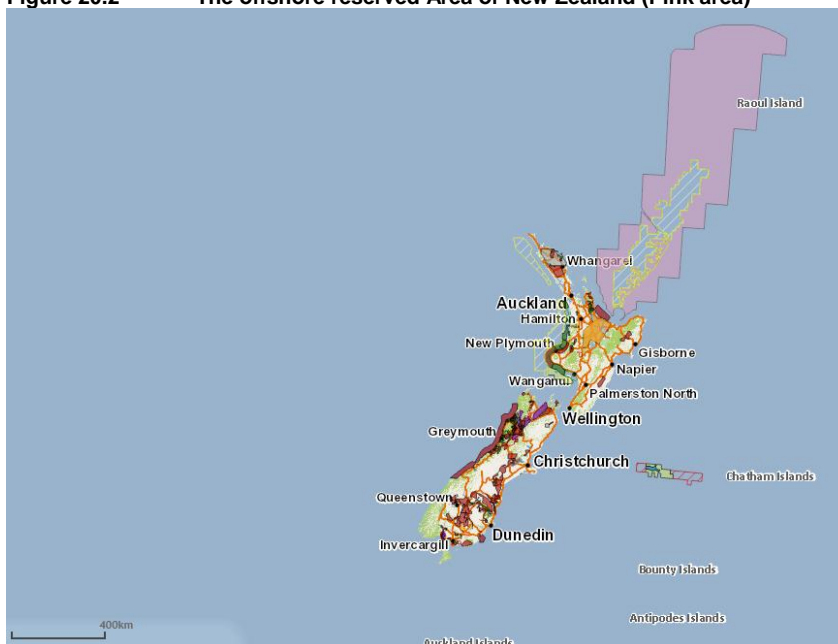
Most of the (exploration) licenses are issued by the Pacific Islands (for example: Papua New Guinea, the Solomon Islands, Kingdom of Tonga, Fiji and Vanuatu). The Cook Islands haven't issued any licenses yet but it is likely to open its EEZ for mining tenders (for nodules) at the end of this year (2014)²⁵⁸

Within Australian waters there are currently no deep sea mining licenses. For the moment it is unknown whether there are any deep sea exploration licenses.

The Namibian Government decided in Oct. 2013 to place a 18-month moratorium on marine phosphate mining. The northern territory government in Australia reached a similar decision in June 2013 with a total ban on seabed mining around Groote Eylands in the Gulf of Carpentaria.

New Zealand has an Offshore Reserved Area (see the pink area in the next figure). For this area the Minister of Energy and Resources of New Zealand will not be accepting any new mineral licence applications. This area is subject to a review by New Zealand Petroleum and Minerals (until 4/7/2015).

Figure 20.2 The offshore reserved Area of New Zealand (Pink area)



Source: <http://data.nzpam.govt.nz/permitwebmaps?commodity=minerals>

20.3 Future activities in order to complete Task 5

As task 5 is still work in progress, the results presented so far need to be quality checked and completed. Furthermore, next steps need to be started. In order to complete Task 5 the following actions are planned:

- Contact the International Seabed Authority to, if possible, receive further information on already licensed projects in international waters as well as applications for licenses
- Contact individual contractors to, if possible, receive further information on their projects as well as projects which could not be found by desk research.
- Structure and summarize received information
- Complete individual project sheets providing a coherent overview on each project

²⁵⁸ Source: Hannah Lily of SOPAC

The main structure of the project sheets to be filled is the following (the example of the Solwara 1 project is provided in the annex):

Table 20.3 Structure of project sheets

Name of the project
Location:
Water depth:
Consortia members
Type of contract:
Time scale:
Financing:
Government involvement:
Type of material to be collected:
Size of expected deposit:
Technology used:
Obstacles:
Sources:

C.Task 7 Public consultation

As part of the first phase of the study, the project team has assisted in the preparation of a public consultation, launched by DG MARE. To this end, Ecorys and its partners have:

- Prepared a questionnaire for the public consultation, targeting both specialist stakeholders as well as the wider public, and addressing not only deep sea mining but also shallow water mining and the mining of sand and gravel. Feedback from the Steering Committee was included. After finalising, the programming into EU web-based survey software was done by the Commission.
- Drafted a consultation paper to accompany the questionnaire, in which the scope and aims were set out in a concise way, accessible to the wider public. The finalised paper was published along with the questionnaire.
- Composed a list of stakeholders to be invited for the consultation, using contacts already known within the consortium, parties to relevant projects identified as well as organisations, scientists and companies identified as part of the research work for all other tasks of this study. The list was then used by the Commission to invite these stakeholders to respond to the public consultation questionnaire.

The questionnaire and consultation paper are accessible on the European Commission's website via http://ec.europa.eu/dgs/maritimeaffairs_fisheries/consultations/seabed-mining/index_en.htm

Workshops on technical and environmental aspects

Apart from the open consultation published by the EC, selected stakeholders will also be consulted in the context of this study with a focus on technology and environmental aspects. To this end, two workshops are being organised for 29 and 30 April in Brussels. The agenda for these workshops is included in annex 4.

Literature

(growing list/will be extended & completed for final report)

Annexes

If any

Annex 1 Legal aspects for selected countries

Annex 1 Legal aspects for selected countries

This annex contains an overview of the legal framework in selected countries, being:

- The Netherlands
- Japan
- Fiji
- Spain

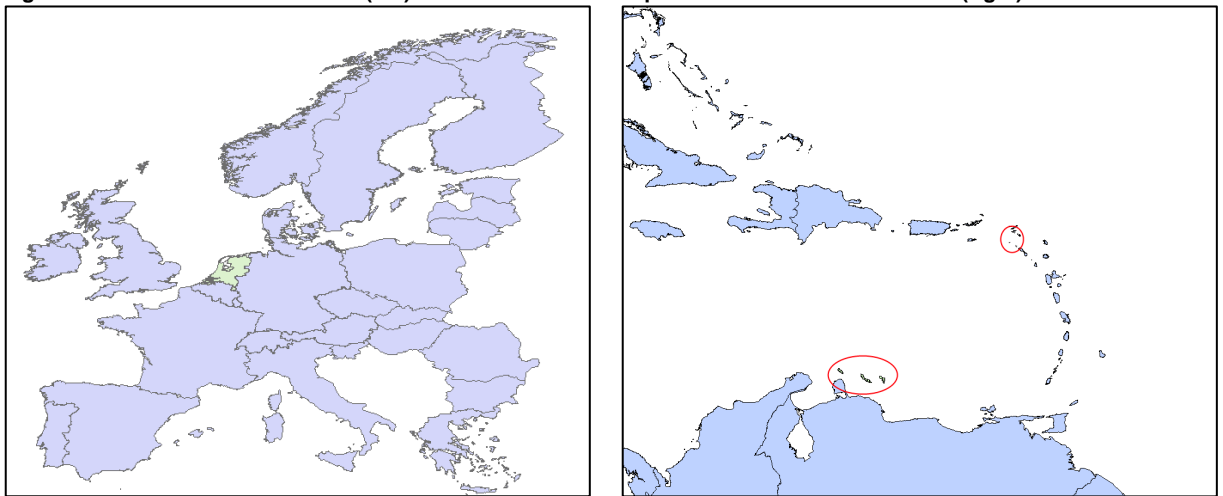
<possibly some more can be inserted before Friday 28th?>

Work ongoing will provide similar overviews for the other selected countries as part of the draft final report.

1 The Kingdom of the Netherlands

The Kingdom of the Netherlands consisted of three countries; the Netherlands, located in Europe and two countries in the Caribbean, i.e. Aruba and the Dutch Antilles. The Dutch Antilles consisted of five islands, i.e. the 'Benedenwindse eilanden'²⁵⁹, Curaçao and Bonaire closely located to the South American continent and the 'Bovenwindse eilanden'²⁶⁰ Sint Maarten (Saint Martin), Sint Eustasius (Statia) and Saba located in the North of the Caribbean. The internal structure of the Kingdom changed in 2010 after a referendum held on the five islands²⁶¹. Since 10 October 2010 the Dutch Antilles no longer exists as a country. Curaçao and Sint Maarten have become individual countries within the Kingdom and with the same status as the Netherlands and Aruba. This means that the Kingdom since 2010 consists of four equal countries²⁶², three of them located in the Caribbean and one in Europe.

Figure 1.1 The Netherlands (left) and the countries and public bodies in the Caribbean (right)



Source: GIS, edited by Ecorys

The figure above shows the location of the different countries within the Kingdom. The left figure shows the location of the Netherlands within Europe and the figure on the right shows the islands in the Caribbean. The circle in north indicates the islands Sint Maarten, Sint Eustasius and Saba (Bovenwindse eilanden) while the circle in the south shows where the Benedenwindse eilanden, Aruba Curaçao and Bonaire are located.

The islands of Bonaire, Sint Eustasius and Saba chose to become overseas dependencies of the Netherlands. They can be qualified as 'openbare lichamen' (Dutch for public bodies) according to article 134 GW²⁶³ and they have a similar status as all municipalities within the Netherlands. Citizens with the Dutch nationality can vote for European Parliament and the Dutch Parliament. The legislation applied on these islands is currently the legislation that was used on the Dutch Antilles, however this will be gradually changed to Dutch legislation. It should be noted that some situations might require specific legislation which is in line with the geographical situation of the islands. An example is the currency used on the islands. Instead of the Euro the leading currency on the islands is the American dollar as this is required by the trade relations of the islands²⁶⁴.

²⁵⁹ In English Leeward Islands

²⁶⁰ In English Windward Islands

²⁶¹ The five islands had four options to choose from: stay member to the country Dutch Antilles, to become a country within the Kingdom, become an independent country outside the Kingdom or become part of the Netherlands.

²⁶² Article 1 sub 1 Statuut voor het Koninkrijk der Nederlanden

²⁶³ Article 134 Grondwet (Dutch Constitution)

²⁶⁴ Ministerie van Binnenlandse Zaken en Koninkrijksrelaties en Ministerie van Buitenlandse Zaken (2010)

The political changes in the Kingdom are internal and therefore the foreign relations which are maintained by the Kingdom on behalf of the countries have not been changed much. The external borders of the Kingdom have not been changed and foreign affairs, including defence, remain an affair of the Kingdom as a whole. Under the Statute of the Kingdom only the Kingdom is able to conclude treaties with international organisations and / or other powers. Often a delegation of Dutch representatives will participate in treaty negotiations, but before the actual concluding of the treaty the parliaments of Aruba, Curaçao and Sint Maarten need to be notified of the treaty²⁶⁵.

Although treaties can only be concluded by the Kingdom of the Netherlands it does not mean that the treaties will always apply to all countries in the Kingdom. If a treaty will harm one of the countries or is not beneficial that country will not be bound by the treaty. The government of the country needs to motivate the rejection²⁶⁶. For instance, rejections might happen in case of bilateral tax or trade agreements. The countries in the Caribbean have concluded tax treaties with neighbouring countries, because their trade relations will benefit. The Netherlands is often not partner to these (bilateral) treaties²⁶⁷.

International treaties, both with international organisations and other powers, are laid down in a Rijkswet (English: *Statue Law*). This Rijkswet will indicate for which part(s) of the Kingdom the new legislation does apply. If a treaty with an international organisation is concluded and the treaty does not apply to all countries, the international organisation will be officially notified of this. The organisation will be asked to include the notification in the list of ratification, however this does not always happen.

An example of an international treaty that does not apply to all countries in the Kingdom is the United Nations Convention on the Law of the Sea (UNCLOS). The treaty was concluded on 10 December 1982 and the Treaty was signed by the Kingdom of the Netherlands on the same day. Initially the treaty only applied to the Netherlands (the European part) and is for this country in force since 28 July 1996. Since 13 February 2009 the treaty also applies to the Dutch Antilles, and so is applicable to Curaçao, Sint Maarten, Bonaire, Sint Eustatius and Saba. After the political changes UNCLOS remained applicable to all five islands. Aruba is not a member to the Treaty²⁶⁸.

²⁶⁵ Article 24 sub 1 and 2 Statuut voor het Koninkrijk der Nederlanden

²⁶⁶ Article 25 Statuut voor het Koninkrijk der Nederlanden

²⁶⁷ Van der Pot and Donner (2006)

²⁶⁸ Soons (2011)

1.1 Legal framework regarding jurisdiction at sea

1.1.1 Regulation in maritime zones

The Kingdom of the Netherlands is member to the United Nations Convention on the Law of the Sea 1982 (UNCLOS or the treaty of Montego Bay) with the exception of Aruba. As indicated in the previous chapter the treaty was originally only concluded for the Netherlands, the European part of the Kingdom. Although the Convention was adopted in 1982, the Kingdom of the Netherlands ratified the Convention on 28 June 1996²⁶⁹. On the same date also the Agreement relating to the implementation of Part XI of the Convention of 10 December 1982 was ratified. Part XI refers to the Area, i.e. the deep seabed and all its resources belonging to the 'common heritage of mankind'. The Kingdom also ratified the Agreement for the implementation of the provisions of the Convention of 10 December 1982 relating to the conservation and management of straddling fish stocks and highly migratory fish stocks. This Agreement was ratified on 19 December 2003.

UNCLOS defines several different areas (zones) that are part of the jurisdiction of coastal states:

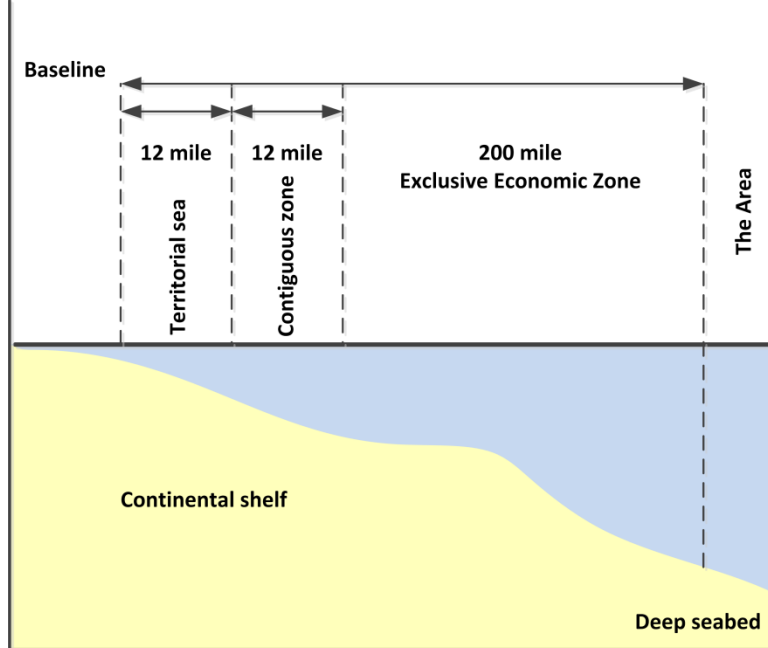
- Internal waters (article 8 UNCLOS)
- The territorial sea (article 3 and onwards UNCLOS)
- Archipelagic waters (article 46 and onwards UNCLOS)
- The contiguous zone (article 33 UNCLOS)
- The exclusive economic zone (article 55 and onwards UNCLOS)
- The continental shelf (article 76 and onwards UNCLOS)

All areas, except the archipelagic waters are of relevance for the Netherlands and will be described in more detail below. Outside the borders of the exclusive economic zone and the continental shelf the High Seas or the Area start. No country has jurisdiction in this part of the sea as the sea belongs to common heritage of mankind and countries need to respect each others presence and activities. Due to the closeness of all North Sea countries there are no areas close to the Dutch EEZ that are part of the Area. All parts of the North Sea belong to the jurisdiction of one of the adjacent countries. However it is possible to deploy activities in other parts of the Area.

The figure below presents a schematic overview of the different maritime zones available.

²⁶⁹ http://www.un.org/depts/los/reference_files/chronological_lists_of_ratifications.htm

Figure 1.2 Schematic overview of maritime zones based on UNCLOS



Source: Ecorys (2014)

1.1.2 The territorial sea

The first zone measured from the landside is the territorial sea which can have a maximum length of twelve nautical miles measured from the baselines (articles 2 and 3 UNCLOS). A coastal state does not have to establish the territorial sea, as the sovereignty over the coastal sea is incidental to the sovereignty over land. However a coastal state needs to specify the exact breath of the territorial sea²⁷⁰. All water at the landside of the baseline is qualified as the internal waters. So all the rivers, the Waddenzee and het IJsselmeer belong to the internal waters of the Netherlands and the country has full sovereignty over these waters²⁷¹.

The Netherlands has the maximum possible territorial sea of 12 nautical miles which equals 22 kilometres and 240 metres. The exact specifications of the Dutch territorial sea were established in the 'Wet grenzen Nederlandse territoriale zee' adopted on 9 January 1985²⁷². Before adaptation of this law the Netherlands used to have territorial sea of 3 miles which was mainly claimed to ensure safe navigation on the North Sea²⁷³. The Dutch territorial sea can be divided into three separate zones:

4. The so-called one kilometre zone (measured from the baseline). In this zone both the general government as well as regional and local government has several powers²⁷⁴. Outside the one kilometre zone only the national government is the legal authority.
5. The one nautical mile zone, which is used in the Waterwet and EU Waterframework Directive.
6. The three nautical mile zone, which is used in fishing. None of the other EU Member States, with exception of Belgium, is allowed to fish in this zone²⁷⁵.

The Dutch territorial sea is closely located to the territorial seas of Belgium and Germany and at some points even overlap. The border of the territorial sea with Belgium has been established by a

²⁷⁰ Aust (2009)

²⁷¹ The sovereignty is equal to the sovereignty the country has over its lands.

²⁷² Wet grenzen Nederlandse territoriale zee

²⁷³ Kooijmans (2002)

²⁷⁴ E.g. Wet van 2 november 1990, houdende regeling provincie- en gemeentegrenzen langs de Noordzeekust van de gemeente Den Helder tot en met de gemeente Sluis; Wet provinciale indeling van de Waddenzee; Wet tot gemeenschappelijke indeling van de Waddenzee.

²⁷⁵ Noordzeeloket, 'Juridische grenzen en zones op de Noordzee'

Treaty which was signed in 1996 and is in force since 1999²⁷⁶. The border between the Dutch and German territorial sea has not been established yet, as there is still a dispute around the Eems Dollar²⁷⁷.

1.1.3 *The contiguous zone*

The second maritime zone possible is the contiguous zone. The contiguous zone can extend the territorial sea up to 24 nautical miles measured from the baselines from which the territorial sea is measured. The Netherlands has adopted a contiguous zone by the 'Rijkswet instelling aansluitende zone'²⁷⁸. The law was adopted on 28 April 2005 and is applicable to all countries in the Kingdom. Main reason for establishing a contiguous zone is to be able to prevent and punish infringements of customs, fiscal, immigration, public health (sanitary laws) and monuments. The exact outer border for the Netherlands has been defined in the 'Besluit grenzen aansluitende zone' dated on 14 June 2006.

1.1.4 *The exclusive economic zone and continental shelf*

The third possible zone is the exclusive economic zone (EEZ). This zone is adjacent to the territorial sea and can extend up to 200 nautical miles from the baselines from which the territorial sea is measured (Article 57 UNCLOS). The coastal states do not have sovereignty in the EEZ, but enjoy sovereign rights for certain purposes. The coastal state has sovereign rights for exploring, exploiting, conserving and managing natural resources in its EEZ (article 56.1.a UNCLOS). Natural resources can both be living (e.g. fish stock) or non-living (e.g. oil and gas). The rights can be exercised for the superjacent waters (above) the seabed and for the seabed and its subsoil.

The EEZ needs to be formally established. The Netherlands has done so and since 28 April 2000 the country has an EEZ²⁷⁹. This was some years before the country established the contiguous zone. The Netherlands cannot claim the full 200 nautical miles as that would imply that the Dutch EEZ would overlap with the EEZs of Belgium, Germany and the United Kingdom. To establish the borders of the Dutch EEZ connection is sought with the treaties regarding the division of the continental shelf²⁸⁰.

Besides an EEZ countries also have a continental shelf. Contrary to an EEZ, the coastal state does not have to establish a continental shelf as, based on customary law, a coastal state is entitled to the seabed descending from its land up to a depth of 200 metres. It is assumed that after the seabed has descended to 200 metres there is a steep slope in the seabed and the deep seabed starts. However the 200 metres is artificial and leads to different continental shelves as some sea beds reach the 200 metres within several nautical miles, while others reached it after hundreds of miles. To solve the inequality between the sea beds UNCLOS states that the maximum continental shelf of a coastal state is up to 200 nautical miles from the baselines from which the territorial sea is measured²⁸¹.

The continental shelf is established by law and so the Netherlands have a continental shelf without claiming it. The Dutch continental shelf has the same size as the EEZ and is divided between the

²⁷⁶ Verdrag tussen het Koninkrijk der Nederlanden en het Koninkrijk België inzake de afbakening van de territoriale zee van 18 december 1996.

²⁷⁷ A few treaties have been signed, but a formal border was never agreed. E.g. Verdrag tussen het Koninkrijk der Nederlanden en de Bondsrepubliek Duitsland tot regeling van de samenwerking in de Eemsmonding van 8 april 1960 and Aanvullende overeenkomst van 14 mei 1962. Both in force since 1 August 1963. Aanvullend protocol tot regeling van de samenwerking met betrekking tot het waterbeheer en het natuurbeheer in de Eemsmonding van 22 augustus 1996, in force since 1 Juli 1998.

²⁷⁸ Rijkswet instelling aansluitende zone

²⁷⁹ Rijkswet instelling exclusieve economische zone

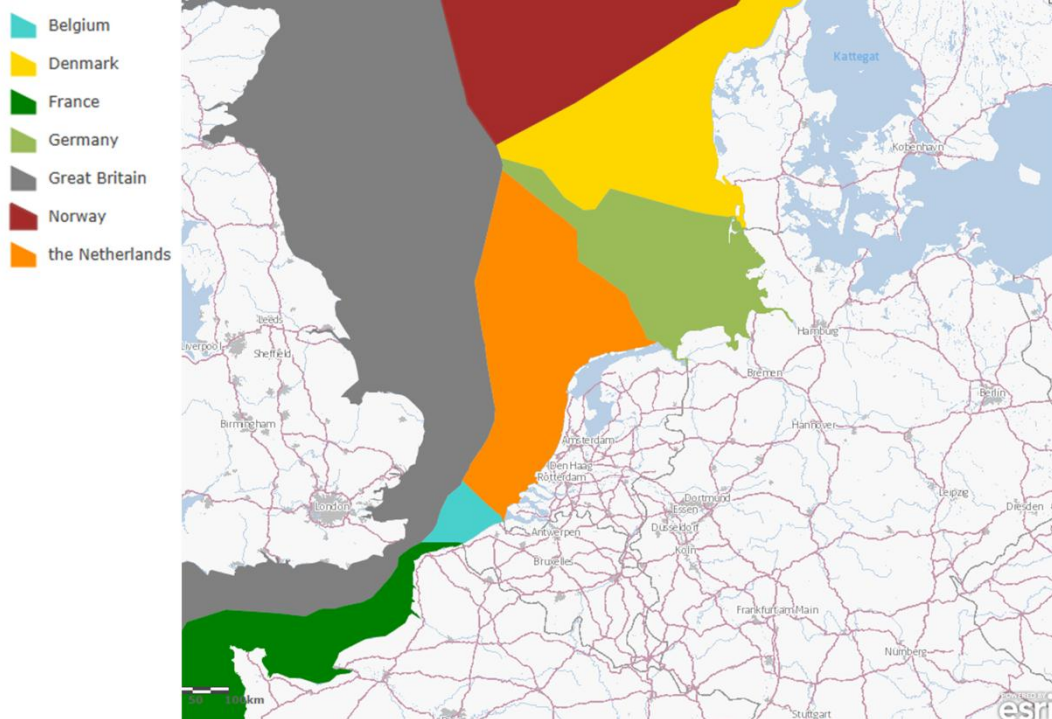
²⁸⁰ Noordzeeloket, 'Juridische grenzen en zones op de Noordzee'

²⁸¹ Kooijmans (2002)

coastal states surrounding the North Sea. The division of the continental shelf between the Netherlands, Belgium, Germany and the United Kingdom is based on several bilateral treaties²⁸². The division of the EEZ is the same as the division of the continental shelf and is presented in the figure below.

Figure 1.3

Division of the continental shelf in the North Sea



Source: <http://www.noordzeeatlas.nl/Kaart/NCP.htm>

Besides the EEZ and the continental shelf the Netherlands also has an exclusive fishery zone, which was established in 1977²⁸³. Although most claims that could be made under the fishery zone can also be made under the regime of the EEZ, the fishery is still of importance as several Dutch acts refer to the exclusive fishery zone. The zone is larger than the EEZ as the regime of the fishery zone is applicable in both the territorial sea and the EEZ²⁸⁴.

As the continental shelf is limited in the North Sea and the borders are carefully negotiated in several treaties it is unlikely that the Netherlands will extend the continental shelf as this would put political relations under pressure.

1.1.5 The Area

Outside the EEZ there is the Area and the High Seas. The Area is not directly linked to the Dutch continental shelf as the Dutch continental shelf is connected to the continental shelf of other North Sea countries. According to UNCLOS it is possible to claim some rights in the Area. However up till to today, the Dutch government did not claim any rights regarding the Area.

²⁸² E.g. Verdrag tussen het Koninkrijk der Nederlanden en het Koninkrijk België inzake de afbakening van het continentaal plat van 18 december 1996; Verdrag tussen het Koninkrijk der Nederlanden en de Bondsrepubliek Duitsland inzake de zijdelingse begrenzing van het continentaal plat in de nabijheid van de kust van 1 december 1964; Verdrag tussen het Koninkrijk der Nederlanden en de Bondsrepubliek Duitsland inzake de begrenzing van het continentaal plat onder de Noordzee van 28 januari 1971; Overeenkomst tussen het Koninkrijk der Nederlanden en het Verenigd Koninkrijk inzake de begrenzing van het tussen deze landen gelegen continentaal plat onder de Noordzee van 6 oktober 1965.

²⁸³ Machtigingswet instelling visserijzone 8 juni 1977

²⁸⁴ Dottinga and Trouwborst (2009)

In a 'note verbale'²⁸⁵ dated 26 March 2012 the Permanent mission of the Kingdom of the Netherlands to the United Nations informed the International Seabed Authority (ISA) that the Kingdom of the Netherlands currently has no regulation in place governing deep sea mining in the Area. The government also has no intention to draft any new legislation in the short run.

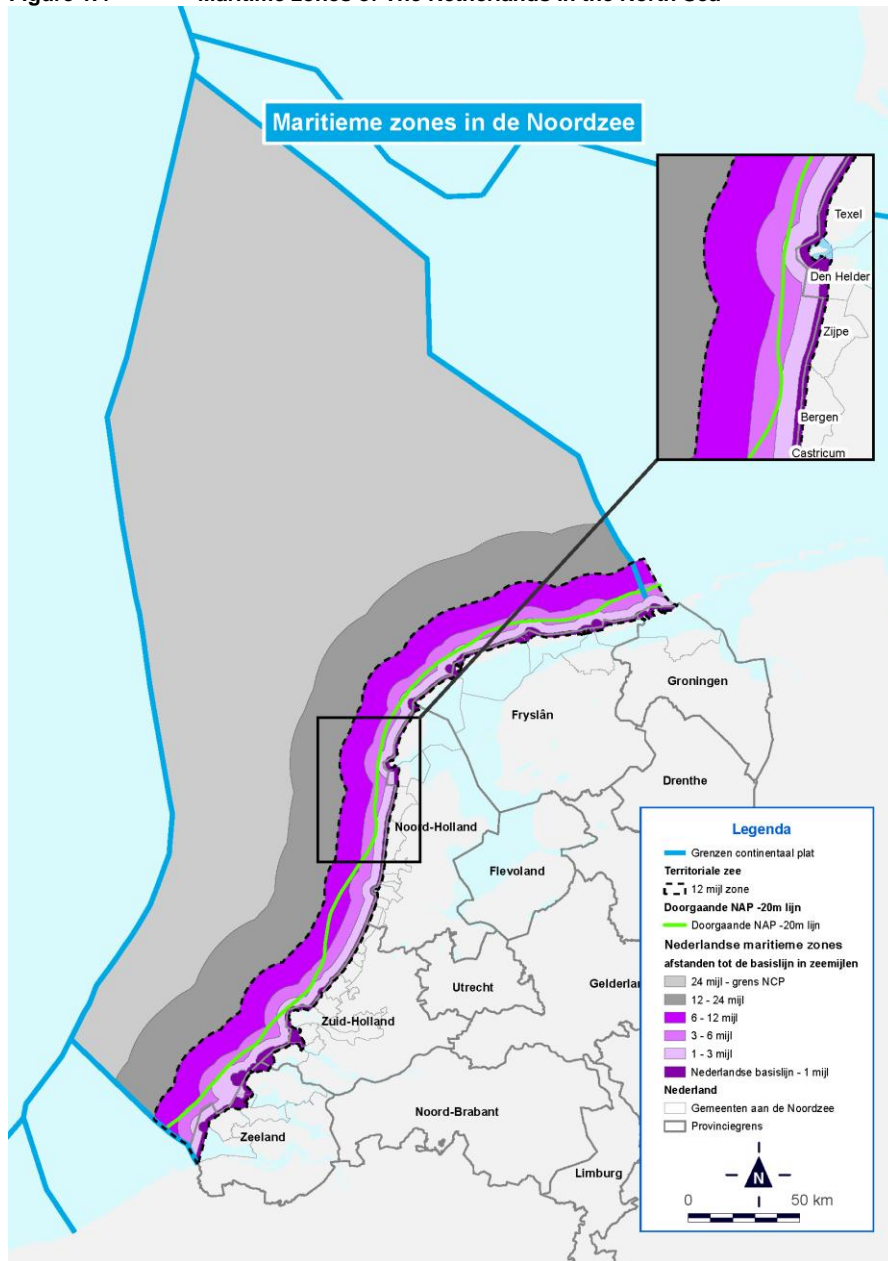
During the analysis no clues were found indicating that since the submission of the note verbale to ISA in 2012, the Dutch government has any concrete plans to draft legislation regarding deep sea mining in the Area.

1.1.6 *Overview of the Dutch maritime zones*

The following figure shows the different maritime zones of the Netherlands in the North Sea. The area of the Dutch maritime zones is approximately 58,000 km². The purple lines in the figure indicate the territorial sea of the country. The territorial sea is located up to 12 nautical miles measured from the baseline. The dark grey area indicates the contiguous zone which lies between 12 and 24 nautical miles measured from the baselines from which the territorial sea is measured. The light grey area indicates the Dutch Exclusive Economic Zone (EEZ) and the Dutch continental shelf. The border of the continental shelf are indicated by the light blue line. The borders of both the continental shelf and the EEZ are based on international negotiations between the different North Sea countries.

²⁸⁵ Note verbale Netherlands on the sea bed (No. NYV/2013/0205)

Figure 1.4 Maritime zones of The Netherlands in the North Sea



Source: www.noordzeeloket.nl

1.2 Regulation of deep sea mining

1.2.1 Legislation on mining activities

In the Netherlands two acts apply to mining activities at sea. If the minerals are located at the surface or not lower than 100 metres under the surface the Ontgrondingenwet (Act on earth removal) applies²⁸⁶. If the minerals are located at a depth of more than 100 metres below the surface the Mijnbouwwet (Mining act) will apply²⁸⁷.

Mining activities up to a depth of 100 metres under the surface

The Ontgrondingenwet is applicable to mining activities both on land and at sea. Article 4a explicitly indicates that the act applies to mining activities in the Dutch continental shelf. Article 8.1 indicates that activities can place in Rijkswateren (English: *national waters*). The 'Regeling ontgrondingen in Rijkswateren' specifies which waters are identified as Rijkswateren. The Dutch territorial sea and EEZ are qualified as Rijkswateren²⁸⁸.

All minerals belong to the State²⁸⁹ and to be able to mine the minerals a license is needed. So all mining activities, including deep sea mining activities, require a license which should be granted by the Minister of Infrastructure and Environment²⁹⁰. Some activities do not require a license and the exemptions can be mainly found in the 'Besluit ontgrondingen in rijkswateren.' Exempted activities are for instance, dredging activities in shipping lanes and soil drilling. To obtain a license a fee needs to be paid²⁹¹. The fee consists of a registration fee of € 680,- plus a premium²⁹². The premium depends on the volume that will be mined.

The Besluit also provides guidelines for the application procedure to obtain a license. According to article 4.2 the application needs to include, amongst others, the name of the company, the name and registration number of the vessels to be used, the location of the mining activities including the coordinates of the North Sea, the method of mining activities as well as the depth on which the mining activities will take place. In addition, the Minister can ask for the results of analysis carried out in case this information will support the interests of stakeholders²⁹³.

Before the Minister will grant the license often an environmental impact assessment needs to be carried out (article 10.1 Ontgrondingenwet). Especially for mining activities where more than 1, million m³ will be mined a assessment is required²⁹⁴. The Besluit indicates some situations in which an environmental impact assessment does not have to be carried out. Exemptions are:

- Renewal of a current license. However the duration for which the renewal is granted is less than half of the period for which the original license was granted;
- Mining activities which are at least 500 metres away from cables, shores and objects and which take place
 - In areas that are not deeper than 2 metres below the original surface and where no mining activities have taken place so far or
 - In shipping lanes according to article 8.1 of the Ontgrondingenwet.

In principle a license will be granted for all areas in the territorial sea and the EEZ. However stricter rules might apply if the applicant wants to mine in an area with ecological important values²⁹⁵. In case the ecological valuable area is appointed as a Natura2000 no mining activities can take

²⁸⁶ Article 4b Ontgrondingenwet

²⁸⁷ Article 2.2 Mijnbouwwet

²⁸⁸ Article 1b Regeling ontgrondingen rijkswateren.

²⁸⁹ Article 4b Ontgrondingenwet

²⁹⁰ Article 1.a Ontgrondingenwet.

²⁹¹ Article 6 Ontgrondingenwet

²⁹² Article 6.2 + Annex Belsuit ontgrondingen Rijkswateren

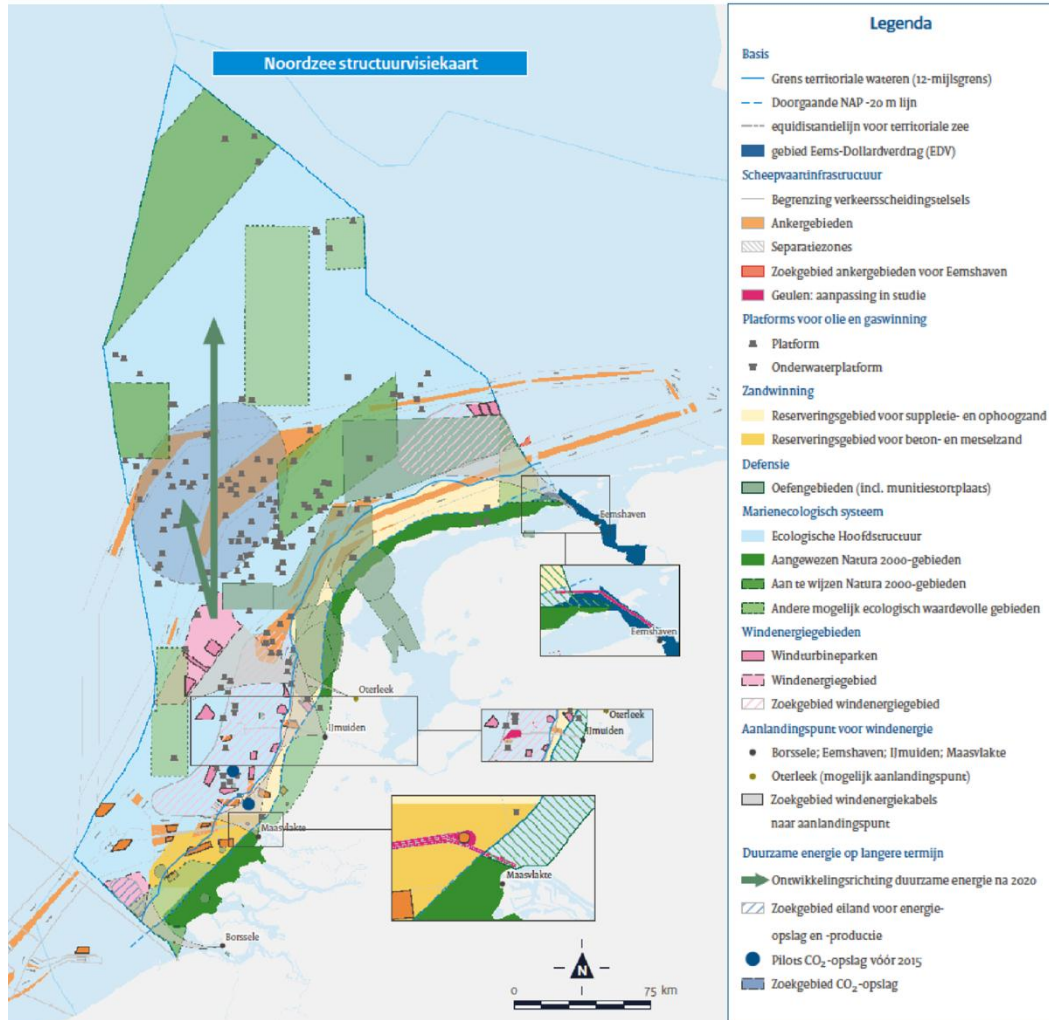
²⁹³ Article 4.3 Belsuit ontgrondingen in rijkswateren

²⁹⁴ http://www.rijkswaterstaat.nl/water/wetten_en_regelgeving/ontgrondingenwet/

²⁹⁵ These areas are indicated in the 'Integraal beheerplan Noordzee 2015'

place²⁹⁶. The mining activities should also fall within the scope of the Integraal Beheerplan Noordzee 2015. The Dutch government has drafted this plan to divide the usage of the North Sea and in this plan the different functions, e.g. oil- and gas activities, Natura2000 area and so on, are indicated for the North Sea and allocated to specific sections. The functions identified are actions of national importance. The activities take precedence in their appointed area. If there are more functions in one area, that are all actions of national importance, a balanced approach needs to be chosen. The figure below shows the different functions and there allocated areas.

Figure 1.5 Vision map national water plan



Source: Integraal beheerplan Noordzee 2015

Mining activities below 100 metres under the surface

The second act regulating mining activities is the Mijnbouwwet (Mining Act). And also this act regulates both mining on land and at sea. This act is relatively new and was concluded in 2002. Before the introduction of the new Mining act four separate acts existed. One of these acts was the 'Mijnwet continentaal plat 1965' (Mining act for the continental shelf 1965). As mining activities on land and water require similar rules it was decided to cluster the four separate acts in to one overall act²⁹⁷.

²⁹⁶ Article 10 and 10a Natuurbeschermingswet 1998

²⁹⁷ Kamerstukken II, 1998/99, 26219, Nr 3. p. 4

The act explicitly mentions that the act is applicable to mining activities in the continental shelf²⁹⁸ once the activities take place below a depth of 100 metres under the surface²⁹⁹. According to article 6.1 Mijnbouwwet a licence is obligatory issued by the Minister of Economic Affairs, to:

- Trace minerals,
- Extract minerals,
- Trace geothermal
- Extract geothermal

Licenses are granted for a specific type of mineral, e.g. only for gas or sand, and if for a certain area already a license is granted, no second license for the same mineral will be provided³⁰⁰. It is possible to obtain a license for the same area, but then for a different type of mineral.

In principle a license will always be granted irrespective the articles 7 and 8 of the act and the exceptions provided in article 9.1 Mijnbouwwet. Exceptions are:

- the applicant is technical or financially not capable of carrying out the mining activities;
- the method used to perform the activities is undesirable;
- a lack of efficiency and responsibility, including a lack of social responsibility; or
- when there are two or more applicants that score equally in the assessment of their applications.

Once the license is granted the applicant should presents its winningsplan³⁰¹ (English: *production plan*) and the Minister of Economic Affairs needs to authorize the plan. The plan shall describe the location and the quantity of minerals available in the area, the start and duration of the mining activities and the methods used to carry out the mining activities³⁰². Besides the plan the license holders also needs to take all measures that reasonably could be expected from him to protect the environment³⁰³.

In case the mining activities take place from a mining facility which is fixed to the seabed the applicant needs to have an emergency response plan in place (article 85 Mijnbouwbesluit) The emergency response plan requires consent of the Minister of Economic Affairs and contains a description of measures that will be taken to prevent or minimize the effects of possible accidents. To measures shall ensure that the effect for the environment and the safety of shipping and fishery are minimal³⁰⁴.

The Mijnbouwwet allows for mining activities in the entire continental shelf and territorial sea. However there are some restrictions to this. The figure below shows the restrictions as laid down in the Mijnbouwregeling, a *lex specialis* compared to the *lex generalis* the Mijnbouwwet. The red areas on the map are the restricted areas, the yellow areas are anchorages, the green areas are approach areas for shipping and the purple areas are the shipping routes. Also no licenses will be granted in the striped areas, as the areas are training areas for the military.

²⁹⁸ Article 2.1 Mijnbouwwet

²⁹⁹ Article 2.2 Mijnbouwwet

³⁰⁰ Article 7.1 Mijnbouwwet

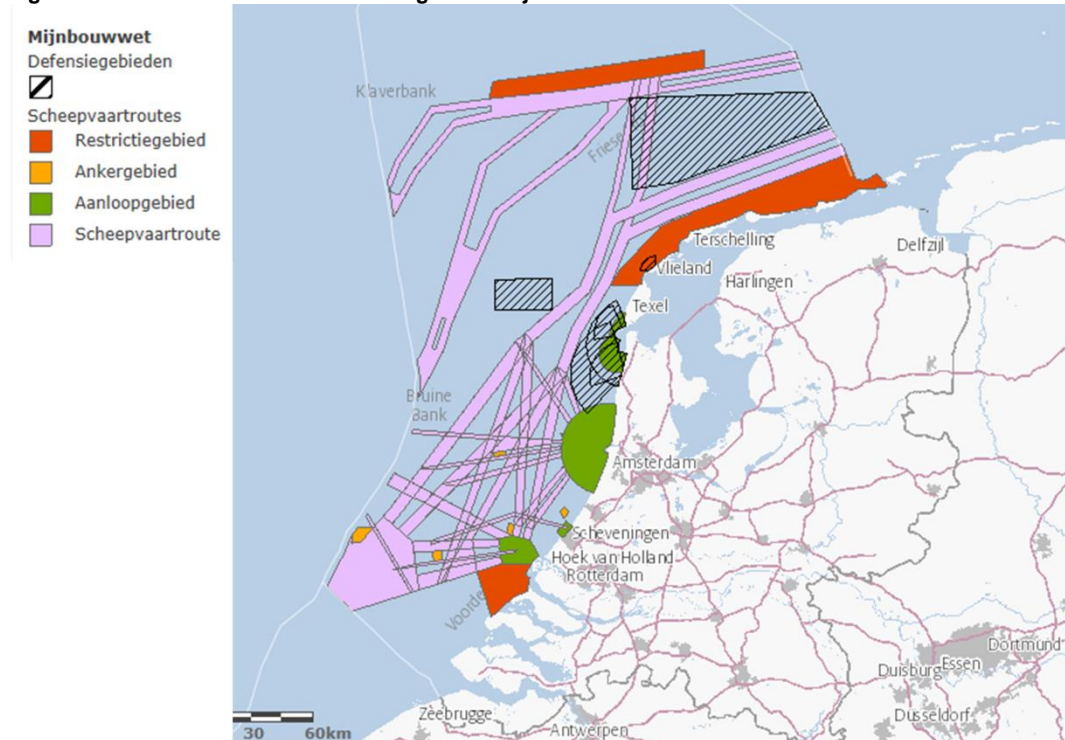
³⁰¹ Article 34 Mijnbouwwet

³⁰² Article 35 Mijnbouwwet

³⁰³ Article 33 Mijnbouwwet

³⁰⁴ Article 86 Mijnbouwbesluit

Figure 1.6 Restrictions according to the Mijnbouwwet



Source: <http://www.noordzeeatlas.nl/Kaart/mijnbouwregeling.htm>

Other mining regulation

The Dutch government is partner to the Preliminary note on deep sea mining³⁰⁵, signed on 3 August 1984 in Geneva, Switzerland. The Note was signed by eight countries, i.e. The Netherlands, Belgium, Japan, Italy, the USA, France, Germany and the United Kingdom. Aim of the note is to notify the other partners once a license for deep sea mining activities is granted in the continental shelf, this to avoid overlapping claims and international disputes. The note also provides guidance on the technical and financial capabilities of the companies that wish to carry out mining activities and basic set of standards is provided to needs to be made before companies are allowed to execute mining activities.

Main reason for the Dutch government for signing the Note is to have some legal relationship with the USA. The USA is no partner to the International Seabed Authority and therefore not bound to the ISA rules. This Note will create a legal set of rules for deep sea mining activities³⁰⁶.

Agencies for authorizing deep sea mining

As indicated in the previous section both acts require licenses before mining activities are allowed. It was also indicated that different Ministers are competent to grant the licenses. If the mining activity takes place less than 100 metres below the surface the Ontgrondingwet applies and the Minister of Infrastructure and Environment is the competent Minister. In this case Rijkswaterstaat will grant the licenses on behalf of the Minister³⁰⁷. Rijkswaterstaat is the executive body of the Ministry of Infrastructure and Environment. On behalf of the Minister they will assess the applications for mining activities and they will provide or reject the license.

If mining activities take place at a depth of more than 100 metres below the surface the Mijnbouwwet applies and the Minister of Economic Affairs is the competent Minister. In this case the applicant needs to the authority 'Staatstoezicht op de mijnen' (SodM, English: State supervision

³⁰⁵ Voorlopige overeenstemming inzake aangelegenheden betreffende de diepzeemijnbouw

³⁰⁶ http://www.polidocs.nl/XML/KVR/SG_KVR0000123456.xml

³⁰⁷ http://www.rijkswaterstaat.nl/water/wetten_en_regelgeving/ontgroningenwet/

on the mines³⁰⁸) which is in charge of the licensing process. The SodM advises the Minister concerning licenses to be granted. Main tasks of SodM are to inspect and enforce the permit conditions. In case of breach of the permit conditions the SodM directly reports to the Minister of Economic Affairs and the Minister can impose a fine.

Besides SodM, who is the main authority in the licensing procedure, two other bodies can advise the Minister, i.e. the 'Mijnraad'³⁰⁹ (English: Mining Council) and the 'Technische commissie bodembeweging'³¹⁰ (English: Technical commission for soil movement). The Mijnraad will always advise the Minister on providing a license for tracing and extracting minerals. Also if the Minister wishes to withdrawal a given license he needs to seek advice from the Mijnraad (article 105.3 Mijnbouwwet). Besides the obligation to seek advice for the licenses with regard the tracing and extraction of minerals, the Minister can also ask for advice on decisions and the execution of proposed regulation and general policies.

The Technische commissie bodembeweging needs to assess the consequences of mining activities on the soil movements and the related damages caused by it. The commission not only advises the Minister, but also the persons that might suffer damages as result of the mining activities. The Minister can ask the mining company to provide a security. This security can be used to pay damages to people suffering from the mining activities. Before setting the security the Minister will ask the commission advice to set the height of the proposed security.

1.2.2 *Legislation on Environmental Impact Assessment*

For most offshore mining activities, including deep sea mining, an environmental impact assessment (EIA) needs to be carried out. Only exception are exploration drilling activities, which aim to assess whether or not minerals are present in the sea bed³¹¹. In case the mining activities are governed by the Mijnbouwwet the EIA needs to be carried out before the 'winningsplan' has been presented to the Minister of Economic Affairs.

For both mining activities the procedure relating to an EIA is laid down in the 'Wet Milieubeheer' (English: environmental act), Chapter 7 and is the same. Article 7.2 sub 1 states that an EIA shall be carried for activities that can have important negative effects on the environment. The activities for which an EIA is obligatory are all formulated in the Besluit milieueffectenrapportage. Annex C 16.2 of this Besluit states that all activities carried out in the continental shelf need to have an EIA before the actual mining can take place, only exemption is extraction of peat.

A second legal ground for carrying out an environmental impact assessment is based on article 7.2, subs 1 and 3 in connection with the Natuurbeschermingswet 1998 (Environment protection act 1998). Activities carried out in the EEZ need to have an EIA in connection with the obligatory winningplan.

The EIA should contain at least a description of the planned activity, a description of the current environmental status of the area where the activities will take place as well as the expected developments of the environmental with and without the activity and a description of measures that will be taken to prevent or minimize negative effects on the environment (article 7.7 Wet milieubeheer).

³⁰⁸ <http://www.helpdeskwater.nl/onderwerpen/kust-zee/delfstoffen/offshore-mijnbouw/>

³⁰⁹ Articles 105-112 Mijnbouwwet

³¹⁰ Articles 113-122 Mijnbouwwet

³¹¹ <http://www.helpdeskwater.nl/onderwerpen/kust-zee/delfstoffen/offshore-mijnbouw/>

The Dutch EIA system is a rather complex one. The Wet Milieubeheer provides one overall environmental impact assessment approach which applies to all activities that might have a negative environmental impact. This means that the same rules apply to the assessment of the construction of a new road as well as to deep sea mining activities. It is not clear from the legislation found what the exact criteria for evaluation are.

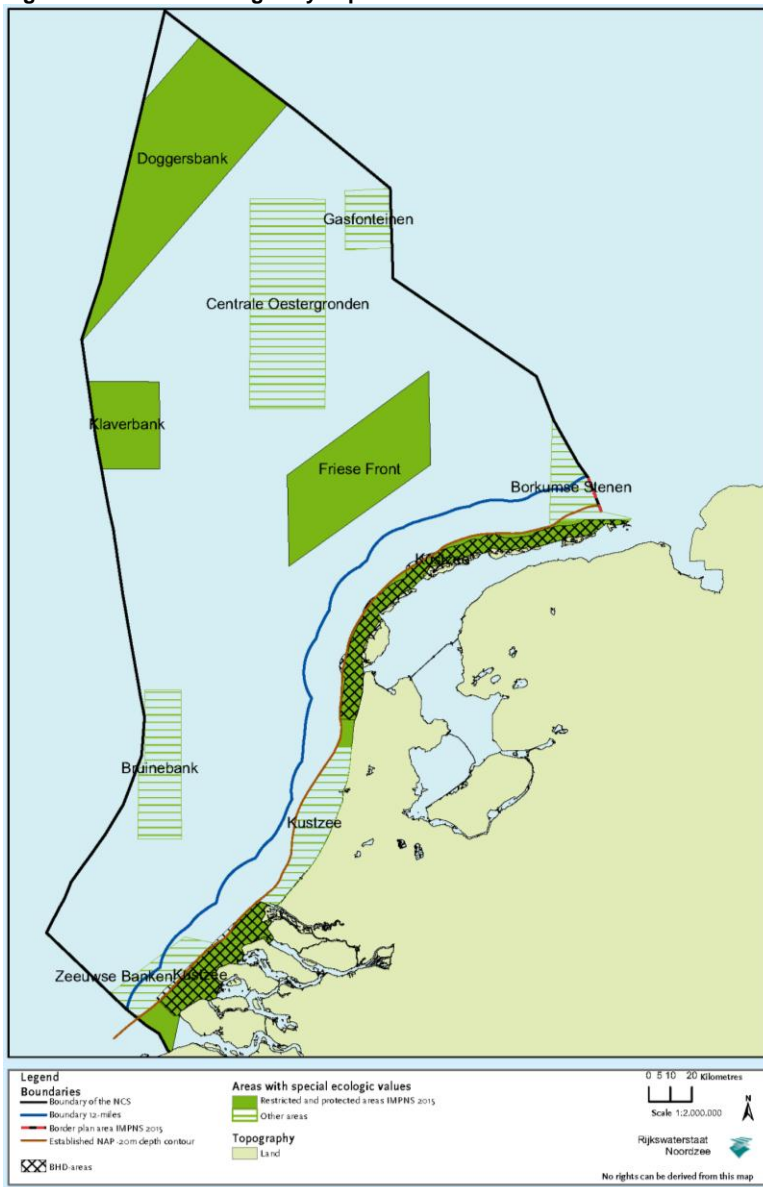
1.2.3 *Other environmental legislation*

The most important act applicable to the Dutch Seabed is the Natuurbeschermingswet 1998. Article 1a states that the largest share of the Act also applies to the Dutch EEZ. Only the national government, i.e. the Minister of Economic Affairs, is able to appoint maritime areas as protected zones. In order to appoint an area as protect area the decision needs to be officially published and the area needs to be indicated on a map.

In the Netherlands several ecologically important areas have been indicated, however not all of them have a protected status yet. In total ten areas in the Dutch territorial sea and EEZ have been identified as ecological valuable areas. It concerns the following areas (which are also indicated in the following figure):

- Kustzee (Coastal Sea);
- Doggersbank (Dogger Bank);
- Klaverbank (Clever bank);
- Friese Front (Frisian Front);
- Centrale Oestergronden (Central Oyster Grounds);
- Borkumse Stenen (Borkumse Stones);
- Zeeuwse Banken (Zeeuwse Banks);
- Bruine Bank (Brown Bank);
- Gasfonteinen (Gas Seeps);
- Noordkrompgebied (Arctica Area).

Figure 1.7 Ecologically important areas in the Dutch EEZ



Source: Integraal beheerplan Noordzee 2015

The Netherlands is member to the OSPAR-treaty which aims to protect the marine environment in the North East part of the Atlantic Ocean. Pollution needs to be prevented or ended and the marine area needs to be protected against negative effects of human activities with the aim of improving the human health and maintain the marine ecosystem. Special attention is paid to the offshore activities and pollution resulting thereof. Under this treaty it is possible to establish Marine Protected Areas (MPA). The Netherlands has established five MPAs, three of them located in the territorial sea and two in the EEZ. It should be noted that a MPA can only be established in waters outside the territory of a country, so all areas within the national borders, i.e. internal waters, fall outside the scope of the OSPAR treaty.

Under the OSPAR Treaty 8,320 km² has been appointed as MPA, which equals 14% of the Dutch territorial sea and EEZ, which is about 58,000 km². The areas appointed under OSPAR are mentioned in the table below.

Table 1.1 Marine Protected Areas under OSPAR

	Jurisdiction	Year of report	Area in km ²
Noordzeekustzone	TW	2009	1,416
Doggerbank	EEZ	2009	4,646
Klaverbank	EEZ	2009	1,240
Vlakte van Raan	TW	2009	199
Voordelta	TW	2009	819

Source: OSPAR Commission (2013)

Besides OSPAR also the European Habitats Directive³¹² applies and this Directive ensures that areas with a high ecological value will be protected. Some of the areas can be located at sea and so it is possible to protect certain ecological valuable areas at sea. To protect such an area a Natura2000 zone can be established. In the Dutch part of the EZZ several zones are indicated as Natura2000 zones or are appointed as possible valuable areas. Once an area is appointed as an ecological valuable area mining activities might no longer be allowed. To see which zones are protected the national water plan³¹³ is the guiding document. The zones are the same zones as shown in Figure 1.7. The full green areas are already Natura2000, while the striped areas are nominated to become a Natura2000 area.

Another European Directive that is applicable to the MPAs is the Marine Strategy Framework Directive³¹⁴ (MSFD). This Directive obliges coastal states to take spatial protection measures that contribute to coherent and representative networks of marine protected areas and that adequately cover the diversity of the constituent ecosystems. The Directive applies to the whole North Sea (article 4.2.a.i) and that implies that all mining activities are indirectly effected by the Directive as the Directive obliges Member States to draft a Marine strategy for protecting the marine environment.

In deep sea mining several installations needs to be used. These installations can be fixed or mobile. The 'Besluit algemene regels milieu mijnbouw' provides additional rules for the installations from an environmental perspective. The Besluit deals with the noise levels (articles 50 and 51), the air quality (articles 52-56), waste and hazardous substances (articles 57-60) and energy usage (article 61).

³¹² Directive 92/43/EEG of 21 May 1992 on the conservation of natural habitats and of wild flora and fauna

³¹³ Which is a part of the Integraal Beheerplan Noordzee 2015

³¹⁴ Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008

Legislation

- Besluit van 4 juli 1994, houdende uitvoering van het hoofdstuk Milieu-Effectenrapportage van de Wet Milieubeheer (Besluit milieueffectenrapportage)
- Besluit van 6 december 2002, houdende regels ter uitvoering van de Mijnbouwwet (Mijnbouwbesluit)
- Besluit van 14 juni 2006 ter uitvoering van de Rijkswet (Besluit grenzen aansluitende zone)
- Besluit van 3 april 2008, houdende regels betreffende het milieu met betrekking tot mobiele installaties en onderzeese installaties (Besluit algemene regels milieu mijnbouw)
- Convention for the protection of the marine environment of the North-East Atlantic (OSPAR treaty)
- Grondwet voor het Koninkrijk der Nederlanden van 24 augustus 181
- Mijnbouwregeling
- *Note verbale* dated 26 March 2012, drafted by the Permanent Mission of the Kingdom of the Netherlands to the United Nations
- Overeenkomst tussen de Regering van het Koninkrijk der Nederlanden en de Regering van het Verenigd Koninkrijk van Groot-Brittannië en Noord-Ierland inzake de begrenzing van het tussen deze landen gelegen continentale plat onder de Noordzee van 6 oktober 1965 (in force since 23 december 1966)
- Rijkswet van 27 mei 1999 tot instelling van een exclusieve economische zone van het Koninkrijk (Rijkswet instelling exclusieve economische zone)
- Rijkswet van 28 april 2005 tot instelling van een aansluitende zone van het Koninkrijk (Rijkswet instelling aansluitende zone)
- United Nations Convention on Law of the Sea 1982 (UNCLOS)
- Verdrag tussen het Koninkrijk der Nederlanden en de Bondsrepubliek Duitsland inzake de zijdelingse begrenzing van het continentale plat in de nabijheid van de kust van 1 december 1964 (in force since 18 september 1965)
- Verdrag tussen het Koninkrijk der Nederlanden en de Bondsrepubliek Duitsland inzake de begrenzing van het continentale plat onder de Noordzee van 28 januari 1971 (in force since 7 december 1972)
- Verdrag tussen het Koninkrijk der Nederlanden en het Koninkrijk België inzake de afbakening van het continentale plat van 18 december 1996 (in force since 1 januari 1999)
- Verdrag tussen het Koninkrijk der Nederlanden en het Koninkrijk België inzake de afbakening van de territoriale zee van 18 december 1996 (in force since 1 januari 1999)
- Voorlopige overeenstemming inzake aangelegenheden betreffende de diepzeemijnbouw (3 augustus 1984)
- Wet van 28 oktober 1954, houdende aanvaarding van een statuut voor het Koninkrijk der Nederlanden (Statuut voor het Koninkrijk der Nederlanden)
- Wet van 13 juni 1979, houdende regelen met betrekking tot een aantal algemene onderwerpen op het gebied van milieuhygiëne (Wet milieubeheer)
- Wet van 8 november 1980, tot provinciale indeling van de Waddenzee
- Wet van 9 januari 1985, houdende vaststelling van de grenzen van de territoriale zee van Nederland (Wet grenzen Nederlandse territoriale zee)
- Wet van 12 december 1985, tot gemeentelijke indeling van de Waddenzee
- Wet van 2 november 1990, houdende regeling provincie- en gemeentegrenzen langs de Noordzeekust van de gemeente Den Helder tot en met de gemeente Sluis en wijziging van de Financiële verhoudingswet 1984
- Wet van 31 oktober 2002, houdende regels met betrekking tot het onderzoek naar en het winnen van delfstoffen en met betrekking tot met de mijnbouw verwante activiteiten (Mijnbouwwet)

2 Japan

2.1 Legislation concerning deep-sea mining within areas under national jurisdiction (i.e., in the exclusive economic zone or on the continental shelf)

This section identifies and analyses the existing legislation of Japan regarding deep sea mining within areas under national jurisdiction (i.e., exclusive economic zone (hereinafter “EEZ”) and the continental shelf (hereinafter “CS”). Following the description of the national legislation in the paragraphs below, sub-sections (a) and (b) address the two specific questions mentioned in the terms of reference.

The Mining Act of 1950 is the principal act which regulates mining in Japan. It is implemented through the Ordinance for Enforcement. For the first time in its history, major amendments of the Act occurred in 2011 (entered into force in 2012). In addition to the Mining Act, deep-sea mining activities are subject to various acts relating to maritime safety and marine environmental protection, including those addressing environmental impact assessments, dumping and the setting of safety zones. For certain mineral resources (i.e., oil, natural gas and those mineral resources exploited in connection with oil and gas exploitation) of the CS in areas subject to the joint development regime agreed on by Japan and South Korea, the Mining Act does not apply and, instead, a special act enacted for this particular situation (i.e., Act on Special Measures concerning the Development of Petroleum and Combustible Natural Gas in connection with the Implementation of the Agreement between Japan and the Republic of Korea concerning Joint Development of the Southern Part of the Continental Shelf adjacent to the Two Countries) applies.

The Mining Act regulates mining activities both in terrestrial areas and marine areas under national jurisdiction of Japan. By virtue of the Act on Exclusive Economic Zone and Continental Shelf, the Act was made applicable not only to the territorial sea and internal waters, but also to the EEZ and the CS (for details on this point, see sub-section 3(a)).

Arguably, the Mining Act was primarily drafted to regulate terrestrial mining since seabed mining was not considered feasible at the same of enactment in 1950. An indication of this focus is the maximum size of mining sites in an application for mining rights. The Act sets the maximum size of a site as 350 ha (3.5 km²), unless it is necessary for the reason of reasonable development of minerals (Article 14(3)). In practice, the exemption clause was hardly used until 2007 when an official notification by the Agency for Natural Resources and Energy made it easier for applicants to use this clause. Nevertheless, some of the provisions of the current Ordinance for Enforcement specifically aim to regulate mining in marine areas, as explained below.

The amendments in 2011 are aimed at addressing three kinds of concerns: acquisition of mining rights by inappropriate entities, inappropriate use (or non-use) of mining rights, and lack of control over exploration activities. The main points of the amendments are three-fold: additional criteria for eligible applicants (financial basis, technological capacities and non-prejudice to public interests), review of "first-to-file" system for the granting of mining rights in respect of specified mineral resources, and the requirement of prior permits for exploration. As fully explained in the following paragraphs, the amendments relate particularly to mining in the EEZ and CS.

The Act declares that the state has the power to grant the right to mine and acquire minerals (Article 1). It provides that only Japanese nationals and juridical persons, unless otherwise stipulated in treaties, may mine with a specific permit from the Minister of Economy, Trade and

Industry (Articles 17, 21 and 39). Mining rights consist of right for prospecting and digging of mineral resources (Article 11). Under the amended Act, the state specifies areas for the mining of specified minerals and invites applications (Articles 38-42). Following the examination of eligibility, the best qualified applicant is selected on the basis of the prospects for reasonable development of mining of specified mineral resources and other considerations of public interest. In addition to oil and natural gas, specified minerals are those designated under Cabinet Order, namely, minerals in the sea-bed and its sub-soil which form hydrothermal deposits and those in the sea-bed and its sub-soil which form sedimentary deposits and asphalt. The newly created system of prior permits for exploration requires the acquisition of a permit for exploration employing one of the three methods. As the two methods (i.e., those other than the seismic method) concern exploration for mineral resources in marine areas (internal waters, territorial sea, EEZ and CS), this exploration permit system was drafted with sea-based mining in mind.

The amended Mining Act does not contain provisions specifically concerning environmental protection. Marine environmental protection may be achieved in other legal instruments, such as those specifically concerning marine environmental protection or those relating to the management of the EEZ and CS.

There is no provision in the Mining Act (or related laws and regulations) that provides for the benefit sharing arising out of the exploitation of mineral resources on the continental shelf beyond 200 nautical miles as stipulated in Article 82 of the United Nations Convention on the Law of the Sea (LOSC).

(a) Specific legislation?

As mentioned above, deep-sea mining in the EEZ and on the CS of Japan is regulated by the Mining Act, which applies to any type of mining (i.e., land-based mining, mining in shallower waters and deep-sea mining). However, some of the important points in its recent amendments relate specifically to the regulation of sea-based mining and, indeed, concerns about the effective exercise of sovereign rights in the EEZ and on the CS underlie these amendments.

(b) Which agency?

The Minister of Economy, Trade and Industry has the overall authority to regulate mining, including the authorization of deep-sea mining, under the Mining Act (e.g., Article 21). He or she may delegate part of authority to the Director of Regional Bureau of Economy, Trade and Industry, pursuant to the provisions of the Ordinance of the Ministry of Economy, Trade and Industry (METI) (Mining Act, Article 145). In accordance with this article, numerous provisions of the Act are listed in paragraph 1 and paragraph 2 of Article 61 of the Ordinance for Enforcement. However, with regard to provisions specified in paragraph 1 of Article 61, Minister's authority relating to specified areas in internal waters, the territorial sea, EEZ and the CS are excluded from the scope of delegation of authority (Ordinance for Enforcement, Article 61(1)). Therefore, a number of matters relating to deep-sea mining are still to be handled at the national level, rather than the regional level.

2.2 Legislation concerning deep-sea mining in the Area

The Act on Interim Measures for Deep Seabed Mining provides for the regulation of mining activities by Japanese persons in the Area. The Act was enacted in 1982 and lastly amended in 2011 (entered into force in 2012). The Act, however, has never been substantively amended. The Act, as the title suggests, was intended to be interim until entry into force of the LOSC for Japan. It was drafted in an expeditious manner so as not to fail the protection of prior investment as a

pioneer investor; indeed, there was no parliamentary debate in the legislative process. The Act is implemented by Ordinance for Enforcement, which were enacted also in 1982 and lastly amended in 2013.

Japan was among the so-called Reciprocating States. Its Act was enacted in this context and based on the assumption that deep seabed mining may be conducted freely by individual states and there is no reference to the LOSC or to the ISA. Although no substantial amendment has been made to accommodate the new circumstance created by the entry into force of the LOSC and Part XI Implementation Agreement for Japan in 1996, some impacts arising out of the recent activities of the ISA are found in the provisions of the Ordinance for Enforcement.

The Act aims to coordinate deep seabed mining activities (Article 1(1)). It does not purport to subject the deep seabed under Japan's sovereignty or jurisdiction and nothing prejudices the interests of other states in exercising freedoms of the high seas (Article 1(2)). In the Act, deep seabed mining means exploration and exploitation of mineral resources and associated activities in areas where deep seabed mineral resources occur or are likely to occur (Article 2(2)). Exploration does not include prospecting (Article 2(3)).

A person who intends to engage in deep seabed mining shall indicate areas for exploration and exploitation and receive permission by the Minister of Economy, Trade and Industry (Article 4). Criteria for permission include: absence of overlapping claims recognized by the Minister or by Deep Seabed Mining States (which means other states which regulate deep seabed mining in a manner not substantially different from Japanese legislation as designated under Article 29), size and duration of exploration and exploitation claims and the date of commencement of exploitation, financial and technical capacities and other criteria relating to reasonable and efficient exploitation (Article 12(1)). Reporting and inspection is provided in Article 35.

Environmental and other damage incurred in Japan in connection with deep seabed mining shall be compensated by the person engaged in deep seabed mining under the Act (Article 27).

In respect of ensuring safety in deep seabed mining, the provisions of the Mining Safety Act are applied *mutatis mutandis* (Article 39). To this end, the Central Mining Safety Council is given certain competence (Article 39 bis).

The Act does not apply to Japanese nationals or juridical persons in partnership with foreign nationals or juridical persons permitted to develop mineral resources by Deep Seabed Mining States when they conduct deep seabed mining under the latter's permission (Article 40).

The Ordinance for Enforcement provides for, *inter alia*, areas designated as being subject to the Act (Article 4), methods of exploration (Article 5), details of permit application, criteria for permit (Article 11) and the definition of "partnership" in Article 40 of the Act. Article 4 specifies three areas by virtue of coordinates (i.e., (i) the Clarion-Clipperton Fracture Zone, (ii) South East Pacific and (iii) south east of the Minamitorishima Island) exclusive of areas under national jurisdiction. Area (i) includes an area where the Deep Ocean Resource Development Co. Ltd. ("DORD"; a company sponsored by Japan) holds an exploratory contract with the International Seabed Authority (hereinafter, "ISA") for manganese nodules. Area (iii) corresponds to areas subject to the Japan Oil, Gas and Metals National Corporation (JOGMEC) contract for cobalt-rich crusts. Article 11 provides a table that specifies the size of exploration and exploitation areas, duration of exploration and exploitation and the date of commencement of exploitation referred to in Article 12(1)(2) of the Act. The table is divided into two parts: one for manganese nodules and the other one for cobalt-rich crusts. For the size and duration, the Ordinance generally follows the ISA Mining Code. For the

commencement date, they specify 1 January 1988 or later for manganese nodules and 1 January 2014 or later for cobalt-rich crusts, as notified by the Minister. Note that the certificate of registration as a pioneer investor was issued on 16 May 1988 following the decision of the General Committee of the PrepCom on 17 December 1987 to register DORD as a pioneer investor and the contract between the ISA and JOGMEC for the exploration of cobalt-rich crusts was concluded on 27 January 2014 following the approval of the plan of work by the ISA Council on 19 July 2013.

The Act only applies to deep seabed mining in areas specified by the Ordinance of the Ministry. Theoretically, exploration and exploitation for mineral resources in the Area outside these areas may escape regulation by Japan. Nevertheless, the fact that a new area (primarily aimed for the exploration of cobalt-rich crusts) was quickly inserted to the specified areas after the approval of a plan of work by the ISA and subjected to its regulation demonstrates that it can adequately address new circumstances such as new exploration/exploitation applications by Japanese sponsored entities.

There is no provision concerning levy or any other payment to the ISA in the Act or its Ordinance for Enforcement. Although the Basic Plan on Ocean Policy, under the Basic Act on Ocean Policy, as revised in 2013 refers to ISA exploration regulations to be taken into account, there is no indication to amend the Act or Ordinance for Enforcement with a view to harmonizing them with the LOSC and Part XI Implementation Agreement in respect of levy or other payment to the ISA. Lack of legislative action relating to deep seabed mining following the ratification of the LOSC was briefly discussed in the Diet in 2006, though.

Although the Act lacks reference to the LOSC or the ISA, exploration and exploitation conducted or sponsored by Japan is expected to follow the approval of the plan of work and to subsequently involve the conclusion of contracts with the ISA. Therefore, in practice, discrepancy from the mining regime developed by the ISA will be limited. Nevertheless, provisions relating to violations have not been amended since 1982 and seem insufficient to deter non-compliance.

2.3 Legislation concerning maritime zones

2.3.1 Existing legislation concerning maritime zones

In conjunction with the ratification of the LOSC, Japan enacted the Act on Exclusive Economic Zone and Continental Shelf. It consists of four articles.

The Act declares EEZ of Japan (Article 1(1)). The outer limit of the EEZ of Japan is defined as 200 nautical miles from the baselines from which the territorial sea is measured or, if the median line between Japan and a neighbouring state is located in a distance less than 200 nautical miles, the median line unless otherwise agreed with the state concerned (Article 1(2)). The Act also defines the continental shelf as seabed and subsoil of: (1) a marine area up to 200 nautical miles from the baselines or, if the median line between Japan and a neighbouring state is located in a distance less than 200 nautical miles, up to the median line between them unless otherwise agreed with the state concerned; and (2) a marine area contiguous to the above-mentioned area, stipulated by a Cabinet Order in accordance with the LOSC (Article 2). Article 3 of the Act provides that Japanese laws and regulations apply to activities taking place or relating to the EEZ or the CS as specified in that Article. They cover many (but not all) of the activities over which the coastal state has sovereign rights, jurisdiction and other rights in the EEZ or the CS under the LOSC, including exploration and exploitation and conservation and management of natural resources, establishment, construction, operation and use of artificial islands, installations and structures, drilling on the continental shelf, law enforcement by Japanese civil servants in the EEZ or on the

CS concerning above activities (Article 3(1)). Japanese laws and regulations apply to artificial islands, installations and structures in the EEZ or on the CS as if they were in the Japanese territory (Article 3(1)). Article 4 provides for the application of other provisions if such provisions are found in the LOSC.

The territorial sea of Japan is defined in the Act on the Territorial Sea and Internal Waters, originally enacted in 1977 and amended in 1996 to address the entry into force of the LOSC for Japan. The breadth of the territorial sea is 12 nautical miles from the baselines unless the median line between Japan and a neighbouring state is located in a distance less than 12 nautical miles. In the latter case, the median line delimits the outer limit of the territorial sea unless otherwise agreed with the state concerned.

2.3.2 *Extended continental shelf claim*

The government of Japan submitted information concerning the continental shelf beyond 200 nautical miles to the Commission on the Limits of the Continental Shelf (CLCS) on 12 November 2008. On 19 April 2012, recommendations for Japan's submission were adopted. The total areas recognized as Japan's extended continental shelf by the CLCS amount to 310,000 km².

Japanese submission concerned seven areas. For two areas (OGP and SKB), Japanese claims were substantially recognized by the CLCS. For two areas (MIT and ODR), Japanese claims were recognized to some extent. For two areas (MTS and MGS), Japanese claims were not recognized at all. For the KPR, CLCS stated as follows: "the Commission considers that it will not be in a position to take action to make recommendations on the Southern Kyushu-Palau Ridge Region (KPR) until such time as the matters referred to in the notes verbales have been resolved". In these notes verbales, the People's Republic of China and the Republic of Korea have taken the view that Okinotorishima is a rock and thus it is not entitled to the continental shelf under Article 121(3) of the LOSC.

Under the Act on Exclusive Economic Zone and Continental Shelf, the government needs to delineate the outer limit of the continental shelf for the part extending beyond 200 nautical miles by way of a Cabinet Order. It has not yet issued such an Order to delineate the outer limit of the continental shelf. For its submission for the KPR, the government of Japan repeatedly expressed its intention to make efforts for the CLCS recommendations to be issued.

2.4 Environmental legislation

2.4.1 *Legislation concerning environmental impact assessment*

The principal act regulating environmental impact assessment in Japan is Environmental Impact Assessment Act but it applies only to 13 specified activities and harbour works. Mining is not included in these categories.

Other acts, however, provide for environmental impact assessment in relation to deep-sea mining to some extent, including the Act on Prevention of Marine Pollution and Maritime Disaster (in particular, provisions relating to dumping), the Mining Act and the Mine Safety Act. [TO BE DEVELOPED]

2.4.2 *Other environmental legislation, including marine protected areas*

Various acts of Japan concern marine protected areas, as interpreted by the government. However, it is not clear whether they apply to deep-sea mining. [TO BE DEVELOPED]

2.4.3 *Draft legislation or policy proposals*

Japan is in the process of drafting a new act on the management of the EEZ and the CS because the Act on exclusive Economic Zone and Continental Shelf only defines the EEZ and the CS and specifies matters subject to Japanese laws and regulations. The Councillors' meeting of the Headquarters on Ocean Policy (constituted by all Cabinet Ministers and led by the Prime Minister as its head and the Cabinet Secretary and the Minister for Ocean Policy as deputy head) through its project team has been engaged in developing the draft. The project team meetings have discussed, among other issues, marine zoning to harmonize development and environmental protection, coordination between existing and new uses of marine areas, review of environmental impact assessment system for EEZ and CS since the current system is developed mainly for land areas and the prevention of acts that jeopardize the exercise of sovereign rights. The project team is scheduled to complete its final report by the end of March 2014.

In the draft for the revised Plan for the Development of Marine Energy and Mineral Resources submitted in December 2013, METI notes the need to review the current legal scheme in order to address environmental impacts caused by the reintroduction of sea water involved in lifting minerals. It also refers to a comprehensive review of the legal scheme concerning marine mineral resource development with a view to realizing commercial development. Regarding the development of rare earth mud, the need to examine legal issues is also mentioned in the draft.

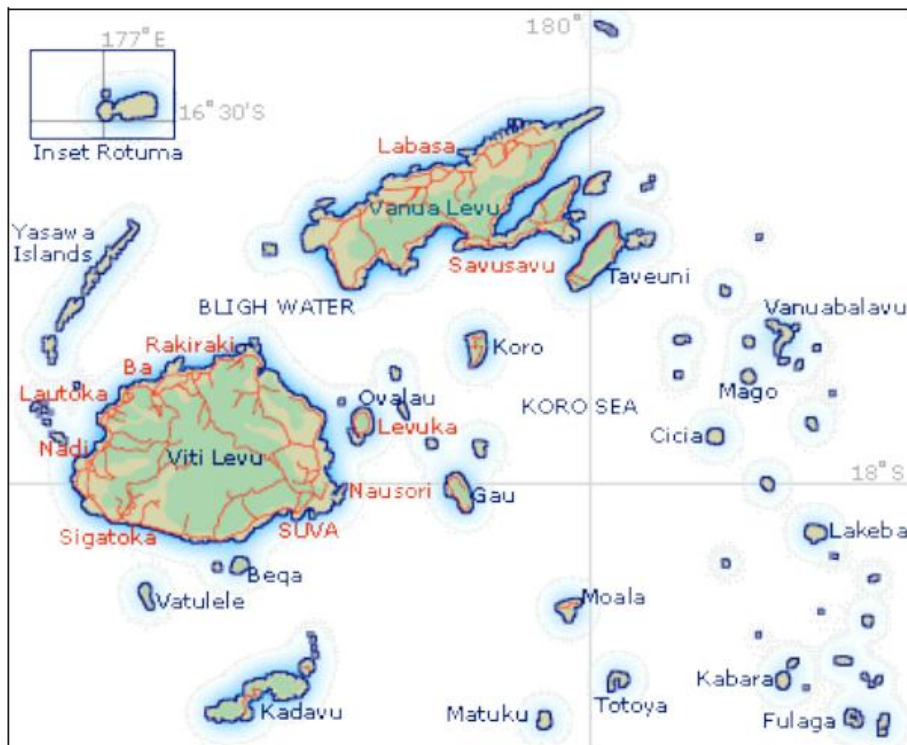
Legislation

- A. Mining Act, Act No. 289 of 20 December 1950, lastly amended 22 July 2011, English translation available at <http://isa.org.jm/files/documents/EN/NatLeg/JapMiningAct.pdf>
- B. Ordinance for Enforcement of the Mining Act, Ordinance of the Ministry of International Trade and Industry No. 2 of 27 January 1951, lastly amended 12 January 2012, Japanese text available at <http://law.e-gov.go.jp/htmldata/S26/S26F03801000002.html>
- C. Order for the Designation of Specified Minerals under Article 6 bis of the Mining Act, Cabinet Order No. 413 of 26 February 2011, Japanese text available at http://law.e-gov.go.jp/cgi-bin/idxselect.cgi?IDX_OPT=1&H_NAME=%8Dz%8B%C6&H_NAME_YOMI=%82%A0&H_NO_GENGO=H&H_NO_YEAR=&H_NO_TYPE=2&H_NO_NO=&H_FILE_NAME=H23SE413&H_RYAKU=1&H_CTG=1&H_YOMI_GUN=1&H_CTG_GUN=1
- D. Mine Safety Act, Act No. 70 of 16 May 1949, lastly amended 27 June 2012, Japanese text available at <http://law.e-gov.go.jp/htmldata/S24/S24HO070.html>
- E. Ordinance for Enforcement of the Mine Safety Act, Ordinance of the Ministry of International Trade and Industry No. 96 of 27 September 2004, lastly amended 21 May 2013, Japanese text available at <http://law.e-gov.go.jp/htmldata/H16/H16F15001000096.html>
- F. Act on Special Measures concerning the Development of Petroleum and Combustible Natural Gas in connection with the Implementation of the Agreement between Japan and the Republic of Korea concerning Joint Development of the Southern Part of the Continental Shelf adjacent to the Two Countries, Act No. 81 of 21 June 1978, lastly amended 22 July 2013, Japanese text available at <http://law.e-gov.go.jp/htmldata/S53/S53HO081.html>
- G. Act on Interim Measures for Deep Seabed Mining, Act No. 64 of 1982, Act No. 64 of 16 July 1982, lastly amended 22 July 2011, English translation available at <http://isa.org.jm/files/documents/EN/NatLeg/Japan.pdf>
- H. Ordinance for Enforcement of the Act on Interim Measures for Deep Seabed Mining, Ordinance of the Ministry of International Trade and Industry No. 34 of 20 July 1982, lastly amended 20 December 2013, Japanese text available at <http://law.e-gov.go.jp/htmldata/S57/S57F03801000034.html>
- I. Act on Exclusive Economic Zone and Continental Shelf, Act No. 74 of 14 June 1996, Japanese text available at <http://law.e-gov.go.jp/htmldata/H08/H08HO074.html>
- J. Act on Territorial Waters and Contiguous Water Area, Act No. 30 of 2 May 1977, lastly amended 14 June 1996, Japanese text available at <http://law.e-gov.go.jp/htmldata/S52/S52HO030.html>
- K. Basic Act on Ocean Policy, Act No. 33 of 27 April 2007, English translation available at <http://www.japaneselawtranslation.go.jp/law/detail/?re=01&dn=1&x=0&y=0&co=1&ia=03&yo=&gn=&sy=&ht=&no=&bu=&ta=&ky=%E5%A4%A7%E9%99%B8%E6%A3%9A&page=1>
- L. Act on Prevention of Marine Pollution and Maritime Disaster, Act No. 136 of 25 December 1970, lastly amended 12 June 2013, Japanese text available at <http://law.e-gov.go.jp/htmldata/S45/S45HO136.html>
- M. Order for Enforcement of the Act on Prevention of Marine Pollution and Maritime Disaster, Cabinet Order No. 201 of 22 June 1971, lastly amended 27 December 2013 (not yet in force), Japanese text available at <http://law.e-gov.go.jp/htmldata/S46/S46SE201.html>
- N. Ordinance for Enforcement of the Act on Prevention of Marine Pollution and Maritime Disaster, Ordinance of the Ministry of Transport No. 38 of 23 June 1971, lastly amended 6 December 2013, Japanese text available at <http://law.e-gov.go.jp/htmldata/S46/S46F03901000038.html>

3 Fiji

Fiji is an independent sovereign Republic located at 18°00'S Latitude and 175°00'E Longitude (Figure 1). Fiji was ceded to Britain on 10 October 1874 and was administered as a colony of Great British until its gained independence on 10 October 1970. From 1970 until 1987 Fiji was an independent state with the Queen as Head of State, a Governor General as her representative, an elected House of Representatives and an appointed Senate. Since the abrogation of the 1970 Constitution in 1987, Fiji has been a Republic with the President of Fiji as its Head of State.

Figure 1 Map of Fiji Islands



Source: Fiji Government website.

During the period of formal dependency, the British administration was responsible for all aspects of government. Applicable laws of the Imperial government were extended to Fiji. The Fiji legal system has been influenced by the colonial administration. Laws are generally sourced from the constitution, statutes and legislation, the common law including pre-1975 English common law, and Fijian customary law.³¹⁵ Fijian customary law is particularly important in determining access, benefit sharing arrangements, and control and enforcement activities in near shore areas.

As a British colony, British laws relating to territorial waters applied coastal sovereignty over a belt of sea measured three nautical miles from the shore. This position was agreed by countries of the British Empire at the 1923 Imperial Conference.³¹⁶ New maritime spaces were claimed post independence in the late 1970s.³¹⁷

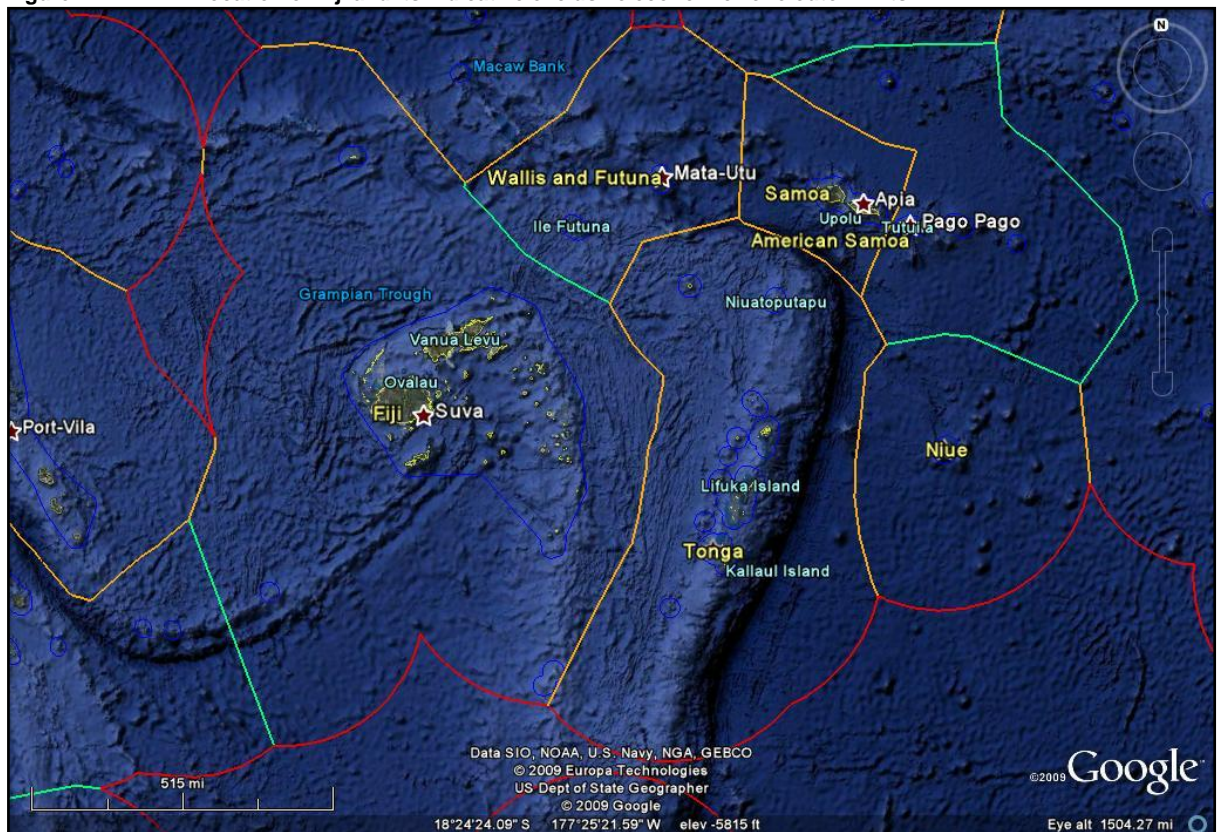
³¹⁵ For further information, see Paterson, D. & Zorn, S. A. 1993. Fiji. In: Ntunmy, M. A. (Ed). 1993. South Pacific Islands Legal Systems. University of Hawaii Press, Honolulu: 26 – 74. Also see Corrin-Care, J., Newton, T. & Paterson, D. 1999. Introduction to South Pacific Law. Cavendish Publishing Ltd, London: 284-289. Note that since independence in 1970 Fiji has had four constitutions.

³¹⁶ Churchill, A. V. & Lowe, R, 1999. *The Law of the Sea*. Third edn. Manchester Uni. Press.

³¹⁷ Section 7, *Territorial Waters Jurisdiction Act 1878* (Britain). See also Lord Stowell in *The Anna* (1805) 5 Ch Rob 573, 165 ER 809.

After dependency, Fiji enacted legislation declaring its baselines and claiming maritime spaces.³¹⁸ Fiji has declared archipelagic baselines over its main islands and normal baselines for Ceva-i-Ra Island.³¹⁹ The claim for maritime spaces, in particular, archipelagic waters, territorial sea and the exclusive economic zone, was made once there was broad agreement on maritime baselines and spaces during the Third United Nations Conference on the Law of the Sea and years before the adoption of the text of the 1982 United Nations Convention on the Law of the Sea (LOSC).³²⁰ Given the negotiation of the text by consensus, the breadth of the maritime spaces claimed and the respective rights and responsibilities are consistent with that permitted under the LOSC. Figure 2 shows the indicative outer limits of Fiji's exclusive economic zone and also identifies the archipelagic baselines (blue line) drawn around the main group of islands.

Figure 2 Location of Fiji and its indicative exclusive economic zone outer limits



3.1 Legislation concerning deep sea mining within areas under national jurisdiction.

Mining in Fiji is governed by the *Mining Act Cap. 146* enacted in 1965 during the period of British dependency.³²¹ The *Mining Act* repealed the earlier mining ordinance and provides better provisions for prospecting and the mining of precious metals and other minerals. Given the interests at the time of enactment, the legislation is focused on the prospecting and mining of terrestrial minerals and aggregates.

³¹⁸ *Continental Shelf Act* Cap. 149 No. 9 of 1970, *Marine Spaces Act* Cap. 158A No. 18 of 1977.

³¹⁹ *Marine Spaces Act, Marine Spaces (Declaration) Order* April 1978, *Marine Spaces (Amendment) Act* No. 15 of 1978, *Marine Spaces (Archipelagic Baselines and Exclusive Economic Zone) Order* 1981 Legal Notice 117. These Orders are published in the *Law of the Sea Bulletin* No. 66 of 2008 at pp. 66 – 70. Note also that these Orders have been amended in 2012 and the amendment is discussed below.

³²⁰ 21 *ILM* 1245 (1982).

³²¹ *Ordinance No. 25 of 1965* and amendments have been made by *Ordinances No. 7 of 1966, 37 of 1966, Order 7th October, 1970, Act No. 14 of 1975, 13 of 1977, and the Mining (Amendment) Decree 2010.*

Minerals are defined broadly to include the following minerals:

- (a) "precious metals" which shall include gold, silver, platinum, palladium, iridium, osmium, or ores containing them, and all other substances of a similar nature;
- (b) "precious stones" which shall include amber, amethyst, beryl, cat's-eye, chrysolite, diamond, emerald, garnet, opal, ruby, sapphire, turquoise, and all other stones of a similar nature;
- (c) "earthy minerals" which shall include asbestos, ball-clay, barytes, bauxite, bentonite, china-clay, fuller's earth, graphite, gypsum, marble, mica, nitrates, phosphates, pipeclay, potash, salt, slate, soda, sulphur, talc and all other substances of a similar nature;
- (d) "radioactive minerals" which shall include minerals either raw or treated (including residues and tailings) which contain by weight at least 0.05 per cent of uranium or thorium or any combination thereof, including but not limited to:
 - (i) monazite sand and other ores containing thorium; and
 - (ii) carnotite, pitch blende and other ores containing uranium;
- (e) "coal" which shall include coal in all its varieties and all other substances of a similar nature;
- (f) "metalliferous minerals" which shall include aluminium, antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, tin, tungsten, vanadium, zinc, and all ores containing them, and all other minerals and mineral substances of whatsoever description but excluding only the minerals and mineral substances included in paragraphs (a), (b), (c), (d) and (e),
but shall not include clay, gravel, sand, stone or other common mineral substances, and for the purpose of avoiding doubt the Minister may from time to time by notice in the Gazette declare any mineral substance to be included in or excluded from this definition;

Requirements for prospecting are distinguished from mining in Part II of the Act. To "prospect" means to search for minerals and includes such working as may be prescribed to enable the prospector to test and assess the mineral bearing qualities of any land. Land is defined broadly to include water and land covered by water.³²² In contrast, a "mining tenement" means any lease, licence, right, permit, title, easement or privilege, other than a prospector's right, relating to prospecting and mining, lawfully granted or acquired under the provisions of the Act and includes the specific parcel of land the subject of such lease, licence, right, permit, title, easement or privilege. The Director of Mineral Resources, subject to the provisions of the Act and any general or special directions of the Minister, may grant, *inter alia*, prospector's rights, prospecting licences, special prospecting licences, permits to mine, mining leases, special mining leases, and special site rights.³²³

In relation to prospecting on the seabed within maritime areas under national jurisdiction, the grant of special prospecting licences is pertinent. Section 30(1) of the Act empowers the Director, subject to the approval of the Minister, to exercise some discretion in granting special prospecting licences upon such terms and conditions, whether in accordance with the provisions of this Act or not, as the Minister thinks fit. The provisions of the Act applicable to a prospecting licence also apply to all special prospecting licences.³²⁴ The only caveat attached to section 30(1) relates to the size of the area in which a special prospecting licence is granted but this may not be particularly relevant to the exploration and exploitation of the seabed given the 2010 amendment discussed below.³²⁵

Given that the Act extends the conditions and rights attached to prospecting licences to special prospecting licences, the rights of the holder of a prospecting (or special prospecting) licence is

³²² Section 2, *Mining Act*.

³²³ Section 18(1), *Mining Act*.

³²⁴ See section 26 Grant of Prospecting Licence and section 27 Rights under Prospecting Licence, *Mining Act*.

³²⁵ The caveat is that unless there are unusual circumstances which warrant it, a special prospecting licence shall not be granted in respect of any area which is less than 1,300 ha in extent.

contained in section 27. In summary, the holder of a prospecting (or special prospecting) licence shall have the exclusive right to prospect for the mineral or minerals specified in his licence on the land the subject of his licence, and for such purposes may -

- (a) enter upon such land with his servants and agents and thereon exercise all or any of the rights conferred upon the holder of a prospector's right by the provisions of this Act;
- (b) on and over any unimproved land the subject of his licence, erect and maintain such machinery and plant and construct such passageways, as may be necessary.

Where all conditions of a prospecting (or special prospecting) licence have been fulfilled the holder may, upon payment of the prescribed fees - (a) apply for extension of such licence at any time before such licence expires or within seven days thereafter; (b) mark out any reduced area or areas within the land the subject of such licence if applying for an extension of such licence in respect of such reduced area or areas only; (c) mark out and apply for the grant of any other mining tenement or tenements over the whole or any part of the land the subject of his licence.³²⁶

The amendment to the *Mining Act* in 2010 provides specific legislative provisions for the regulation of mining in the seabed and subsoil within Fiji's marine zones, in particular, the internal waters, archipelagic waters, territorial sea and exclusive economic zone (see Annex C for full text). The amendment enables the granting of special prospecting licences over the seabed and the graticulation of the earth's surface or the delineation of a grid system to delineate blocks on the seabed. The amendment first broadens the definition of "land" to include water and land covered by water, and,

- (a) any interest in land;
- (b) inland waters including the bed of any river, stream, estuary, lake or swamp;
- (c) the foreshore, being that area between the mean high water spring level of the sea and the mean low water spring level of the sea;
- (d) the seabed and deep seabed and subsoil of the area between the mean low water spring level of the sea and the outer boundary or boundaries of the exclusive economic zone within the meaning of the Marine Spaces Act.

This extended definition of "land" only applies to special prospecting licences.³²⁷

Secondly the 2010 amendment divides the surface of the earth into particular sections bounded by a) portions of two meridians of longitude that are separated by six minutes of longitude from each other and each separated by six minutes, or any multiple of six minutes, of longitude from the meridian of Greenwich; and b) portions of two parallels of latitude that are separated by six minutes of latitude from each other and are each separated by six minutes, or any multiple of six minutes, of latitude from the equator.

After reviewing the *Mining Act* and its amendments, it is evident that the rudimentary framework for the regulation of prospecting and mining may not be adequate to address seabed exploration and exploitation activities. Contemporary provisions including in regulations are required to supplement this framework. In the absence of such supplementary provisions, related laws such as the *Environment Management Act 2005* apply *albeit* generally.

The primary institution responsible for mineral resources in Fiji is the Department of Mineral Resources of the Ministry of Lands and Mineral Resources. Key decision makers in the

³²⁶ Section 27(2), *Mining Act*.

³²⁷ Section 17A(2), *Mining Act*.

consideration of prospecting and mining applications and the granting of rights or licences are the Director of Mineral Resources and the Minister of Mineral Resources.

There are several government institutions that have a secondary role in the consideration of seabed exploration and exploitation activities including:

- Ministry for Foreign Affairs;
- Ministry for Public Enterprise;
- Ministry responsible for the Environment;
- Ministry responsible for Fisheries;
- Ministry of iTaukei Affairs;
- Maritime Safety Authority of Fiji;
- Fiji Islands Revenue and Customs Authority;
- Biosecurity Authority of Fiji; and
- Investment Fiji.

3.2 Legislation on deep sea mining in the Area;

In 2013, the President of Fiji enacted the *International Seabed Mineral Management Decree* (see Annex D).³²⁸ The ISMM Decree governs Fiji's engagement in seabed mineral activities in the Area and also establishes the institutional framework in support of such engagement. The objectives of the ISMM Decree are to—

- a) enable Fiji to act as a Sponsoring State for the purposes of engaging in Seabed Mineral Activities;
- b) empower Fiji to engage in Seabed Mineral Activities through either a body corporate established under this Decree or by way of sponsorship of a Sponsored Party;
- c) establish a clear and stable legal operating environment for Sponsored Parties or parties engaged by the Authority to undertake Seabed Mineral Activities in the Area;
- d) ensure that Seabed Mineral Activities are carried out under Fiji's effective control and in a manner that is consistent with the Rules of the ISA and Fiji's responsibilities under the UN Convention on the Law of the Sea and other applicable requirements of international law; and
- e) implement measures to maximise the benefits of Seabed Mineral Activities for present and future generations.³²⁹

There are four key institutions identified: the Fiji International Seabed Authority (FISA), the Fiji International Seabed Minerals Working Group (FISMWG), the Fiji Seabed Mineral Resources Corporation (FSMRC) and the High Court of Fiji. While the FISA, FISMWG and FSMRC are new creations, the existing High Court of Fiji's jurisdiction is widened to include the judicial review of administrative decisions, determinations and actions under the ISMM Decree, and the conduct of proceedings to establish liability and to provide recourse for prompt and adequate compensation in the event of unlawful damage caused by Seabed Mineral Activities.³³⁰

Of the new institutions created under the ISMM Decree, the most prominent is the FISA.³³¹ The objectives of the FISA are four-fold: (a) provide a stable, transparent and accountable process for the sponsorship and supervision of Seabed Mineral Activities; (b) ensure the protection and preservation of the marine environment; (c) ensure compliance by Sponsored Parties or other parties engaged in Seabed Mineral Activities with relevant rules and internationally agreed standards; and (d) ensure that the conduct of Seabed Mineral Activities maximises benefits to

³²⁸ Decree No. 21 of 2013, hereafter "ISMM Decree".

³²⁹ Section 3(1), *ISMM Decree 2013*.

³³⁰ Section 20, *ISMM Decree 2013*.

³³¹ The establishment, composition, objectives, functions, and powers of the FISA is contained in sections 6, 7, 8, 9, and 10 respectively.

Fiji.³³² The functions of the FISA are robust and are intended to address Fiji's rights and responsibilities under the 1982 United Nations Convention on the Law of the Sea.

Section 9 of the ISMM Decree states:

(1) The functions of the Authority shall be to—

(a) facilitate—

(i) the application of a body corporate or Sponsored Party to the ISA for a contract to conduct exploration or exploitation activities; and

(ii) Fiji's and its Sponsored Parties' understanding of and compliance with relevant international laws, standards and rules;

(b) monitor, implement and secure compliance of Sponsored Parties and other parties engaged in Seabed Mineral Activities with the Rules of the ISA;

(c) undertake any advisory, supervisory or enforcement activities in relation to Seabed Mineral Activities or the protection of the marine environment, in the event this is required in addition to the ISA's work in order for Fiji to meet its obligations under the UN Convention of the Law of the Sea, whether as a State enterprise or as a Sponsoring State;

(d) require and review relevant reports and information provided by Sponsored Parties or other parties engaged in Seabed Mineral Activities;

(e) maintain appropriate records, pertaining to Seabed Mineral Activities conducted by those Parties specified in (d);

(f) ensure that contractual arrangements are fair for parties undertaking or proposing to undertake Seabed Mineral Activities in the Area for which a contract has been granted;

(g) ensure that Seabed Mineral Activities are carried out in a manner that is consistent with the Rules of the ISA and Fiji's responsibilities under the UN Convention on the Law of the Sea, and any other applicable requirement of international law;

(h) facilitate any applications to the ISA relating to Seabed Mineral Activities;

(i) set terms and conditions of any licences granted by the Authority to other parties engaged in Seabed Mineral Activities; and

(j) negotiate fees, royalties and taxes in respect of Seabed Mineral Activities on a case by case basis with Sponsored Parties and other parties engaged in Seabed Mineral Activities.

(2) The Authority shall be responsible for the administration of Fiji's sponsorship responsibilities in accordance with the UN Convention on the Law of the Sea.

.....

In light of its objectives and functions, the FISA's powers include the processing of applications for exploration and exploitation in the Area, the prevention, reduction and control of pollution and other hazards, and the formulation of rules, regulations and procedures for (i) the conduct of exploration and exploitation in the Area, and (ii) the protection and preservation of the natural resources of the Area and the prevention of damage to the flora and fauna of the marine environment.³³³

The Fiji International Seabed Minerals Working Group is established to provide technical and policy advice and recommendations to the FISA in the performance of its functions.³³⁴ The working group is required to work in consultation with the FISA on all matters regarding Seabed Mineral Activities. "Seabed Mineral Activities" is defined as "operations for the exploration or exploitation of Seabed Minerals within the Area under contract with the ISA and under sponsorship by a State Party". "Seabed Mineral" or "Seabed Minerals" on the other hand means "the hard mineral resources of any part of the Area, including those in crust, nodule or hydrothermal deposit form, which contain (in quantities greater than trace) metalliferous or non-metalliferous elements".³³⁵

³³² Section 8(1), *ISMM Decree 2013*.

³³³ Section 10, *ISMM Decree 2013*.

³³⁴ Section 19, *ISMM Decree 2013*.

³³⁵ Section 2, *ISMM Decree 2013*.

In addition to the FISA and the FISMWG, the Fiji Seabed Mineral Resources Corporation is a limited liability company incorporated for the purposes of engaging in partnership or joint venture arrangements to conduct Seabed Mineral Activities. Since the FSMRC is a government corporation within the scope of the Public Enterprises Act 1996, the Minister for Public Enterprises may give such directions necessary for its performance, operation and administration.

Institutional matters aside, Part 3 of the ISMM Decree 2013 provides for applications for sponsorship and applications to the International Seabed Authority. To be eligible to perform Seabed Mineral Activities a Sponsorship Application must first obtain a valid Sponsorship Certificate from the Fiji International Seabed Authority, and obtain a valid contract from the International Seabed Authority.³³⁶ The requirements and processes for application for sponsorship to the Authority and the issuance of sponsorship certificates and sponsorship agreements are set out in sections 23 - 31.

Part 4 of the ISMM Decree 2013 is devoted to the duties pertaining to Seabed Mineral Activities and Indemnification.³³⁷ A person engaged in Seabed Mineral Activities is required to comply with the obligations set out in this Part. For the purposes of indemnification, a Sponsored Party or a party engaged in a partnership or joint venture with a body corporate wholly owned by Fiji shall be –

- (a) Responsible for the performance of all Seabed Mineral Activities out within the Contract Area and their compliance with the rules of the International Seabed Authority; and
- (b) Liable for the actual amount of any compensation, damage or penalties arising out of non-compliance or from any wrongful acts or omissions in the conduct of the Seabed Mineral Activities.³³⁸

Section 33 indemnifies Fiji against all actions, proceedings, costs, charges, claims and demands which may be made or brought in relation to the performance of Seabed Mineral Activities or for the performance of any function or exercise of any power under the ISMM Decree 2013.

Provisions on the role of the Sponsoring State constitute Part 5 of the ISMM Decree 2013. The obligations of Fiji through the FISA to adhere to the requirements and standards in the rules of the International Seabed Authority and general principles of international law are laid out in section 34. The FISA has the power to monitor and make such examinations, inspections and enquiries of Sponsored Parties and the conduct of Seabed Mineral Activities as are necessary to meet its responsibilities under international law. Where the FISA is of the opinion that a Sponsored Party is at serious risk of materially breaching the rules of the International Seabed Authority, or the ISMM Decree 2013, the FISA may take administrative action.³³⁹

Part 6 provides among other things for the maintenance by the FISA of records, termination of sponsorship certificates, the surrender of such certificates, revocation and renewal of sponsorship.³⁴⁰ Financial requirements are provided in Part 7 and Part 8 provides for miscellaneous matters including the commission of inquiries into incidents, and the settlement of disputes.

³³⁶ Section 22, ISMM Decree 2013.

³³⁷ Sections 32 and 33, ISMM Decree 2013.

³³⁸ Section 33(1), ISMM Decree 2013.

³³⁹ Section 36, ISMM Decree 2013.

³⁴⁰ Sections 37 – 44, ISMM Decree 2013.

3.3 Legislation concerning maritime zones

3.3.1 *Maritime Zones Legislation*

The *Marine Spaces Act Cap. 158A* is the principal legislation governing Fiji's marine spaces. It came into force in 1978. Part II of the *Marine Spaces Act* contains Fiji's marine zones claims and the powers of the Minister responsible for Foreign Affairs in the making of regulations.

Fiji has drawn archipelagic baselines around the main group of islands and the Rotuma archipelago to the North West of the main group of islands. Normal baselines are drawn around Ceva-i-Ra Island to the South West of the main group. The Act claims internal waters, archipelagic waters, territorial sea, and the exclusive economic zone. This legislation has been deposited with the United Nations.³⁴¹

In 2012 Fiji revised its reference system from the World Geodetic System 1972 datum to the International Terrestrial Reference System 2005 Geodetic datum, and also declared revised coordinates for the Rotuma and its dependencies archipelago, the Fiji archipelago, and Ceva-i-Ra Island.³⁴² These declarations are yet to be deposited with the United Nations.

In addition to the *Marine Spaces Act*, the *Continental Shelf Act Cap. 149* provides for Fiji's continental shelf. The "continental shelf" is defined as: "the seabed and subsoil of those submarine areas adjacent to the coasts of the islands of Fiji, but beyond the territorial limits of Fiji, to a depth of two hundred metres below the surface of the sea, or, beyond that limit, to where the depth of the superjacent waters admits of exploitation of the natural resources of those areas".³⁴³ Natural resources includes the mineral and other natural non-living resources of the seabed and subsoil.

3.3.2 *Extended Continental Shelf submission*

On 20 April 2009 Fiji made a partial submission to the Commission on the Limits of the Continental Shelf in accordance with Article 76, paragraph 8, of the 1982 United Nations Convention on the Law of the Sea. On 30 April 2012, Fiji submitted a revision to its partial submission. The partial submission relates to the delineation of the outer limits of the continental shelf in the region of the Lau-Colville and Tonga-Kermadec Complex (see Figure 3).

Furthermore, preliminary joint extended continental shelf submissions have been made by Fiji and the Solomon Islands, and Fiji, Solomon Islands and Vanuatu (Figure 4).³⁴⁴

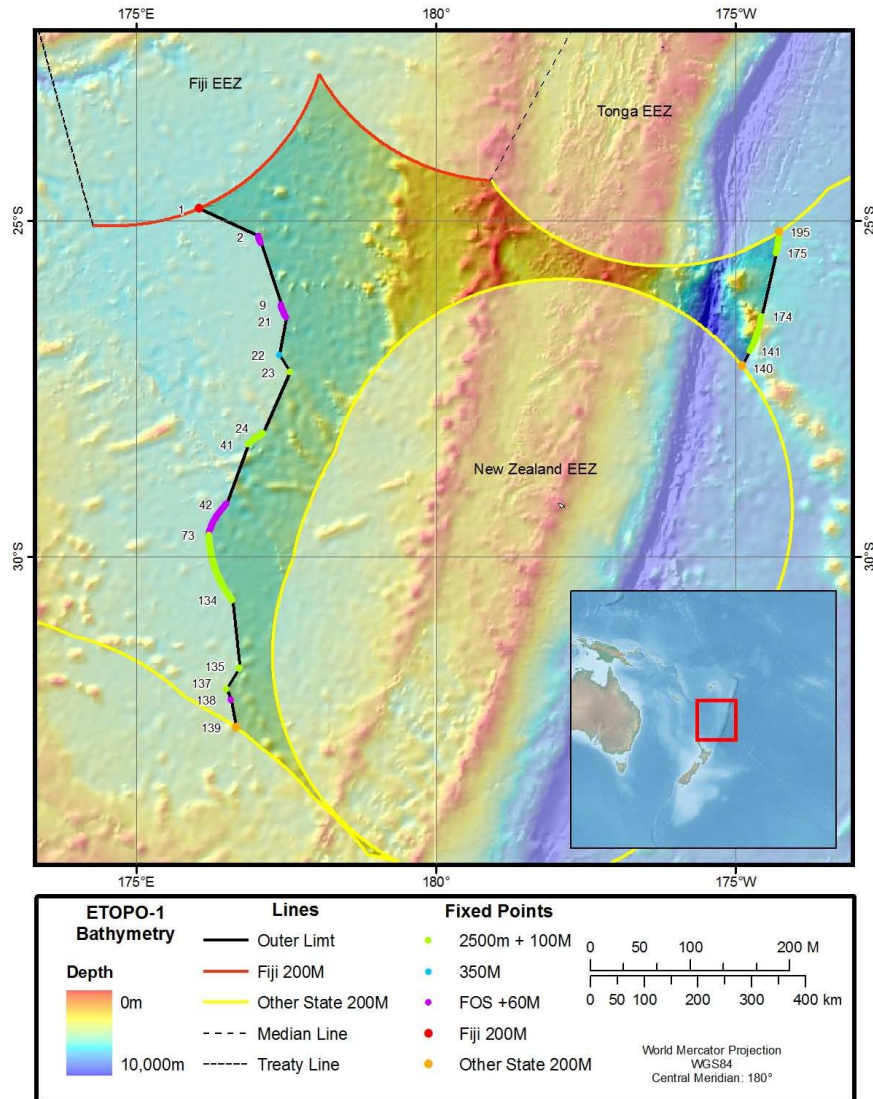
³⁴¹ See <https://www.un.org/depts/los/LEGISLATIONANDTREATIES/STATEFILES/FJI.htm>

³⁴² *Marine Spaces (Territorial Seas)(Rotuma and its Dependencies)(Amendment) Order 2012 L.N. No. 82*, and *Marine Spaces (Archipelagic Baselines and Exclusive Economic Zone)(Amendment) Order 2012 L.N. No. 83*.

³⁴³ Section 2, *Continental Shelf Act*.

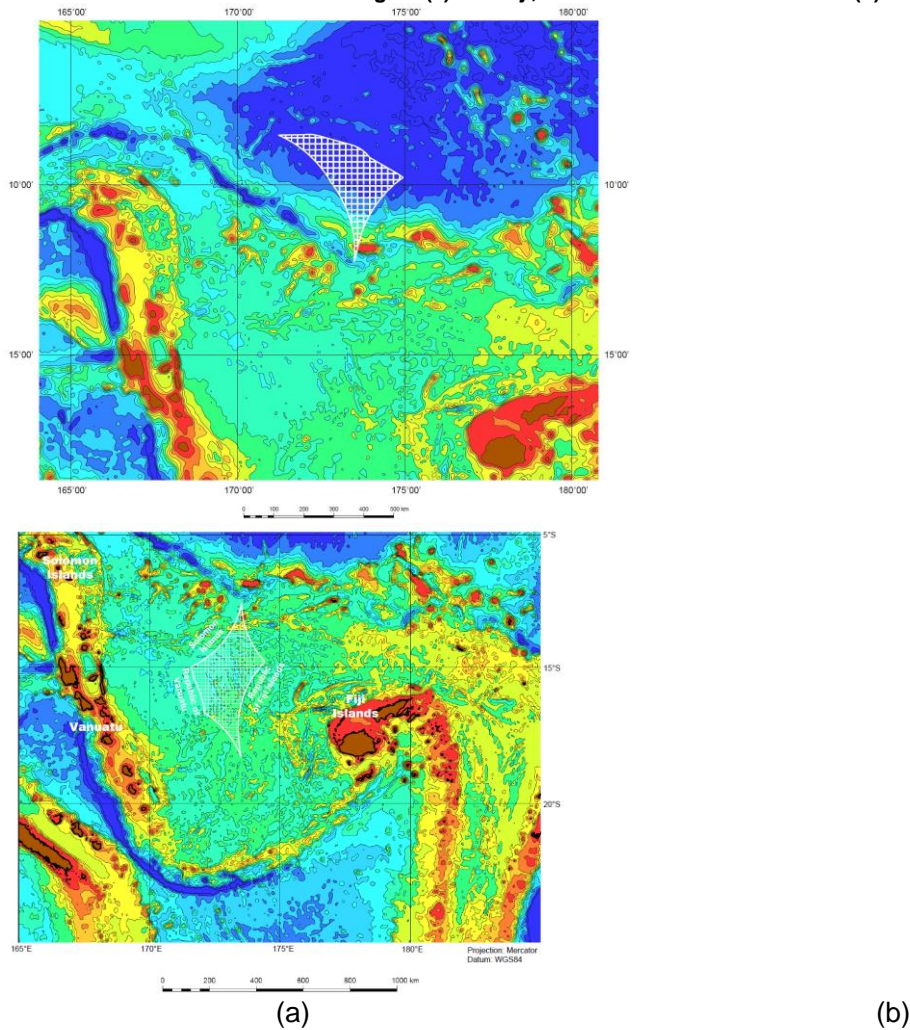
³⁴⁴ For information see: http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/fji_2009_preliminaryinfo.pdf; http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/fji_slb_2009_preliminaryinfo.pdf; http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/fji_slb_2009_figure.pdf; http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/fji_slb_vut_2009_preliminaryinfo.pdf

Figure 3 Outer Limits of the Continental Shelf claimed by Fiji



Source: Fiji revised submission in 2012 to the Commission on the Limits of the Continental Shelf – UNDOALOS CLCS website.

Figure 4 Maps showing preliminary submissions of Fiji and the Solomon Islands for the Charlotte Bank region (a) and Fiji, Solomon Islands and Vanuatu (b)



Sources: UNDOALOS CLCS website

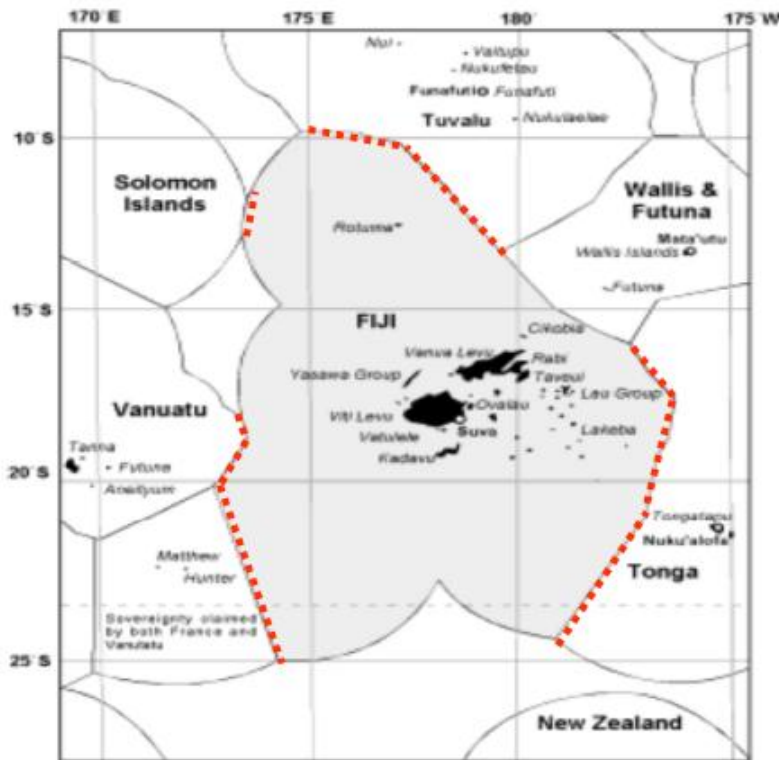
3.3.3 *Maritime boundary agreements*

There are two maritime delimitation agreements which Fiji is party to that have been deposited with the United Nations. Both have been made with France on behalf of Wallis and Futuna, and New Caledonia.³⁴⁵ Maritime delimitation agreements are being negotiated with Tuvalu and the Solomon Islands. Given certain complexities, negotiations with Vanuatu and Tonga are anticipated in the near future. The dashed lines in Figure 5 indicates the maritime boundaries that are the subject of delimitation negotiations.

³⁴⁵ [Agreement between the Government of the Republic of France and the Government of Fiji relating to the delimitation of their economic zone \(with annex and maps\)](#), 19 January 1983 (entry into force; 21 August 1984; registration #: 27963; registration date: 7 March 1991;), and

[Codicil modifying the Agreement of 19 January 1983 between the Government of the French Republic and the Government of Fiji relating to the delimitation of their economic zone](#), 8 November 1990 (entry into force: 8 November 1990; registration #: 27963; registration date: 7 March 1991).

Figure 5 Map showing Fiji's maritime boundaries yet to be formally agreed with neighbouring countries



3.4 Environmental legislation

The *Environment Management Act 2005* (EM Act) is the primary environmental legislation in Fiji. It applies to Fiji's land territory and marine spaces including the exclusive economic zone. The EM Act is intended to aid, primarily, the protection of natural resources and for the control and management of developments, waste management and pollution control.

In relation to the exploration and exploitation of marine non-living resources, the provisions of the EM Act provide, among other things for: the requirement of environmental impact assessments; protected areas; waste management and marine pollution control, and the protection and preservation of the marine environment up to the outer limits of Fiji's exclusive economic zone.

The management of developments on land and within Fiji's marine spaces is undertaken through an environmental impact assessment process. Mining operations are included in the EM Act. Schedule 2 of the EM Act provides for the types of development proposals which are required to be approved by the Environment Impact Assessment Administrator. This potentially places an additional burden on the mining proponent to comply with development approvals. With particular relevance to commercial mining operations are the following proposals that require approval of the Administrator -

(b) a proposal that could result in the pollution of any marine waters, ground water, freshwater body or other water resource;

(f) a proposal for mining, reclaiming of minerals or reprocessing of tailings;

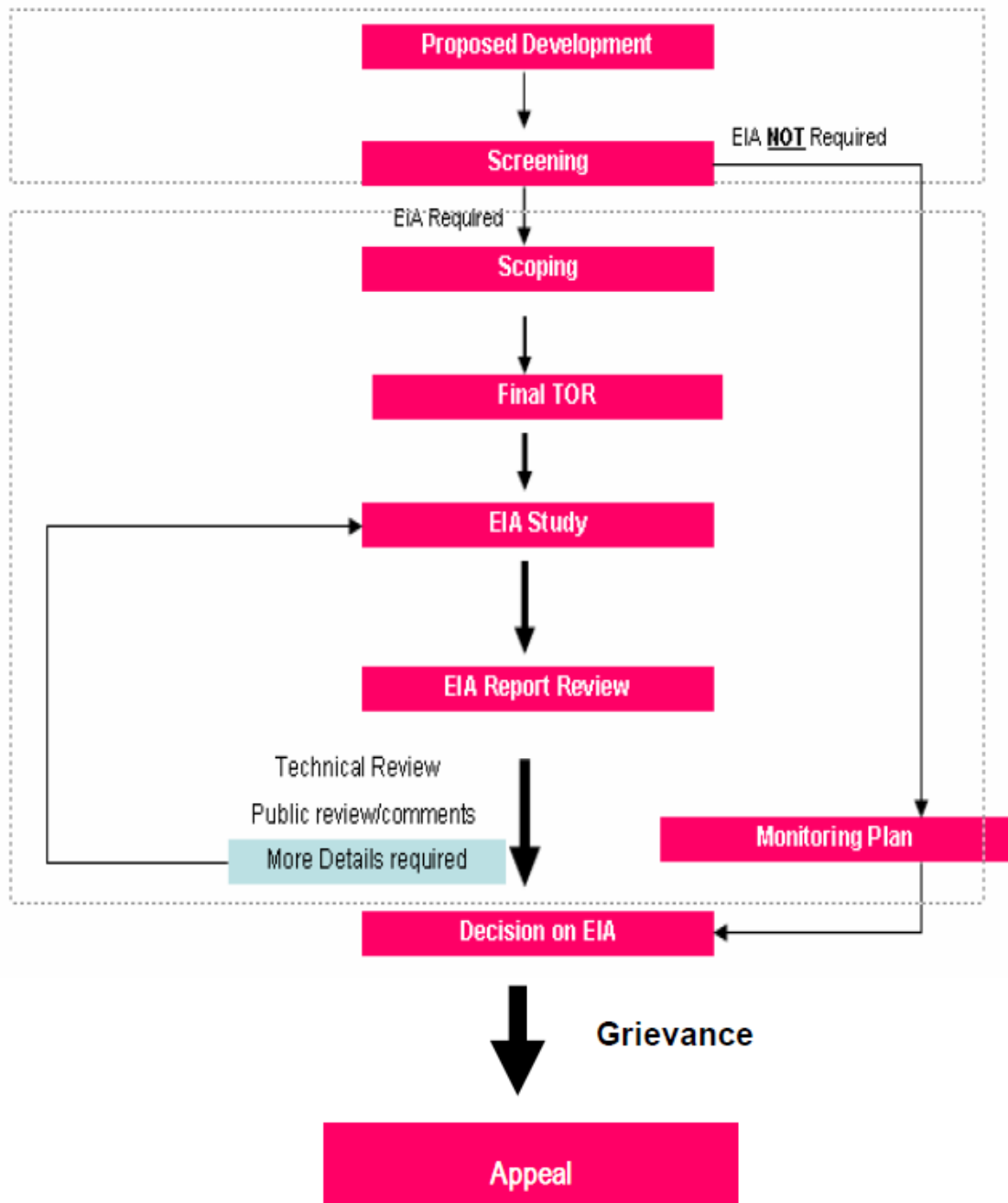
(m) a proposal that could deplete populations of migratory species including, but not limited to, birds, sea turtles, fish, marine mammals;

(n) a proposal that could harm or destroy designated or proposed protected areas including, but not limited to, conservation areas, national parks, wildlife refuges, wildlife preserves, wildlife sanctuaries, mangrove conservation areas, forest reserves, fishing grounds (including reef fisheries), fish aggregation and spawning sites, fishing or gleaning areas, fish nursery areas, urban parks, recreational areas and any other category or area designated by a written law;

(o) a proposal that could destroy or damage an ecosystem of national importance, including, but not limited to, a beach, coral reef, rock and gravel deposit, sand deposit, island, native forest, agricultural area, lagoon, sea-grass bed, mangrove swamp, natural pass or channel, natural lake or pond, a pelagic (open ocean) ecosystem or an estuary;

The process for the consideration of proposals is comparable with other jurisdictions around the world (see Figure 6). Complementing the EM Act in the EIA process are the *Environment Management (EIA Process) Regulations 2007* and the EIA Guidelines. The EIA Regulations set out the legal requirements and processes to be complied with by development proponents and EIA consultants registered with the Department of Environment.

Figure 6 Flowchart of the EIA Process



Source: Fiji's EIA Guidelines, p.8.

- A) Identify and analyse other environmental legislation potentially applicable to deep sea mining including as regards marine protected area (MPA) establishment that is, or could potentially, be used to establish an MPA to protect fragile seabed ecosystems such as sea-mounts;**

The key environmental legislation that relate to deep seabed mining that relate to the establishment of MPAs or the protection of fragile ecosystems are the *Environment Management Act 2005*, the *Endangered and Protected Species Act 2002*, the *Fisheries Act Cap. 158* and the *Offshore Fisheries Management Decree 2012*. While there is potential for the development of specific regulations under the EM Act in particular for the protection of fragile seabed ecosystems, it would be a significant challenge for the administration to monitor, and ensure compliance with

requirements and standards. Marine protected areas or marine reserves may also be established under the *Fisheries Act*, *Offshore Fisheries Management Decree 2012* and the *EM Act*.

Marine reserves and protected areas are already identified in the *Fisheries Act* and its regulations. These reserves however prohibit commercial fishing or place restrictions on certain activities in identified areas within the internal waters, archipelagic waters and territorial sea.

The *Offshore Fisheries Management Decree 2012* is the primary legislation that makes provision for the management, development and sustainable use of Fiji's offshore fisheries and living marine resources. While focused on offshore fisheries, the Decree also applies in "Fiji fisheries waters" i.e., the internal waters, the archipelagic waters, the territorial sea, the exclusive economic zone and any other waters over which Fiji exercises its sovereignty or sovereign rights, and includes the bed and subsoil underlying those waters. The Decree provides the regime for licensing and authorisations for fishing and related activities within areas under national jurisdiction and for the authorisation of flagged vessels fishing on the high seas. The Minister responsible for Fisheries has broad powers in the making of regulations including for prescribing measures for the conservation, management, development and regulation of fisheries or any particular fishery and may also make regulations elaborating on area, seasonal or other prohibitions and restrictions relating to the fishery.³⁴⁶ Notably, the Decree contains contemporary principles for the conservation and management of fisheries, and associated ecosystems, provides the application of the precautionary approach and supports the protection of biodiversity in the marine environment.³⁴⁷

In addition to the protection of marine areas, marine species may also be protected under the *Offshore Fisheries Management Decree 2012*, *Fisheries Act Cap. 158* and the *Endangered and Protected Species Act 2002* and its regulations. The *Endangered and Protected Species Act 2002* regulates and controls the international trade, domestic trade, possession and transportation of species protected under the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). The Act came into force in 2003 and applies to all endangered species listed in Appendices I, II, and III of CITES and indigenous species listed in its first and second Schedules.

3.5 Draft legislation or policy proposals

The Department of Mineral Resources is working to strengthen its legislative framework. Apart from the 2010 amendment to the *Mining Act*, there have been plans for additional legislation. For instance before 2010 the Department was working on a draft Mining Bill which was robust but did not provide adequately for seabed mining. The need for an Offshore Mining Decree has also been identified in the Department's legal reform plan but it is not clear whether this proposed law will be developed.

With respect to the role of the Department of Environment, there are several policies and regulations in existence that are designed to address terrestrial and near-shore issues such as the Environment Management (Waste Disposal and Recycling) Regulations 2007, and the Litter Promulgation 2008. General environmental policies include the: National Solid Waste Management Strategy 2011 – 2014, National Liquid Waste Management Strategy and Action Plan 2006, and the National Air Pollution Control Strategy 2007.

³⁴⁶ Section 104(2)(a), *Offshore Fisheries Management Decree 2012*.

³⁴⁷ See section 6, *Offshore Fisheries Management Decree 2012*.

4 Spain

4.1 The legal regime of maritime zones

According to article 132.2. of the 1978 Spanish Constitution the territorial sea, the natural resources found in the exclusive economic zone and in the continental shelf are public goods (property under public state domain).

4.1.1 Legislation on the territorial sea

To measure the width of the territorial sea, Spain uses a combination of the normal baseline provided by Article 5 of UNCLOS and of straight baselines provided in Article 7, although the predominant is the straight baselines. The Law which gave origin to that system is Ley 20/1967 de 8 de Abril sobre extensión de las aguas jurisdiccionales españolas a 12 millas, a efectos de pesca³⁴⁸ (Law 20/1967 of 8 April on the extension to 12 nautical miles of the Spanish jurisdictional waters for fisheries purposes) whose Article 2 establishes that the baselines from which the width of jurisdictional waters are measured are those defined by the low-water line along the coast although the Government might agree to use the straight baselines. This Law was developed through Real Decreto 2510/1977 de 5 de Agosto³⁴⁹ (Royal Decree 2510/1977, of 5 August on the trace of straight baselines developing Law 10/1967). This RD establishes 123 straight baselines of which 46 correspond to the two archipelagos, 29 in the Canary Islands and 17 in the Balearic Islands).

Internal waters resulting from the use of the straight baselines as provided by Article 8 of UNCLOS were first referred to by Ley 93/1962, de 24 de Diciembre, sobre sanciones a las infracciones que en materia de pesca cometan embarcaciones extranjeras en aguas españolas³⁵⁰ (Law 93/1962, of 24 December, on sanctions to fisheries infractions committed by foreign vessels in Spanish waters). Afterwards, its legal statute was defined by Ley 22/1988, de 28 de julio, de Costas³⁵¹ (Law 22/1988, of 28 July, on Coasts) as part of the marine public domain.

In Spain, the total length of internal waters generated by the use of straight baselines is approximately of 14.394 km² of which 4.744 km² are located within the two archipelagos, corresponding 2.398 Km² to the Canary Islands³⁵². On these internal waters the ten coastal Autonomous Communities (CC.AA-regions) out of the seventeen CC.AA in Spain, exercise exclusive powers on fisheries, shell fishing and aquaculture³⁵³. However powers of CC.AA in the territorial sea and internal waters in other affairs depends on the specific sector regulations. One example is the field of marine biodiversity protection which is relevant for the establishment of MPA and for the protection of marine species we are in front of an environmental competence provided for by Article 149.1.23 of the CE. It provides for the exclusive competence of the Spanish Central State to approve basic legislation for environmental protection without detriment to the competence of the Autonomous Communities to establish additional protection measures and develop the basic legislation. It is important to take into consideration that according to Article 36.1. of Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad³⁵⁴ (Law 22/2007, on Natural Heritage and Biodiversity) CC.AA are competent to declare and determine the management system

³⁴⁸ Published in the Spanish Official Journal (BOE) BOE núm. 86, of 11.04.1967. Available at: http://www.boe.es/diario_boe/txt.php?id=BOE-A-1967-5595

³⁴⁹ Real Decreto 2510/1977, de 5 de Agosto, sobre trazado de líneas de base recta en desarrollo de la Ley 20/1967, de 8 de abril, sobre extensiones de aguas jurisdiccionales españolas a 12 millas, a efectos de pesca (BOE núm. 234, de 30.10.1977)- text available at: <http://www.boe.es/buscar/act.php?id=BOE-A-1977-23967>

³⁵⁰ This Law has been repealed. BOE núm. 310, de 27.12.1962.

³⁵¹ BOE núm. 181, de 29.07.1988.

³⁵² Suárez de Vivero, J.L.: El nuevo orden oceánico. Consecuencias territoriales. Sevilla, Junta de Andalucía, 1985.

³⁵³ Art. 148.1.11 CE and Ley 3/2001, de 26 de marzo, de Pesca Marítima del Estado (BOE núm. 75, de 28.03.2001)

³⁵⁴ BOE núm. 299, de 14.12.2009.

for MPA when the best available scientific evidence shows the ecological connectivity between the marine ecosystem and the terrestrial natural space protected.

The definition of the territorial sea and its width it is provided by Ley 10/1977, de 4 de Enero, sobre el mar territorial³⁵⁵ (Law 10/1977, of 4 January, on the territorial sea, text available at: <https://www.boe.es/buscar/act.php?id=BOE-A-1977-465>). According to its Article 1 the Spanish State sovereignty extends to “the water column, the seabed and its subsoil and the resources of that sea as well as on its suprajacent air space”. Its width is of 12 nautical miles from the normal or straight baselines and on those waters the right of innocent passage can be exercised³⁵⁶.

4.1.2 *Legislation on the Exclusive Economic Zone*

The Ley 15/1978 de 20 de marzo sobre Zona Económica³⁵⁷ (Law 15/1978 of 20 March on the Exclusive Economic Zone- EEZ, text available at http://noticias.juridicas.com/base_datos/Admin/15-1978.html) provides for the EEZ where the jurisdiction only falls on the natural resources in accordance with the provisions of UNCLOS: “(...) the Spanish State has sovereign rights for the exploration and exploitation over natural resources on the seabed and its subsoil and in the waters superjacent to the seabed”³⁵⁸.

The EEZ extends until 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. In accordance with this Law, it corresponds to the Spanish State³⁵⁹:

- a) exclusive rights on the natural resources of the EEZ,
- b) the power to regulate the conservation, exploration and exploitation of those resources and for this purpose the marine environment shall be preserve,
- c) exclusive jurisdiction to enforce the applicable provisions,
- d) any other competence that the Government provides for in accordance with International Law.

Law 15/1978 only applies to Spanish peninsula and archipelagic marine areas of the Atlantic Ocean, including the Mar Cantabrico, and allows the Spanish Government to extend its application to other Spanish marine areas³⁶⁰. Following that faculty given to the Spanish Government, Real Decreto 236/2013, de 5 de abril, por el que se establece la Zona Económica Exclusiva de España en el Mediterráneo noroccidental (Royal Decree 236/2013, of 5 April, establishing a EEZ in the Northwestern Mediterranean, text available at: <http://www.boe.es/boe/dias/2013/04/17/pdfs/BOE-A-2013-4049.pdf>) was passed. According to this RD, the Spanish EEZ in the Northwestern Mediterranean extends from the exterior line of the territorial sea until a coordinates point I: 35° 57,46'N; L: 2° 5,31'W (datum W GS84), located in delay 173° (S 007 E) of Gata Cape and 46 nautical miles far from it, following towards east through the equidistant line with the coastal countries and drawn in accordance with International Law until the maritime border with France.

Before the approval of that Royal Decree, Spain had proclaimed a fisheries protection zone in the Mediterranean through Real Decreto 1315/1997, de 1 de agosto, por el que se establece una zona de protección pesquera en el mar Mediterráneo (Royal Decree 1315/1997, of 1 August, establishing a fisheries protection zone in the Mediterranean sea, text available at: http://noticias.juridicas.com/base_datos/Admin/rd1315-1997.html). That protection zone was delimited by a line towards South from Punta Negra-Cabo de Gata until 49 nautical miles continuing

³⁵⁵ BOE núm. 7, de 8.01.1977.

³⁵⁶ From the territorial sea up to a distance of 24 nautical miles the contiguous zone is found. (Art. 33 UNCLOS). Article 7.1. and the second additional provision of Ley 27/1992, de 24 de noviembre, de Puertos del Estado y de la Marina Mercante (Law 27/1992, of 24 November on State Ports and Merchant Marine) created a 24 miles contiguous zone.

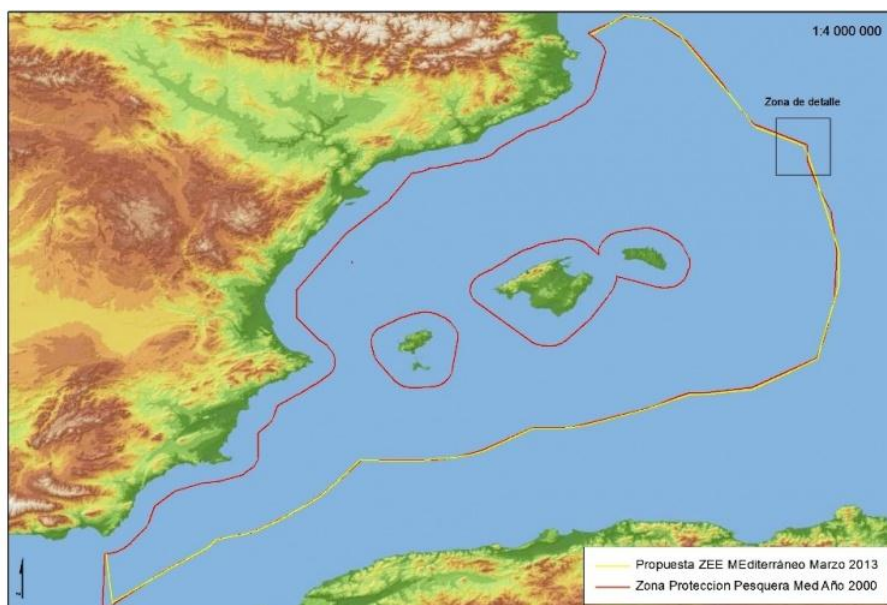
³⁵⁷ BOE núm. 46, of 23.02.1978.

³⁵⁸ Art. 1.1., Ley 15/1978.

³⁵⁹ Art. 1.2., Ley 15/1978.

³⁶⁰ First final provision of Law 15/1078.

towards East following the equidistant line with the coastal countries until the maritime border with France.



Map of the Spanish Mediterranean Sea. The red line corresponds to the fisheries protection zone and the yellow line to the EEZ.

The Spanish Continental Shelf

The Spanish legal order does not count with a specific law on the continental shelf as it exists for the territorial sea and the EEZ.

In 2006, Spain, France, Ireland and the United Kingdom in accordance with Article 76 (8) of UNCLOS jointly submitted to the UN Commission on the Limits of the Continental Shelf to extend the outer limits of the continental shelf beyond 200 nautical miles from the baselines in respect of the Celtic Sea and Biscay Gulf³⁶¹. The final recommendations were approved on 24 March 2009 (CLCS/62).

On 8 May 2009, the Spanish Council of Ministers approved an agreement acknowledging the submission of a verbal note submitted to the UN Commission on the Limits of the Continental Shelf related to the widening of the continental shelf to the West of Canary Island beyond the 200 nautical miles from the coast baseline³⁶². The submission took place on 11 May 2009 and would represent an extension of 206.000 Km². The Kingdom of Morocco rejected this proposal until an agreement is reached³⁶³.

Also on 11 May 2009, the Kingdom of Spain submitted to the Commission on the Limits of the Continental Shelf information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured in respect of the area of Galicia³⁶⁴. Portugal also sent its comments on this submission³⁶⁵.

³⁶¹ http://www.un.org/depts/los/clcs_new/submissions_files/submission_frgbires.htm

³⁶² http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/esp_can_2009_preliminaryinfo.pdf

³⁶³ http://www.un.org/depts/los/clcs_new/submissions_files/preliminary/mar_re_esp2009e.pdf

³⁶⁴ http://www.un.org/depts/los/clcs_new/submissions_files/submission_esp_47_2009.htm

³⁶⁵ http://www.un.org/depts/los/clcs_new/submissions_files/esp47_09/prt_re_esp2009.pdf

In addition, Spain is signatory to two bilateral Conventions to delimitate the continental shelf: one with France of 1974 in the Viscay Gulf³⁶⁶ and the other with Italy of 1974 between Balearic Island and Sardinia³⁶⁷.

4.2 Legislation on Deep Sea Mining

Law 22/1973, of 21 July, on Mines (Ley 22/1973, de 21 de julio, de Minas- Law on Mines³⁶⁸, consolidated text available at: <https://www.boe.es/buscar/act.php?id=BOE-A-1973-1018>) provides the legal regime for the exploration, investigation and exploitation of mineral deposits and of any other geological resource irrespective of its origin and physical state (Art. 1.1) in Spain. This Law establishes that all mines deposits of a natural origin and the rest of existing geological resources found in the Spanish territory, including the territorial sea and the continental shelf are public domain goods whose exploration, investigation and exploitation can be done directly by the Spanish State or can be transferred following the procedures and conditions provided in this Law and other applicable provisions in force (Art. 2.1).

Among those applicable provisions is Real Decreto 2857/1978, de 25 de agosto, por el que se aprueba el Reglamento General para el régimen de la minería (Royal Decree 2857/1978, of 25 August, approving the General Regulation for Mining Regime³⁶⁹- Regulation on Mining text available at: <http://www.boe.es/buscar/act.php?id=BOE-A-1978-29905>)

Article 1.1. of this Regulation provides for its scope of implementation establishing that exploration, investigation and exploitation activities and the benefits derived from all mines deposits and the rest of geological resources irrespective of its origin and physical state found in the national territory, including the territorial sea, the continental shelf and the seabed under Spanish jurisdiction or sovereignty according to Spanish Law and international conventions ratified by Spain, shall be regulated by the Law on Mines and this Regulation.

Therefore, the Spanish legal regime for deep sea mining it is the very same as that regime provided for land-based mining. As a result, minerals found in the deep seabed under Spanish jurisdiction or sovereignty are public goods or goods under public domain whose exploration and exploitation are subject to Public Law or Administrative Law. Exploration and exploitation of goods under public domain are mainly subject to administrative authorizations and concessions.

The Law on Mines divides the types of mines deposits and other geological resources into the following kinds called sections (Art. 3, Law on Mines and Art. 5 Regulation on Mining):

- i. **Section A.-** Those of reduced economic value and restricted geographical commercialization, as well as those whose sole exploitation purpose is to obtain small fragments of appropriate shape for their direct use in public infrastructure and constructions works which only requires operations of initiation, weakening and calibration.
- ii. **Section B.-** Terrestrial and marine mineral and thermal waters , underground structures and deposits created as a consequence of the operations regulated by the Law on Mines.
- iii. **Section C.-** Those minerals and geological resources which are not included under sections A and B and which are subject to exploitation in accordance with this Law.
- iv. **Section D.-** Coals, radioactive minerals, geothermal resources, bituminous rocks and any other mineral deposits or geological resources of energy interest which the Government agrees to include in this section under the proposal of the Ministry of Industry, Energy and

³⁶⁶ Instrumento de Ratificación del Convenio entre España y Francia sobre Delimitación de Plataformas Continentales entre los dos Estados en el Golfo de Vizcaya (Golfo de Gascuña), París 29 January 1974 (BOE núm. 159, de 4.07.1975).

³⁶⁷ Instrumento de Ratificación del Convenio entre España e Italia sobre Delimitación de la Plataforma Continental entre los dos Estados, hecho 19 February 1974 (BOE núm. 290, of 5.12.1978).

³⁶⁸ This Law has been subject to different amendments, the last in 2010.

³⁶⁹ As the Law, the Regulation has been also subject to a series of amendments, the last also in 2010.

Tourism, after hearing the report of the Instituto Geológico y Minero de España (Spanish Geological and Mining Institute).

The Law on Mines and the Regulation on Mining stipulates the form and conditions under which these kind of mines deposits and geological resources can be explored and exploited by the State or transferred to a third party. The main legal regime for those activities requires:

- a) An “exploitation authorization” for Section A mineral deposits and resources.
- b) An “authorization” or an “exploitation (use) concession” for Section B mineral deposits and resources.
- c) An “exploration permit”, an “investigation permit” or “exploitation concession” for Section C and D mineral deposits and resources.

We will analyse the conditions and procedures to explore, investigate and exploit mineral deposits and resources, but before it is useful for a better understanding to identify the competent authorities and the role of the State in deep sea mining.

4.2.1 *Competent authorities*

The competent authority for issuing deep sea mining authorizations, permits and concessions is DG for Energy Policy and Mining of the Ministry of Industry, Energy and Tourism (Art. 6, Regulation on Mining). The Deputy DG for Mines (<http://www.minetur.gob.es/energia/mineria/Paginas/Index.aspx>) depends on this DG. In addition, this DG implements the Mining legal regime in Spain³⁷⁰.

The Instituto Geológico y Minero de España (IGME) is the principal Government mineral-resource agency and offers assistance in the fields of geology and mining to the private and public sectors through the production of maps and scientific publications (www.igme.es)

4.2.2 *The role of the Spanish State in Deep Sea Mining*

Following the procedures and conditions provided by the mining legislation, the Spanish State can establish **reserve zones** of any extension in the Spanish territory, including in the territorial sea and continental shelf in which the exploitation-use of any or several mineral deposits and the rest of geological resources of Sections A, B, C or D can have special interest for economic and social development and for national defence. The establishment of a reserve zone implies the consideration of the resource(s) found within that zone of national interests (public interest).

The reserve zones can be (Art. 8 of Law on Mines and Art. 10 of Regulation on Mining):

- a) Special, for one or several determined resources found in all terrestrial territory, territorial sea and continental shelf. This reserve must be declared by Decree for a period of five years.
- b) Provisional for the exploration and investigation in zones or areas defined by mining grids of all or any of their resources. The provisional reserve zones for exploration have one year validity and those for investigation have three years validity.
- c) Final for the exploitation of assessed resources found in concrete zones or areas of a provisional reserve.

The reserve of zones in favor of the State do not limit the rights acquired by the applicants or title holders of exploration, investigation permits or of concessions of direct or derived exploitation of resources under Sections C and D and of authorizations of exploitation of resources under Sections A and B before the inscription of the reserve zone proposal.

³⁷⁰ Article 3 of Real Decreto 344/2012, de 10 de febrero, por el que se desarrolla la estructura orgánica básica del Ministerio de Industria, Energía y Turismo provides in detail the competences of this DG.

In the reserve zones exploration, investigation and exploitation operations can be developed depending on the existing level of knowledge about those zones. Those operations can be carried out by the State itself or by third parties. The procedures to carry out them are regulated by Law on Mines (Arts 13-15) and by Regulation on Mining (Arts. 13-26).

4.2.3 *Requirements for carrying out mining activities in Spain*

To exploit and use Section A mining resources found in lands under public domain and public use the mining legislation requires a previous “exploitation authorization” (Arts. 16-17 Law on Mines and 27-35 Regulation on Mining). Given that the deep sea mining takes place in the continental shelf which is an area under public domain as we have seen, the exploitation of Section A mining resources found in the continental shelf requires such an authorization.

Resources under Section B are mineral waters which are divided into medicinal waters and industrial water, thermal waters, underground structures which are geological deposits of a natural origin as well as those artificially produced as a consequence of activities regulated in the Law on Mines when they allow the in-depth retention of any product or waste discharged or injected.

To obtain an authorization or concession to exploit mineral and thermal waters it is a condition *sine qua non* that the condition as mineral of those is declared by the Minister of Industry, Energy and Tourism and it is published in the BOE.

Law on Mining provides that for granting an investigation permit and a direct concession for the exploitation of resources under Section C it is a *sine qua non* condition that the land on which the permits and concession are granted are clear³⁷¹ and registrable. The availability to be registered under the Law on Mining means that has the minimum extension to be delimited. The procedures and conditions are provided for by Title V of the Law on Mining (Arts. 37-81) and by Title V of the Regulation on Mining (Arts. 56-104). It is important to take into consideration that conditions and procedures for exploration, investigation and exploitation of Section D resources are the same as those for Section C resources.

The Ministry of Industry, Energy and Tourism can grant an **exploration permit** that confers upon the holders the following rights:

- a) Conduct studies and surveys in certain areas by applying techniques of any kind that do not substantially alter the configuration of the terrain, being able to extend this work in terms of earth works.
- b) Priority during the validity of the request of investigation permission or direct exploration concessions on the terrain that, included in its perimeter, would be direct and registrable at the moment of presentation of exploration application.

The exploration permit will be granted for a period of one year, and can be extended, taking into consideration the context of geological area, one year at the most counting from the termination of initial time limit, if it had been requested extension one month before, at least, the expiration date.

The **investigation permit** grants the holder the rights to carry out this the studies and work aimed to highlight and define one or various resources of the Section C) within the delimited perimeter and during the validity of, and that, once it is defined by the accomplished investigation and it is

³⁷¹ A clear land is that outside a perimeter of a State reserve zone or of the perimeters of a requested or granted exploration or investigation permit or of a requested or granted exploitation concession (Art. 56 Regulation on Mining).

demonstrated that is susceptible of rational use, confers the right of being granted the corresponding exploitation concession.

The investigation permit will be granted for the requested period, which cannot be longer than three years, can be extended by the same authorities who granted previously, up to maximum of three years.

The rights of exploitation of mineral resources of the Section C) will be granted by the State through mineral exploitation concession. The **mineral exploitation concession** will be granted for the period of thirty years, extendable for other two periods of the same time, up to the maximum of ninety years.

The granting of exploitation concession confers the holder the right to use all the resources of the Section C) that is included within his perimeter, except those which were previously reserved to the State.

As soon as the investigation demonstrates sufficiently the existence of a resource or resources of the Section C), and always within the validity of the period of the investigation permit, the holder can apply for the concession of exploitation on whole or part of terrain included in the perimeter of investigation.

4.3 Legislation on deep sea mining in the Area;

Spain does not count with specific legislation governing deep sea mining in the Area.

4.4 Environmental Impact Assessment Legislation in Spain

Ley 21/2013, de 9 de diciembre, de evaluación ambiental³⁷² (Law 21/2013, of 9 December, on environmental assessment) has merged existing legislation on Environmental Impact Assessment and on Strategic Environmental Assessment³⁷³.

Article 7 of Law on Environmental Assessment provides for the scope of EIA and establishes two kinds of EIA procedures: the ordinary EIA and the simplified EIA.

Projects subject to **ordinary EIA** procedure are:

- a. those listed in its Annex I as well as those which submitted as fragmented projects reach the thresholds of Annex I through the accumulation of magnitudes or dimensions of each of the projects under consideration.
- b. Those which are subject to simplified EIA- which are those listed in Annex II- when the environmental body on case by case basis decides so in the environmental impact report in accordance with criteria listed in Annex III. This is the screening procedure.
- c. Any modification of the characteristics of a project listed in Annex I or II when such a modification reaches by itself the thresholds provided in Annex I.

³⁷² BOE núm. 26 of 11.12.2013. Text available at: http://www.boe.es/diario_boe/txt.php?id=BOE-A-2013-12913

³⁷³ Thus, this Law repealed Real Decreto Legislativo 1/2008, de 11 de enero, por el que se aprueba el texto refundido de la Ley de Evaluación de Impacto Ambiental de proyectos (Royal Legislative Decree 1/2008 of 11 January, approving the consolidated text of Law on Environmental Impact Assessment), a 1988 Regulation on EIA and Ley 9/2006, de 28 de abril, sobre evaluación de los efectos de determinados planes y programas en el medio ambiente (Law 9/2006, of 28 April, on the assessment of the effects on the environment of certain plans and programmes).

Projects subject to a **simplified EIA** procedure are:

- a. Projects listed in Annex II.
- b. Projects not included in Annex I or II which might, directly or indirectly, significantly affect to Natura 2000 protected sites.
- c. Any modification of the characteristics of an Annex I or II project different from the modifications listed in paragraph c) above which has already been authorized, executed or in execution process and that can have significant adverse effects on the environment. It is understood that this modification has a significant adverse effect on the environment when represents:
 1. A significant increase of emissions to the air.
 2. A significant increase of discharges to the water public domain or to offshore.
 3. A significant increase of waste generation.
 4. A significant increase of the use of natural resources
 5. An impact to Natura 2000 protected sites.
 6. A significant impact to cultural heritage.
- d. Fragmented projects which reach thresholds in Annex II through the accumulation of the magnitude or dimension of each of the projects under consideration.
- e. Projects in Annex I serving exclusively or mainly to develop or rehearse new methods or products when the time-expand of the project is not more than two years.

Thus, to check whether the scope of EIA under Spanish Law also covers deep sea mining it is necessary to examine Annexes I and II of Law on Environmental Assessment. It is difficult for us, given that we do not understand well the techniques used for deep sea mining to see if some of the projects may relate to deep sea mining. For this reason, we have included those that we believe might entail deep sea mining operations.

Group 2 of Annex I covers extractive industries. It lists different kind of mining activities. Paragraph a) of that group contains a series of open sky mining projects which must be subject to EIA. Deep sea mining is not an open sky activity. Paragraph b) lists subsoil mining projects carried out in exploitations in which a series of circumstances take place. We only list those circumstances that may be related to deep sea mining operations:

1. That their paragenesis can, by oxidation, hydration or dissolution, produce acidic or alkaline waters leading to changes in pH or release metallic or non-metallic ions involving an alteration of the natural environment.
2. Exploiting radioactive minerals.

In addition, paragraph d) of group 2 refers to the projects consisting on the drilling for exploration, research and exploitation of hydrocarbons, CO₂ storage, gas storage and geothermal of medium and high enthalpy which require the use of hydraulic fracturing techniques. This section does not include drilling research surveys aimed at making witness pre-drilling projects requiring the use of hydraulic fracturing techniques. It is worthwhile to emphasise that while drilling for exploration, research and exploitation of all those activities are included there is no such a requirement when the activity relates to deep sea mining.

In all sections of this group 2 facilities and structures necessary for the extraction, processing, storage, use and transport of ore, stockpiles sterile, rafts, and power lines, water supply and treatment and new access roads are included.

Annex II includes projects which are subject to simplified EIA procedure although through this procedure it might be decided that they must be subject to an ordinary EIA procedure taking into consideration their impacts (see below). Among the projects listed in Annex II we found some which might relate to deep sea mining:

Group 3. Drilling, dredging and other mining and industrial facilities. Paragraph a) of this group lists deep drillings with the exception of drillings for investigating the stability or the stratigraphy of the soil and subsoil, in particular those which might entail deep sea mining are:

1. Geothermal Drilling of over 500 meters.

Point 4 lists oil and gas drilling for exploration or research purposes. Again only oil and gas drilling for exploration or research purposes are covered and not the drilling carried out for exploration or research for deep sea mining.

Paragraph c) of this group lists those projects using marine seismic exploration. Paragraph d) lists the extraction of materials through marine drilling except when the purpose of the project is to keep hydrodynamic or navigational conditions. Finally, paragraph i) lists outdoors industrial installations for the extraction of coal, oil, natural gas, minerals and oil shale not included in Annex I.

4.4.1 *Competent bodies for EIA*

In Spain there are two kind of administrative bodies which participate in an EIA procedure³⁷⁴:

- The EIA **substantive body** which is in charge of authorizing the project and to which the application for authorization must be submitted to. When the EIA substantive body is simultaneously the project developer it has to comply with all the obligations of a developer. In the case of deep sea mining this may happens as we have seen that the mining legislation allows the State to reserve zones. The substantive body in the case of deep sea mining will be the DG for Energy Policy and Mining.
- The EIA **environmental body** which is in charge of producing the Environmental Impact Statement. In the case of deep sea mining the environmental body is the Ministry of Agriculture, Food and Environment (MAFE), specifically DG for Environmental Assessment and Quality and Nature Protection.

4.4.2 *The ordinary EIA procedure*

The ordinary EIA procedure is regulated from Articles 33 to 44 of the Law on Environmental Assessment. It starts when the environmental body receives the complete file of the EIA. Before submitting to the environmental body that file, the substantive body which has received the authorization application has to carry out a consultation to interested administrations and persons and to the public. It may also requests to the environmental body to prepare a document on the scope of the Environmental Impact Study when the developer asks for it.

The developer has to submit an Environmental Impact Study whose main content is provided by Article 35 of the Law on Environmental Assessment. This EI Study in addition to the project itself must be subject to a public consultation period which cannot be less than 30 days and must be announced in the BOE. In addition, interested public administrations and persons must be consulted. Once the consultation phase is finished the substantive body will facilitate within 30 days the results of the consultations on which the developer can submit allegations. Then the developer must submit to the substantive body an application to initiate the EIA procedure which must contain:

- a. The project technical document
- b. The EI Study
- c. The allegations and reports received from the public consultation and the consultations to interested administrations and persons
- d. The comments which the substantive body considers appropriate, if any.

Then, the substantive body submits that application to the environmental body which will analyze the documents and issue after that analysis the Environmental Impact Statement. This Statement can be positive or negative and must be published in the BOE. The Statement cannot be challenged through administrative review procedure or judicial review procedure until a final decision on the authorization of the project is reached. Therefore, when the authorization is challenged the Statement can be challenged.

³⁷⁴ Article 9, Law on Environmental Assessment.

4.4.3 *The simplified EIA procedure*

This procedure is regulated from Articles 45 to 48 of the Law on Environmental Assessment. The developer of the project must submit to the substantive body when submitting the authorization application a requests to initiate a simplified EIA together with the following documents:

- a. The reasons why it is applying for a simplified EIA
- b. The definition, characteristics and location of the project.
- c. An explanation of the main studied alternatives and the main reasons of the submitted solutions taking into considerations its environmental impacts.
- d. An assessment of the foreseen direct and indirect cumulative and synergic effects on the population, the human health, flora and fauna, biodiversity, soil, air, water, climate change, landscape, material goods, including the cultural heritage and the interaction among those factors during the execution, exploitation phases including also during the demolition or abandoning of the project.

If the project may affect directly or indirectly to Natura 2000 sites a section on the assessment of the effects on the site shall be included taking into consideration the conservation objectives of the site.

- e. The measures allowing to prevent, reduce or compensate and, as far as possible, to correct any relevant negative impact in the environment during the execution of the project.
- f. The manner to carry out a follow up which guarantees the compliance with protection and correction indications and measures contained in the environmental document (document listed under d)).

The substantive body submits those documents to the environmental body. The environmental body has to open a consultation period on the environmental document to interested administrations and interested persons. There is no public consultation open to the public in general. Then, three months after receiving the application for a simplified EIA and taking into consideration the consultation results, the environmental body has to issue an EI Report where it can resolve:

- a. The project must be subject to an ordinary EIA procedure for having a significant effect on the environment. In such a case, the developer must prepare an EI Study.
- b. The project has no significant effects on the environment in the terms stated in the EI Report.

The EI Report has to be published in the BOE which as in the case of the EI Statement cannot be challenged through administrative review and judicial review procedures until an authorization on the project is issued.

4.4.4 *Environmental Legislation and Deep Sea Mining*

The two most important pieces of legislation which might potentially apply to deep sea mining are:

- Ley 41/2010, de 29 de diciembre, de Protección del Medio Marino³⁷⁵ (Law 41/2010, of 29 December, on the Protection of the Marine Environment) which transposed Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) into Spanish Law, and
- Ley 42/2007, de 13 de diciembre, del Patrimonio Natural y de la Biodiversidad³⁷⁶ (Law 22/2007, on Natural Heritage and Biodiversity).

³⁷⁵ BOE núm. 317, of 30.12.2010. Text available at : http://noticias.juridicas.com/base_datos/Admin/l41-2010.t1.html

³⁷⁶ BOE núm. 299, de 14.12.2009. Text available at: http://noticias.juridicas.com/base_datos/Admin/l42-2007.html

4.4.5 *MPAs and other instruments to protect marine areas*

The protection of a marine area is without doubt an issue to take into consideration by deep sea mining operations. In accordance with Law 42/2007 on Natural Heritage and Biodiversity, the State through the MAFE and specifically the DG for the Sustainability of the Coast and the Sea³⁷⁷ is competent in the field of conservation, sustainable use and improvement and restoration of the marine environment when³⁷⁸:

- a) It deals with areas, habitats or critical areas located in marine zones under the sovereignty or jurisdiction of Spain, except in the case where there is ecological connectivity between the marine ecosystem and terrestrial area to be protected³⁷⁹.
- b) It affects those species whose habitats are found in the areas previously referred to or to highly migratory species.
- c) In accordance with International Law, Spain has to manage areas located in the Straits subject to international law or the high seas.

According to Law 42/2007, a MPA can be designated through this specific category or through any other of the existing categories for the protection of natural areas (see below). Article 32 of Law 42/2007 provided the possibility to include MPAs in the Spanish Network of MPAs. The legal requirements and specifications for this Network have been established by Title III on “The MPAs Network and the conservation of marine species and habitats” of Law 41/2010.

According to Article 26.1 of Law 41/2010, it can be part of the Network of Spanish MPAs a series of protected sites the most relevant are:

- a) MPAs as provided in Article 32 of Law 42/2007
- b) SCAs and SPAs which are part of Natura 2000 Network.
- c) Other categories of protected sites as provided in article 29 of Law 42/2007³⁸⁰.
- d) Protected sites under international conventions.
- e) Marine reserves provided in article 14 of Law 3/2001, of 26 of March, on Fisheries.

To protect MPAs and its natural values management plans and instruments are adopted. They must contain the necessary conservation measures and the appropriate limitation to the exploitation of resources (Art. 32.2 Law 42/2007). The establishment of MPAs under the competence of the State is done through Royal Decree (Art. 27.1 Law 41/2010).

The declaration establishing a National Park must contain the prohibitions and limitations to those uses and activities which alter or endanger the achievement of the objectives of the Park in the Network of National Parks (Art. 12.d) of Law 5/2007, of 3 April, on the National Parks Network, among other elements. For each National Park a Use and Management Plan must be adopted (Art. 17 Law 5/2007).

The exploitation of natural resources can be limited in Parks and those uses incompatible with the purpose which justified their establishment must be prohibited (Art. 30.3 Law 42/2007). A Use and Management Plan must be also adopted for Parks (Art. 30.5 Law 42/2007).

In Natural Reserves the exploitation of resources is limited except in those cases in which the exploitation is compatible with the conservation of the values to be protected It is prohibited the collection of biological or geological material from natural reserves unless it is collected for research, conservation or educative purposes and in such a case an administrative authorization is required (Art. 31.2 Law 42/2007).

Previously to the establishment of Parks and Natural Reserves a Natural Resources Planning Document must be developed and approved (Art. 35.1 Law 42/2007).

³⁷⁷ Art. 5. l) of Royal Decree 401/2012, of 17 February, developing the organic structure of the MAFE (BOE núm. 42, of 8.02.2012). According to paragraph k) of the same article this DG is also competent for the marine strategies, the Network of MPAs of Spain, habitats and species, and dumping in accordance with Law on the Protection of the Marine Environment.

³⁷⁸ Art. 6 L 42/2007.

³⁷⁹ Art. 36.1. L 42/2007.

³⁸⁰ At the State level these categories are: National park, Park, natural reserve, natural monument and protected landscape.

In Natural Monuments the exploitation of resources is prohibited although it can be allowed for research, conservation or educative purposes and in such a case an administrative authorization is required (Art. 33.3 Law 42/2007).

In the statements establishing protected sites protected peripheral areas might be established with the purpose of avoiding ecological or landscape impacts from outside. In such cases, the legal instrument creating the site shall establish the necessary limits (Art. 37 Law 42/2007).

The General Administration of the State through MAFE without prejudice to the competences falling within the remit of the Ministry of Foreign Affairs and Development³⁸¹ has the following functions in relation to the MPAs Network³⁸²:

- a) Managing of MPAs under the competence of the State and ensuring its conservation and coordinating the Network of MPAs.
- b) Proposing to international organizations and European institutions the inclusion in international networks of those marine areas of the Spanish Network of MPAs which comply with the requirements provided for their respective protection categories.
- c) Declaring and managing SACs and SPAs in the marine environment, in those cases provided in Article 7 of Law 42/2007.
- d) Preparing together with the coastal CC.AA competent to declare and manage MPAs the proposal to establish minimum common criteria for a coordinated and coherent management of the Network of MPAs which shall be approved by the Environment Sectorial Conference as well as the Guiding Plan for the Network of MPAs.
- e) Carrying out the follow-up and assessment of the Network and of their common guidelines.
- f) Fostering and proposing cooperation instruments to achieve the objectives of the Network of MPAs of Spain.
- g) Representing the Spanish Government at international networks of MPAs and establishing international cooperation mechanisms allowing the external promotion of the Spanish Network of MPAs.
- h) Adopting and implementing the Marine Species Plans for Recovery and Conservation included in the Spanish Catalogue of Threatened Species which are under the competence of the State in accordance with Law 42/2007.
- i) Adopting and implementing the Strategies and Plans for the conservation and restoration of marine habitats included in the Spanish Catalogue of Critically Endangered Habitats under the state competence according to Article 6 of Law 42/2007.
- j) Preparation of an annual memorandum providing a follow-up of the activities within the Network of MPAs and of triennial reports on the situation of that Network.

4.4.6 *Other environmental aspects to take into consideration*

It is important to recall the aim of the Marine Strategy Framework Directive (MSFD): to achieve the good environmental status of the EU's marine waters by 2020, and its main instrument to achieve it: the marine strategies. One of the descriptors of that status is sea-floor integrity. For this reason, the marine strategies prepared by Spain for the five Spanish marine subregions are documents to take into consideration³⁸³. The five marine subregions are³⁸⁴:

- North Atlantic
- South Atlantic
- Gibraltar Strait and Alborán
- East-balearic

³⁸¹ These are the competences when the areas are under a category of protection being part of the Network are included in an international convention or in the EU legislation.

³⁸² Art.28, Law 41/2010.

³⁸³ Once the marine strategies are finalized they will be approved by the Government through a Royal Decree (Art. 15, Law 41/2010).

³⁸⁴ Art. 6.2, Law 41/2010.

- Canary



Map of the Spanish marine subregions

In addition, Article 35 of Law 41/2010 establishes conditions and prohibitions to place matters in the seabed. It bans the deposit of matter and any other object when the purpose is its discharge and abandonment. It also bans the placement of vessels of any kind and of oil and gas platforms in the sea bed except when the purpose of placing a vessel is creating an artificial reef and counts with an authorization. To place and deposit of matters and any other substances on the seabed and its subsoil requires a project which shall be authorized by the competent administration after receiving a favorable report from MAFE with the purpose of determining its compatibility with the applicable marine strategy without prejudice to any other reports required by legislation in force. The authorization can be granted only in the case that the application justifies that the matters have been assessed following the applicable procedures in accordance to the legislation applicable to the nature of those matters or if none, with the criteria, guidances and appropriate procedures adopted by applicable marine conventions. The project shall include an assessment of the seabed where the placement or deposit will take place as well as of the impacts that it can have on the marine environment and the human activities in the sea. When the monitoring programmes or any marine environment follow-up shows that the deposited matter or substances in the seabed are provoking non-foreseen impacts or are not complying with its aims, the competent body to authorize its placement shall determine the corrective measures to apply or if needed shall order its withdrawal.

4.5 Future legislation

Taking into consideration that the object of marine strategies are to achieve good environmental status of marine waters, the existing draft legislation which will have to be considered in deep sea mining operations is the amendment to Ley 26/2007, de 23 de octubre, de Responsabilidad Medioambiental (Law 26/2007, of 23 October, of Environmental Liability). This amendment will transpose into Spanish Law Article 38 of **Directive 2013/30/EU of the European Parliament and of the Council of 12 June 2013 on safety of offshore oil and gas operations and amending Directive 2004/35/EC which amended the definition of “water damage” under Directive 2004/35/EC as follows:**

“water damage”, which is any damage that significantly adversely affects:

- (i) the ecological, chemical or quantitative status or the ecological potential, as defined in Directive 2000/60/EC, of the waters concerned, with the exception of adverse effects where Article 4(7) of that Directive applies; or
- (ii) the environmental status of the marine waters concerned, as defined in Directive 2008/56/EC, in so far as particular aspects of the environmental status of the marine environment are not already addressed through Directive 2000/60/EC;¹.

Annex 2. Commodity markets: silver

Precious metals: Silver

Supply

In 2012, around 75% of silver supply came from mine production.³⁸⁵ 60% of mined silver is mined as a by-product of copper and lead-zinc ores, and 11% as a by-product of gold ores; only 29% come from genuine silver ores. Therefore many of the leading producers of silver are equivalently leading producers of the mentioned metals, such as Peru, Mexico, and China.³⁸⁶ The same pattern is visible in Poland, the largest European silver producer, where silver is mostly mined from copper ores.³⁸⁷ With a production of 1,190 tonnes in 2008, Poland provides around 40% of European silver supply.

The following table gives an overview of the worldwide reserves and production of silver, as well as EU imports by country.

	Reserves (in t / percentage of total)		Production (in t / percentage of total)		Imports of EU	
Peru	120,000	22%	3,450	14%	1	0.1%
Poland	85,000	16%	1,170	5%		
Chile	77,000	14%	1,130	5%	13	1.3%
Australia	69,000	13%	1,900	8%	36	3.7%
China	43,000	8%	3,800	16%		
Mexico	37,000	7%	4,250	18%		
USA	25,000	5%	1,050	4%	5	0.5%
Bolivia	22,000	4%	1,300	5%		
Canada	7,000	1%	530	2%		
Russia	n.a.		1,500	6%		
Other countries	50,000	9%	3,900	16%	918	94.8%
World	540,000		24,000			

Sources: USGS (2013) for data on reserves and production, pertaining to 2012. European Commission (2010) for data on EU imports, valid for 2008.

The table shows that supply of silver is relatively diversified; Latin America has a large market share, but China, Australia and the US are important players as well, which means that political risk is also diversified. Notably, Poland had 5.6% of world production in 2008, but a significantly higher share of international reserves (13.9%), which shows its potential to contribute to diversification and further EU import independence.

Figure 4.1 shows the development of silver mine production from 2003 until 2012, with respective regional shares.

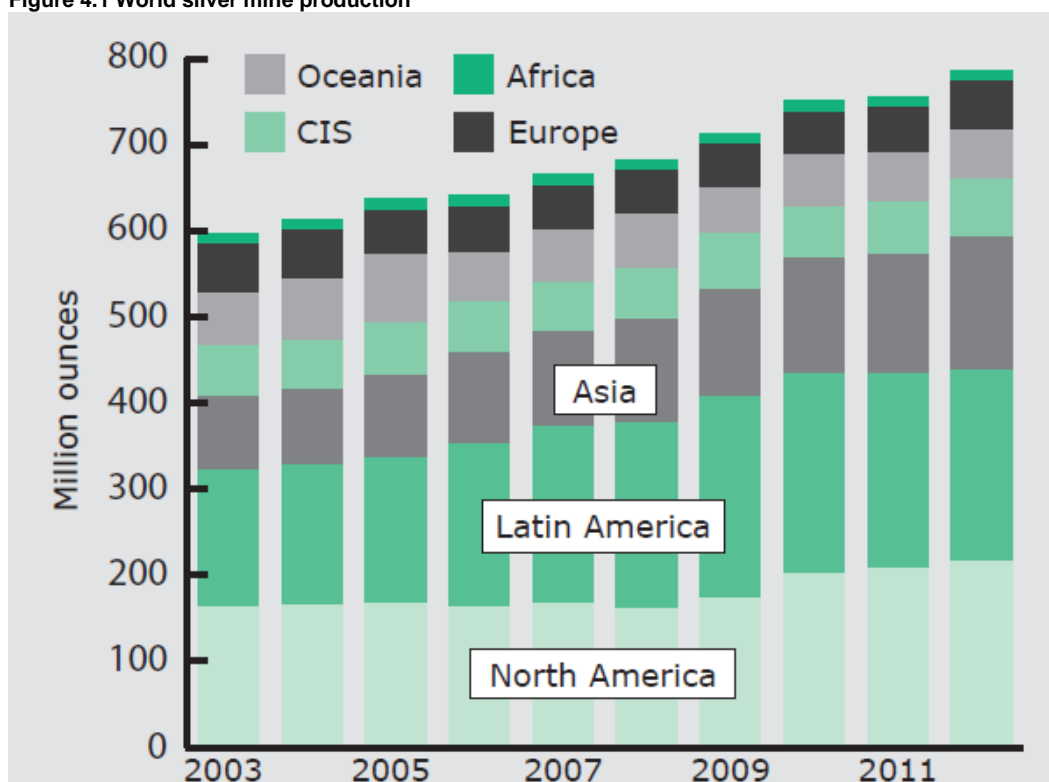
³⁸⁵ Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary. Available at

http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf

³⁸⁶ European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials. Available at http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf

³⁸⁷ http://geoportal.pgi.gov.pl/surowce/metaliczne/rudy_cu-ag

Figure 4.1 World silver mine production



Source: Thomson Reuters GFMS / The Silver Institute (2013).

Apart from mine production, silver supply comes from silver scrap (around 20%) as well as government sales and private sector disinvestment; notably governments and private investors can be net suppliers, but also net buyers, which would put them on the demand side.

Some export taxes on ores and concentrates are in place, e.g. China taxes silver ore exports with 10%. Indonesia introduced a 20% export tax in 2012, very specifically on unrefined ores, aiming at securing more rents in the processing. There are also cases of non-tariff measures, such as licensing / approval requirements for exporting unwrought precious metals in South Africa and other African countries.³⁸⁸

The EOL-RR of silver is between estimated at around 50%³⁸⁹, varying significantly between end products. Jewellery, silverware and coins are recycled with over 90%. But especially recycling rates of WEEE (waste electrical and electronic equipment) are low, which shows potential of increasing scrap silver supply if recycling is triggered. However, for some products recycling is not expected to become economically interesting, such as RFID, textiles, mirrors, glass or solar panels.³⁹⁰

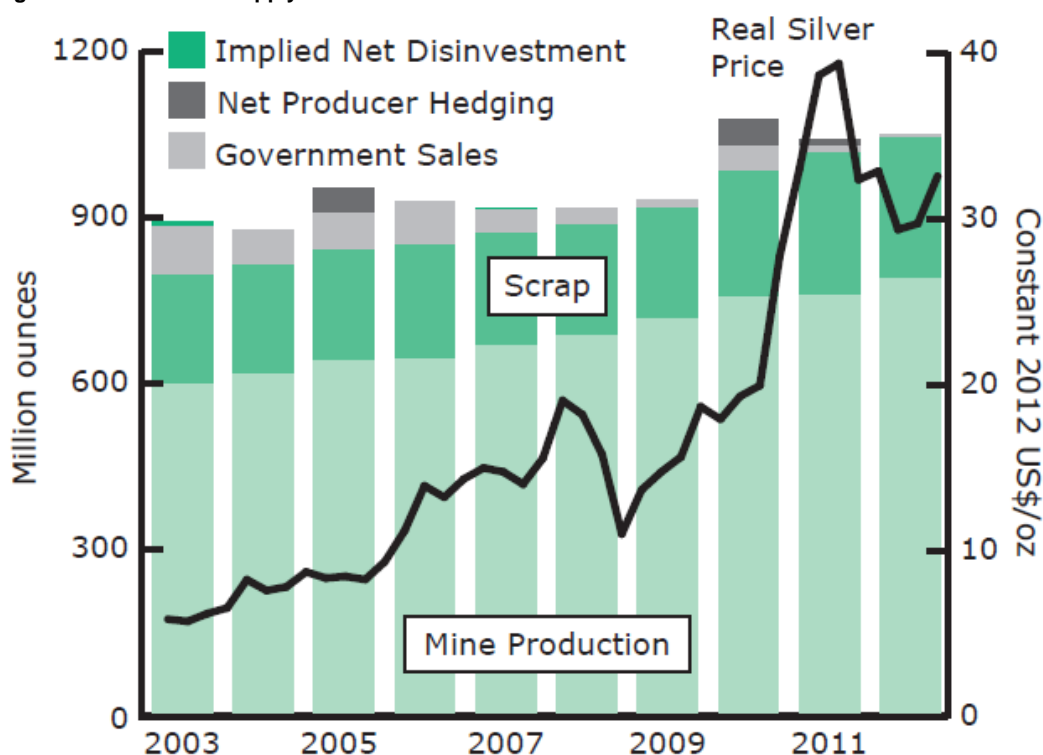
Figure 4.2 shows the development of total silver supply by different sources, plotted against the silver price development. It is clear from this figure that the price development cannot be explained sufficiently by supply.

³⁸⁸ See OECD (2010): The Economic Impact of Export Restrictions on Raw Materials. OECD Trade Policy Studies; and Kim, J. (2010), "Recent Trends in Export Restrictions", OECD Trade Policy Papers, No. 101, OECD Publishing. <http://dx.doi.org/10.1787/5kmbjx63sl27-en>

³⁸⁹ The European Commission (2010) states that the overall EOL-RR is between 30 and 50%, whereas UNEP (2011) puts it at above 50%.

³⁹⁰ European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials. Available at http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf

Figure 4.2 World silver supply



Source: Thomson Reuters GFMS / The Silver Institute (2013)

Demand

The most important uses of silver are for industrial applications (electric/electronics), due to its high conductivity, accounting for 44% of demand in 2012; jewellery (18% of demand in 2012), coins (9%), and silverware (4%), due to its decorative and bacteria-countering characteristics; coins function mainly as an investment vehicle nowadays³⁹¹, but their share of demand only reflects newly made coins; photography and mirrors (6%), using silver's highest optical reflectivity of all metals.

The remainder of demand is comprised of investment and hedging uses.

The chart below shows the development of silver demand over the last 10 years. It shows how with the financial crisis in 2009, industrial demand fell, but this was more than compensated by increased investment demand also related to the financial turmoil. "The traditional 'safe-haven' appeal of precious metals has attracted many investors to this asset class."³⁹² Industrial demand went back to pre-crisis levels as early as 2010, but has been declining since. What can also be seen is that while jewellery use of silver is relatively constant, its use in photographic applications "continued its secular decline"³⁹³ due to technological development and the corresponding increase in digital camera use.

³⁹¹ Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary. Available at

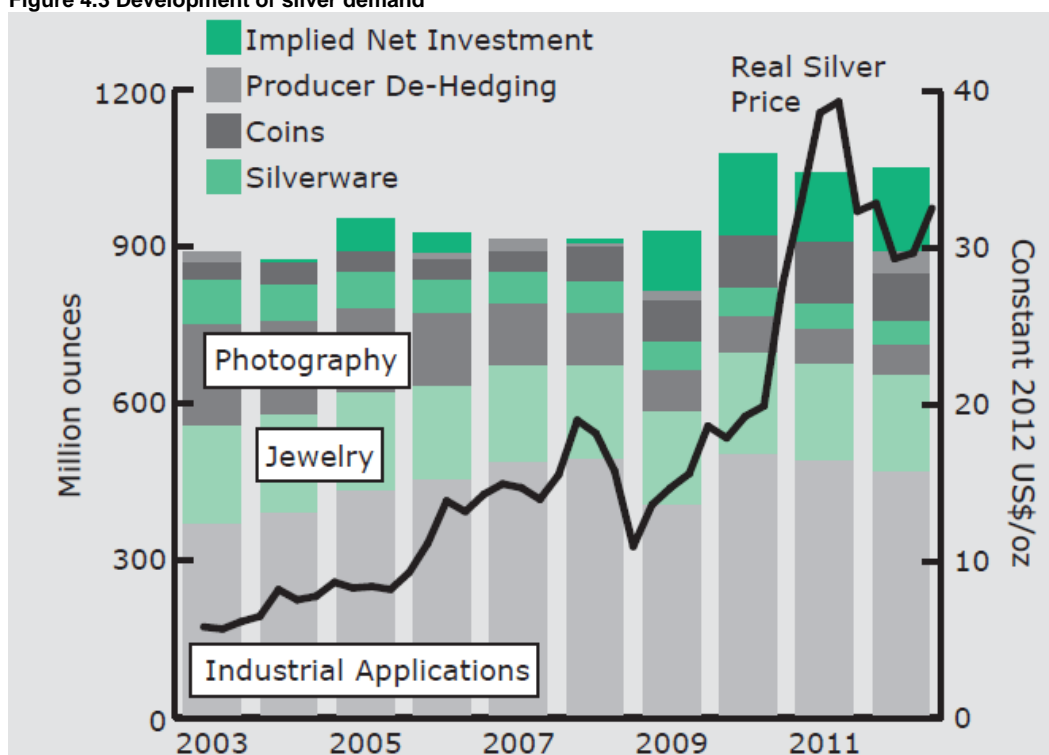
http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf

³⁹² IFSL Research (2009): Bullion Markets 2009. Available at <http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf>

³⁹³ Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary. Available at

http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf

Figure 4.3 Development of silver demand



Source: Thomson Reuters GFMS / The Silver Institute (2013)

Nevertheless, looking into the future, several areas for likely future growth in industrial silver demand can be identified:³⁹⁴

- The increased use of RFID tags and solar panels;
- The construction sector could use silver in windows as insulation;
- Mass application in small quantities as bactericide and odour-absorbing material in textiles and medical application.
- We can therefore summarize future areas for usage growth into two categories, one related to climate/energy (renewables and energy efficiency) and the other to consumer goods with small amounts of silver used, but mass production.

As the past shows, industrial use of silver has been shown as relatively volatile, depending on the general status of the world economy, and on the development of particular industrial uses. Jewellery use remained quite constant – with emerging economies compensating for demand losses from developed countries³⁹⁵ – whereas silverware seemed to respond to the low market environment as well, but its production is on a high level compared to historical standards. Net investment has clearly remained on a high level since 2009, in the same period when strong price increases could be observed.

Silver has some substitutes for its application in electrical and electronic uses, such as aluminium, copper, gold, palladium, or platinum, although their use would mean a loss of performance. Substitution in photography has already taken place due to a change in underlying technology. Substitutes for dissipative use, such as in RFID and textiles, are not available yet, but the research on this has the potential to change future demand for (physical) silver.³⁹⁶

³⁹⁴ European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials. Available at http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf

³⁹⁵ Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary. Available at http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf

³⁹⁶ European Commission, DG Enterprise & Industry (2010): Annex V to the Report of the Ad-hoc Working Group on defining critical raw materials. Available at http://ec.europa.eu/enterprise/policies/raw-materials/files/docs/annex-v_en.pdf

Supply and demand interaction

The main markets for silver can be described as transparent, but old-fashioned and investment-driven. The largest over-the-counter (OTC) trading place for silver is the London Bullion Market, where a bidding process results in a daily reference price known as the fix. The trading is dominated by institutional investors. On average in November 2008, the London Bullion Market Association (LBMA) traded 107.6 ounces of silver daily, worth \$1.1 bn. This means that an amount equal to the annual silver production was cleared at this market every 6.2 days.³⁹⁷ These figures underline the importance of silver in investment markets, and at the same time, the importance of investors in determining the silver price.

There is even an exchange concentrating on virtual trade: the Comex in New York is the main futures and options exchange, where most fund activity is focused.³⁹⁸ “Only a small percentage of the futures market turnover ever comes to physical delivery of the gold or silver represented by the contracts traded.”³⁹⁹

Notably, the market for silver is much smaller in money terms than that for gold, with gold turnover in London being more than 17 times larger than that of silver⁴⁰⁰ (and 4 times as large in exchange trading⁴⁰¹). This is one of the reasons often stated why the silver price is more volatile than that of gold. What is also peculiar about the market for silver, however, is that its price is closely linked to that of gold, but its industrial use plays a comparatively larger role. It is difficult to predict which of the two forces will dominate.

Volatility of the silver price can also be explained by the relatively low price elasticities of demand and supply: Demand’s reaction to prices is limited, as silver is needed in certain industrial applications and even investors tend to take high prices into account when urgently looking for “safe havens”. The price elasticity of supply is not very large either, as silver is mainly mined as a by-product of other materials (thus depending on their extraction, or indirectly on their price) and recycling of silver has also shown to be slow to react to price increases.

Important aspects for DSM

The following aspects are important to take away from this analysis in the context of DSM:

- The demand outlook for silver is positive (due to expected uses in the resource efficiency and renewable energy technologies and mass consumer products), but industrial demand has shown to be relatively volatile in the past;
- Low price elasticities and a multitude of factors influencing the price (in particular different types of demand) increase volatility and uncertainty;
- Global supply of silver is quite diversified, leaving no role for DSM as a global game changer in this market.

³⁹⁷ IFSL Research (2009): Bullion Markets 2009. Available at <http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf>

³⁹⁸ Thomson Reuters GFMS / The Silver Institute (2013): World Silver Survey 2013. A Summary. Available at

http://www.silverwheaton.com/files/docs_quick%20links/World%20Silver%20Survey%202013%20Summary.pdf

³⁹⁹ IFSL Research (2009): Bullion Markets 2009. Available at <http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf>

⁴⁰⁰ http://goldnews.bullionvault.com/silver_case_032520106

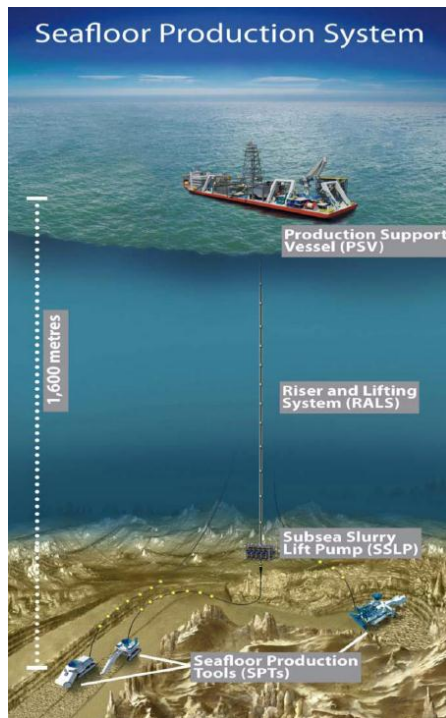
⁴⁰¹ IFSL Research (2009): Bullion Markets 2009. Available at <http://www.thecityuk.com/assets/Uploads/Bullion-Markets-2009.pdf>

Annex 3 Project sheets (example)

Solwara 1 project		
<p>Location: EEZ of Papua New Guinea (Bismarck Sea), 30 km off the coast of New Ireland Province. Latitude 3°47'25.06"S. Longitude 152°05'41.65"E</p>		
 <p style="text-align: center;">Figure 1: Nautilus Minerals PNG</p>		
<p>Source: Seafloor Mining of Massive Sulfide Deposits, Nicholas Hegedus, Patrick D'Elia, Michael Sloan, December 14, 2010</p>		
<p>Water depth: 1,600 metres</p>		
<p>Consortia members</p>		
Nautilus Minerals	Core company	
Nautilus Alliance Group	Supporting company	Supporting Nautilus technically
Placer Dome	Supporting company	Supporting Nautilus financially and technically
<p>Type of contract: Extraction</p>		
<p>Time scale:</p>		
<p>Financing: Nautilus, a Canadian company with headquarters in Toronto, is jointly owned by several of the largest mining companies in the world – Barrick Gold Corporation, Anglo-American, Teck Cominco, and Epion Holdings. The Government of PNG has a legal right to acquire up to 30% equity in the project.</p>		
<p>Government involvement: The Government of PNG has a legal right to acquire up to 30% equity in the project.</p>		
<p>Type of material to be collected: polymetallic sulphides</p>		
<p>Size of expected deposit:</p>		

Technology used:

The offshore production system comprises three main components: the seafloor production tools (SPTs), the riser and lifting system (RALS), and the production support vessel (PSV). Using the SPTs, rock is



disaggregated by two large robotic machines that excavate material using a continuous cutting process, not unlike coal or other bulk continuous mining machines on land. The Auxiliary Cutter (AC) is a preparatory machine that deals with the initial 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 Bulk Cutter (BC), has higher cutting capacity and will be limited to working benches created by the AC. Both machines leave cut material on the seafloor for collection by the Collecting Machine (CM). The CM, also a large robotic vehicle, will collect the cut material by drawing it in as seawater slurry with internal pumps and pumping it through a flexible pipe to the RALS. The RALS comprises a large pump and rigid riser pipe hanging from a vessel which delivers the slurry to the surface.

On deck of the PSV, the slurry is dewatered by conventional methods. The dewatered solid material is transferred to a transportation barge moored alongside the PSV. The return seawater is pumped back to the seafloor through the riser pipes, which also provides hydraulic power to operate the RALS pump. Discharge of the return water close to the seafloor helps to minimize impacts to surface waters.

Source: Nautilus

Obstacles:

Nautilus announced on June 1, 2012 that it was in dispute with the Independent State of Papua New Guinea ("State") as to the parties' obligations to complete the Agreement entered into in March 2011. A further announcement was made on June 20, 2012 confirming that the State had issued a Notice of Arbitration to the Company.

Nautilus considers that the State has a contractual obligation to pay an amount of approximately \$23.5 million in respect of costs incurred in the development of the Solwara 1 Project up to January 2011, and to make pro-rata capital contributions in respect of subsequent Project development costs which, at the end of September 2012 totalled approximately \$51.5 million (excluding interest). The State disputes that it is required to meet such obligations at this time.

On November 13, 2012 Nautilus Minerals Inc. announces it has decided to preserve its cash position by terminating the construction of the equipment for its Seafloor Production System.

Sources:

Annex 4 Agenda for technology and environment workshops

WORKSHOP ON THE TECHNOLOGICAL ASPECTS OF DEEP-SEA MINING

*Hotel Bloom! Brussels
29 April 2014*



We are pleased to announce an international workshop organised by Ecorys and its partners on deep-sea mining. The focus of the workshop will be to discuss findings of the on-going study on deep-sea mining and to allow for an interactive discussion on possible technology advancement.

On 30 April, another workshop is held with a focus on environmental impacts of deep-sea mining. Participants interested to join this workshop as well are invited to attend the networking dinner in the evening of the 29th April.

Preliminary schedule for the workshop technology in focus

TUESDAY, 29 APRIL 2014

10.00 - 11.00	REGISTRATION
11.00-11.30	Welcome and Introduction to the study (Roelof-Jan Molemaker - Ecorys)
11.30 -12.00	Findings of the technology analysis (Mike Buxton - TU Delft)
12.00 -12.30	Moderated discussion on: state of play of technological development (comments on the value chain, missing technologies, R&D developments) (Johan Gille - Ecorys)
12.30-14.00	LUNCH
14.00- 14.30	Plenary: statements on technology readiness levels, economic feasibility and environmental implications of various technologies

14.30-15.30	Breakout sessions (moderated by Mike Buxton, Joerg Bendorff - TU Delft, Phil Weaver - Seascope, Johan Gille - Ecorys): <ul style="list-style-type: none"> • what are key technology issues to be solved • who are key players • what stands between current and future TRL (specific issues) • have we missed any technology in the selection that you consider key bottleneck?
15.30-16.00	COFFEE/TEA BREAK
16.00-16.45	Plenary reporting back from the breakout sessions; interactive discussion on follow-up steps (Moderator: Jan Maarten de Vet)
16.45 - 17.00	Emerging key findings from the day (Roelof-Jan Molemaker)
17.00	END OF MEETING
19.00 - 21.30	Networking Dinner

WORKSHOP ON THE ENVIRONMENTAL ASPECTS OF DEEP-SEA MINING

Hotel Bloom! Brussels
30 April 2014



We are pleased to announce an international workshop organised by Ecorys and GRID Arendal on deep-sea mining. The focus of the workshop will be to discuss findings of the on-going study on deep-sea mining and to allow for an interactive discussion on possible environmental impacts.

The day before, on 29 April, another workshop is held with a focus on technological aspects of deep-sea mining. Participants interested to join this workshop as well as those arriving on the 29th in the afternoon are invited to attend the networking dinner in the evening of the 29th April.

Preliminary schedule for the workshop: environment in focus

Wednesday, 30 APRIL 2014

10.00 - 11.00 REGISTRATION

- | | |
|---------------|--|
| 11.00-11.30 | Welcome and Introduction to the study (Presenter Roelof-Jan Molemaker) |
| 11.30 -12.00 | Highlights of the environmental analysis (Presenter Yannick Beaudoin) |
| 12.00-12.30 | Land-based mining vs. Seabed mining: environmental perspective (Presenters Charles Roche and Mike Buxton) |
| 12.30-14.00 | LUNCH |
| 14.00- 16.00 | Knowledge gaps questionnaire: Live expert elicitation session
(Facilitators: Yannick Beaudoin, Phil Weaver, and Allison Bredbenner) |
| 16.00 - 16:15 | COFFEE/TEA BREAK |
| 16.15 - 16.30 | Summarizing the knowledge gaps session: What actions are needed now? (Presenter Yannick Beaudoin) |
| 16.30-17.00 | Moderated discussion on: good practices (Phil Weaver and Sven Petersen) |
| 17.00- 17.15 | Emerging findings (Roelof-Jan Molemaker) |

17.15 - 18.00

Wrap-up cocktail



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