Meeting of the Parliamentary and Scientific Committee on Tuesday 10th December

ENVIRONMENTALLY RESPONSIBLE DEEP SEA MINING

Mary Vayou MSc
Research Director Designate,
BMT Group Ltd

Deep sea and its sub-sea floor contain a vast reservoir of renewable and non-renewable physical and biological resources that are rapidly gaining scientific and economic interest. There are mineral resources (hydrothermal sulphides, polymetallic nodules and manganese crusts), huge quantities of gas-hydrates buried along continental margins, and biological resources of the deep sea floor with biotechnological and pharmaceutical applications. Related to hydrothermal systems, there is a potential for natural hydrogen from serpentinisation reactions, which may be used as an energy source. These resources have increasingly been attracting attention due to the imbalance of existing resources' distribution around the globe, affecting industrial production, energy security, seafood consumption and many other areas of maritime relevance. This is particularly true for Europe, which, though once self-sufficient in ore-production and metals, is nowadays heavily reliant on imports owing to lower-cost mining in other countries.

... potential for natural hydrogen ...

Creating a viable future, economically, socially and environmentally, is critically dependent on sustainable management of deep sea and sub-sea floor resources, as outlined in the Commission Communication [1] on tackling the challenges in commodity markets and on raw materials. Recently the EU passed extensive marine environmental protection legislation, with the clear goal that standards need to be established for the environmentally sustainable extraction, transport and use of resources taken from the oceans.

The international legal framework also comprises a whole range of relevant treaties and institutions, including: the United Nations' Convention on the Law of the Seas (UNCLOS) with fundamental goals to establish a legal order to facilitate international communication and to promote, inter alia, the peaceful uses of the seas and oceans, equitable and efficient utilisation of their resources, conservation of their living resources, and the study, protection and preservation of the marine environment; the Convention on Biological Diversity (CBD); the UN Fish Stocks Agreement; the Convention on Migratory Species (CMS); the European Marine Strategy Framework Directive; the Antarctic Treaty System; Regional Seas conventions and action plans, Regional Fisheries Management Organisations (RFMOs); the International Maritime Organization (IMO); the International Council for the Exploration of the Sea (ICES); The Convention for the Protection of the marine Environment of the North-East Atlantic (OSPAR); the Atlantic Strategy; the Blue Growth Strategy; the International Seabed Authority (ISA) and others.

... standards need to be established ...

Scientific exploration has led to the discovery of various types of deposits, but modern mapping exists over only a small portion of the seafloor. For example, on the Azores Plateau and along the Mid-Atlantic Ridge there are several recognised hydrothermal fields (sources for copper, zinc, gold and silver, high technology metals among others) and plume driven anomalies hosting massive sulphides. Between mainland Portugal and the Azores region, there are about 250 seamounts and guyots with recognised occurrences of iron-manganese crusts. Abyssal plains have revealed occurrence of nodules (sources for nickel, cobalt, Platinum Group - PGM). Gas hydrate deposits are recognised from south Portugal to north of Norway along the deeper sections of continental margins in most cases linked with deeper petroleum systems.

On the extraction front, only a limited number of companies are exclusively dealing with sub-sea mining. However, many of those already involved in oil and gas exploration and extraction, have launched innovation initiatives and follow the developments closely. To date, far reaching plans to start mining have been made by Nautilus Minerals and UK Seabed Resources – a subsidiary of the British arm of Lockheed Martin, whereas Chatham Rock Phosphate Ltd aims to start in 2015 with mining phosphates at approximately 400m depth.

... already involved in oil and gas exploration...

Nevertheless, European companies are world leaders in technologies such as dredging, drilling, cutting, transport and ROV manufacturing and operation, which will be essential when large scale offshore mining takes off. There is an opportunity for them to capitalise in the global market for production technologies, operational expertise, Environmental Impact Assessment techniques and technologies and equipment and know-how.

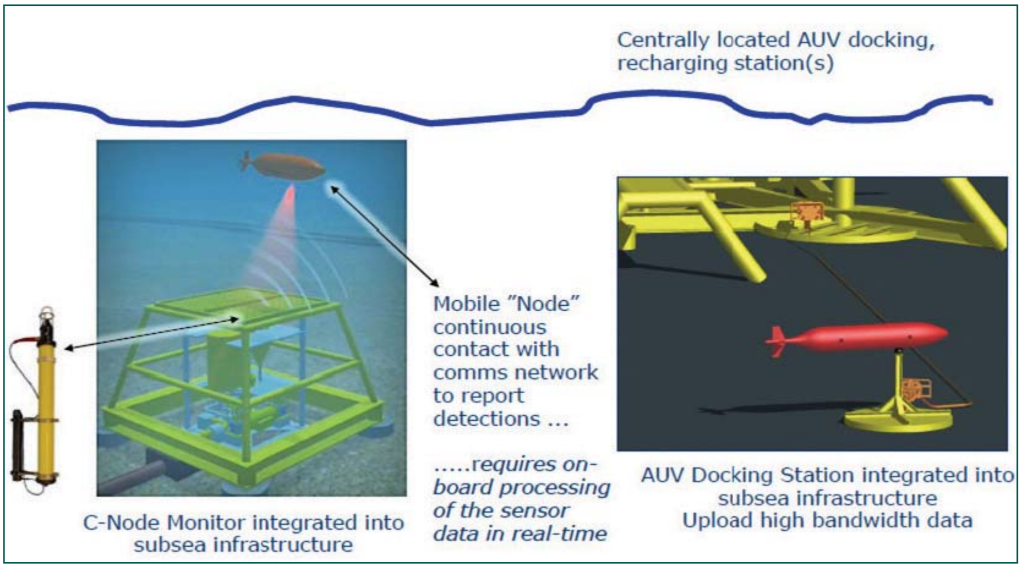
... opportunity to capitalise in the global market...

Much about the composition and distribution of the resources on and within the sea subsurface, their quantitative importance for chemical cycles and biological activity, and the potential impacts of exploitation on ocean chemistry and ecosystems remains incompletely understood. Studies indicate that removal of the target substrate will lead to local alteration or destruction of the sea floor and its associated fauna, suspension and sedimentation of sediments and will have a footprint that easily could affect areas several times larger. With nodules, sediment plumes may smother fauna and alter the seabed changing habitat and inhibiting recovery. With massive sulphides, the oxidation of released plume sediment may also have toxicological effects.

The need to maintain ecosystem integrity is key, although this may not always be possible with localised reserves. The common occurrence of endemic species on localised hydrothermal massive sulphides may seriously limit the options for conservation in one area to compensate for biodiversity loss in another (UNEP 2007)[2]. Impacts will strongly depend on local hydrodynamic conditions as well as on the activities conducted, the sensitivity of the environment and its potential for recovery. Despite emerging studies on the impact of deep-sea mining in the Pacific, our knowledge of the ecosystem/habitat resilience to deep-sea mining is limited and biased by site specifics. Current techniques and methodologies are not well suited to monitor the mining activities and measure environmental changes not only locally but also over vast areas. Deployment of research equipment still depends on scientific cruises and is prone to high cost. In order to meet environmental monitoring requirements, new techniques able to operate over long periods independent of frequent power supply and data recovery are needed.

... new techniques able to operate over long periods ...

Observatories are key emerging tools to understand the ocean and the complex physical, biological, chemical, and geological processes taken place at the sea-floor. They have evolved rapidly over the last decades by means of programs and projects based on new instrumentation and permanent



Mobile Autonomous Monitoring System with the use of AUVs underwater networks. The main on-going initiatives at global scale are in Canada (NEPTUNE), USA (OOI[3] - Ocean Observatories Initiative), Japan (DONET[4], - Dense Oceanfloor Network system for Earthquakes and Tsunamis), Taiwan

... sediment plumes may smother fauna...

(MACHO[5] - Marine Cable Hosted Observatory) and Europe (through ESONET-NoE[6] - European Seas Observatory Network of Excellence and recently with the infrastructure project EMSO - European Multidisciplinary Seafloor Observatory).

In these networks, most oceanographic instruments on the seafloor are not connected with the surface: they run on batteries and store data locally. Scientists have access to their data only after recovery of the instrument. This makes it impossible to adjust monitoring protocols until after data have been analysed and equipment redeployed. Though still in the future, the development of Mobile Autonomous Monitoring Systems using Autonomous Underwater Vehicles, as the one shown, would solve the above challenges and provide the necessary information to close the gap in real time understanding of deep-sea mining impact.

... real time understanding of deep-sea mining impact...

Responsible exploitation of this resource is directed by a need to fill knowledge gaps in resource appraisal and environmental and ecosystem functioning. Similarly, there is a need to develop protocols and technologies to mitigate against undue impacts. To achieve this will require work directly with industry towards these common goals. The very high costs of equipment and mobilisation means that Environmental Impact Assessment activities must be integrated at all stages to optimise synergies, as in the offshore hydrocarbon industry. There is a need to shorten the feedback time in design-operations cycle to reduce impact at source and increase operational efficiency.

References

1 COM (2011) 25 , February 2011

2 UNEP (2007) Deep-Sea Biodiversity and Ecosystems: A scoping report on their socio-economy, management and governance

3 http://www.whoi.edu/ooi_cgsn/home

4 http://www.jamstec.go.jp/donet/e/

5 K. Hsu, C. S. Lee, T. C. Shin, C. S. Liu, B. S. Huang, B. Y. Kuo, C. H. Lin, D. Tang, H. Y. Chang, and C. H. J. Kuo, "Marine Cable Hosted Observatory (MACHO) Project in Taiwan," in Underwater Technology and Workshop on Scientific Use of Submarine Cables and Related Technologies, 2007. Symposium on 2007, pp. 305&307

6 http://www.esonet-noe.org/

SUB-SEA MINING

DEVELOPMENTS IN SEAFLOOR MINING TECHNOLOGY

Michael Jones
Managing Director, Soil Machine Dynamics Ltd

BACKGROUND

Soil Machine Dynamics (SMD) is a leading subsea engineering company specialising in the design of subsea remote control systems for the oil and gas, telecommunications, defence, scientific, renewable and mining sectors. The company has developed since 1971, as a spin out from the University of Newcastle upon Tyne, gaining a reputation for supplying innovative equipment for the burial of pipelines and cables. In 2003 SMD entered the work-class Remotely Operated Vehicle market and is now the world's number one manufacturer. SMD has recently expanded from deep-sea trenching into seafloor mining equipment. It has received five Queen's Awards for both International Trade and Innovation, with three of those awarded consecutively since 2011.

This article focuses on the technology being developed by SMD for the Seafloor Production Tools (SPTs) for Nautilus Minerals Inc (NMI) for their Solwara 1 copper/gold deposits in the Bismarck Sea, off Papua New Guinea.

Solwara 1 Project

As economic surface resources are gradually depleted, the search for replacement mineral commodities is shifting towards new environments such as seabed mineral deposits. Nautilus Minerals Inc is a pioneer in the exploration of the seafloor to find economically attractive massive sulphide deposits. NMI is developing the world's first deepwater copper/gold deposit for commercial extraction known as Solwara 1. The deposit is a massive sulphide formed around hydrothermal vents. It lies in the Bismarck Sea at 1600m depth between New Ireland and New Britain in the territorial waters of Papua New Guinea. More details can be found at www.nautilus minerals.com

The solution for recovering the ore from the seafloor (figure 1) comprises:

- Production support vessel – which provides the operational base for deploying the riser and lift system and the seafloor production tools. It also dewaters the ore, and stores it until it is offloaded to transport vessels.
- Riser and Lifting System – which comprises a steel riser and a subsea slurry lift pump.
- Seafloor Production Tools – three remotely operated machines which cut and collect the ore and feed it to the subsea lift pump.

... flexibility with respect to the mining conditions likely to be encountered ...

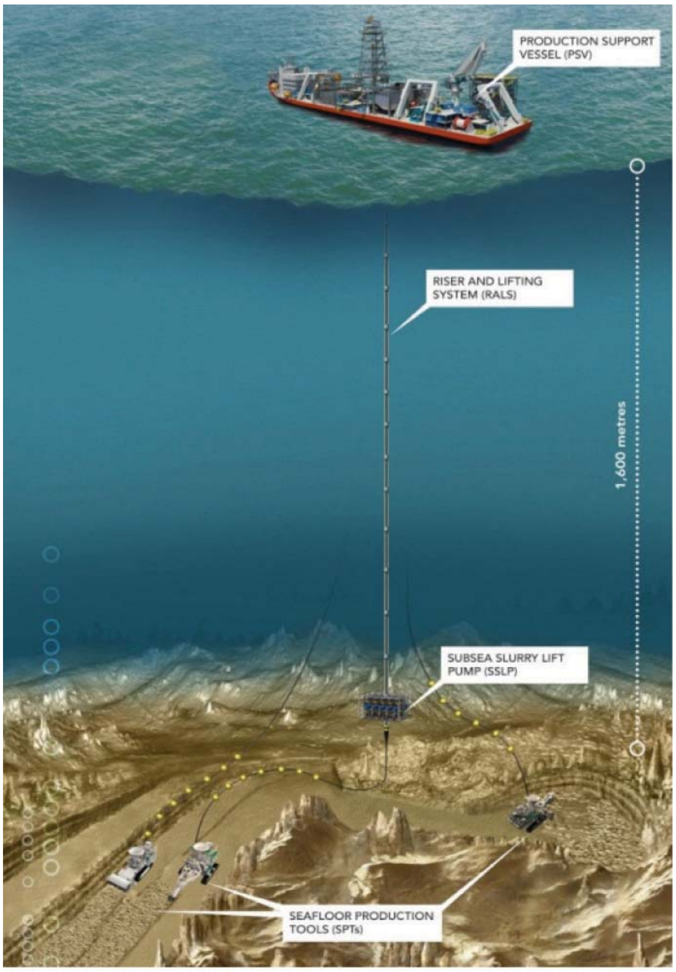


Figure 1: Ore recovery system – Courtesy of Nautilus Minerals Inc

Seafloor Production Tools

The seafloor production tools which are currently being developed by SMD for delivery in 2015 comprise three remotely operated mining vehicles: the Auxiliary Cutter, the Bulk Cutter and the Collection Machine. These are illustrated in Figures 3 to 5. The philosophy has been to leverage technology developed by SMD in their deep water remotely operated heavy duty trenching systems (figure 2). This technology has been combined with proven techniques such as continuous miners and road headers used in underground mines and in shallow water dredging used for extracting sediments. They have been designed to provide flexibility with respect to the mining conditions likely to be encountered. At the same time, commonality of components has been built in wherever possible, minimising the amount of critical spares to be carried for successful remote operation.

The first of these tools, known as the Auxiliary Cutter (AC), is the pioneer machine which will be used to level remnant thermal chimneys, provide access and prepare initial benches for the other production tools. The machine weighs 250 tonnes and uses 600kW counter-rotating cutter-heads on a swinging boom. It moves on heavy duty tracked undercarriage and has two spuds for stabilisation during cutting operations. A pump collects the cut ore and moves it to stockpiles on the seafloor for further processing.

... The drum cutter of this machine will be the largest ever built ...

The second is the primary production tool, the Bulk Cutter (BC). This is a heavy duty tool which runs on tracks. The drum cutter of this machine, which is based on existing technology, will be the largest ever built. The BC operates on the pre-mined bench with the drum engaged in the ground in front of the machine. The machine, like the AC has a collection system which pumps the cut material to

Figure 2: SMD heavy duty remote controlled subsea trenching machine, RT1 – Courtesy of Deepocean Ltd

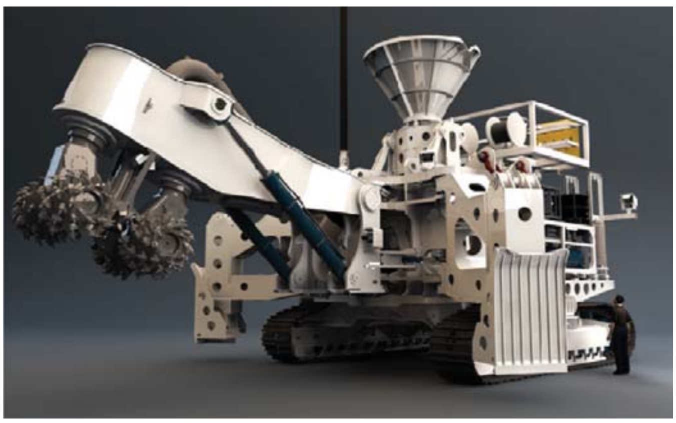


Figure 3: Auxiliary Cutter – Courtesy of Nautilus Minerals Inc

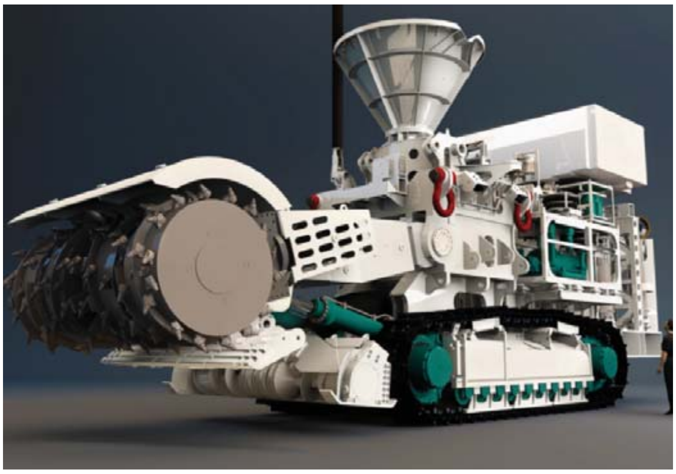


Figure 4: Bulk Cutter – Courtesy of Nautilus Minerals Inc

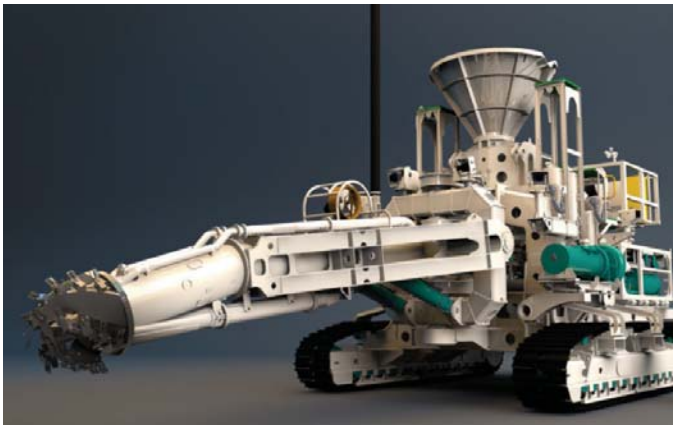


Figure 5: Collection Machine – Courtesy of Nautilus Minerals Inc

stockpiles ready for extraction as a slurry by the Collection Machine (CM). The CM is connected to a riser transfer pipe. It collects stockpiled ore and pumps it through the flexible transfer pipe to the subsea lifting pumps. From there the ore is pumped through the riser and up to the support vessel. This machine has a crown cutter on a ranging boom used to collect pre-mined ore. It also has a bank of dredge pumps used to mobilise the ore slurry. Due to its permanent connection to the subsea pump, which is in turn connected to the vessel, the CM's operating range and that of the vessel is inextricably linked.

... minimise dispersion of sediments ...

The design of the SPTs and their operation is based around minimising impact on the environment. For instance biodegradable oils are used, and the cutting and collection systems have been designed to minimise dispersion of sediments in the water column.

Remote Control System

With a subsea system operating a mile below the vessel connected only by an umbilical, ensuring that the vehicles are reliable and the operator is aware of the position and status of the vehicle is paramount. The water depth, seascape and mining process make all of these criteria challenging. Using SMD's years of experience of developing control systems for subsea vehicles an ergonomically designed "active chair" with monitor wall has been chosen to guarantee that the operators can monitor and control the vehicles comfortably for long periods of time. The chairs are designed around the concept of a pilot and a co-pilot for each vehicle. The pilot is concerned with the primary driving and production requirements of a vehicle, whereas the co-pilot is more involved in monitoring and recording events. Both active chairs contain a mixture of joysticks, push buttons and touch screen controls (figure 6). The operator's control screens are based around SMD's standard software control platform, with a number of operational, status and logging screens being available. The operator screens can be navigated around via the touch screen or roller ball controls mounted in the arm of the active chairs.

Figure 6: Pilot Control – Courtesy of Nautilus Minerals Inc

To allow the pilots to see what is going on during mining operations in addition to standard survey equipment and cameras a novel 3D sonar system is fitted to each vehicle. The system utilises nine imaging and profiling multi-beam sonar heads to allow the operator to see around the vehicle and measure cut depths accurately. As well as providing real time sonar images to the pilots, the system also provides a virtual seascape with the vehicles mounted upon it and the cutting or suction heads articulated so that the pilot can see what is happening on the seabed.

SUMMARY

This programme is one of the most exciting offshore engineering projects currently being undertaken. There has been interest from the subsea and mining industries and a high level of cross-industry co-operation throughout the project. This will enable the dawn of a new industry to extract minerals from the seafloor. The UK subsea industry, with 53,000 employees and worth £8.9 billion per annum in services and products, is already a world leader in technology for deep water oil and gas exploration and production. The UK is uniquely positioned to be at the forefront of a developing market in subsea mining.

... system also provides a virtual seascape ...

THE ENVIRONMENTAL IMPACTS OF DEEP SEA MINING

Daniel Brutto MBA MSc BSc (Hons)
Director, Marine Ecological Surveys Limited

The idea of extracting minerals from deep seabed environments fomented in the 1960s, following reports by Mero [1] that large volumes of high grade metalliferous nodules could be found on the seabed across vast swathes of the oceans. However, initial enthusiasm for the idea dissipated and the concept drifted out of vogue as research demonstrated that the extent of resources appeared to have been over-estimated and global metal prices declined considerably. This combination of factors meant that the economic arguments which supported the industry, and which had once sounded so compelling, were undermined and riven with flaws. The nascent industry became less attractive to developers and progress during the 1980s and early 1990s was negligible.

However, the idea of deep sea mining is again moving up the marine industry agenda with activity within the industry gaining significant momentum. This upturn in momentum is being driven by the scarcity and the accessibility of terrestrial resources. Metal prices, while volatile, are moving upwards across medium to long-term time horizons, increasing the economic viability of the industry.

... initial enthusiasm for the idea dissipated ...

The focus of the industry is on three principal resources, namely [2]:

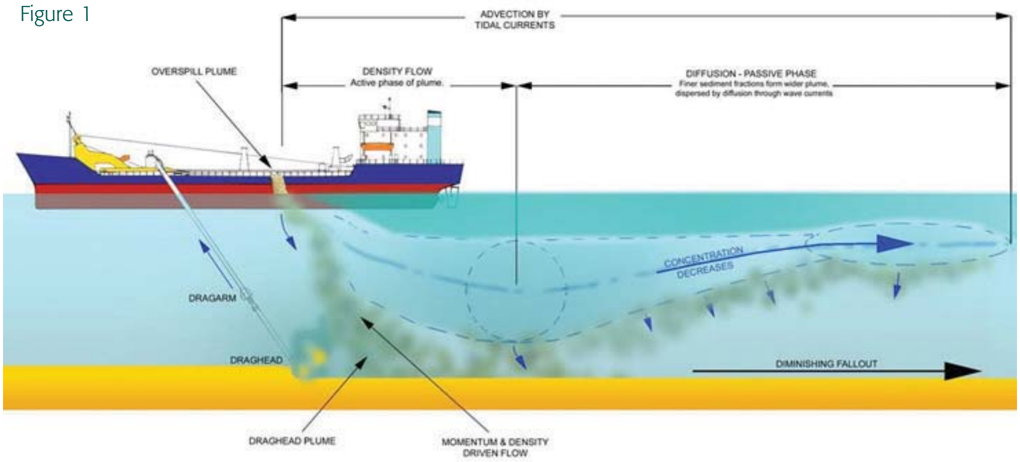
- Seafloor Massive Sulphides (SMS);
- Polymetallic Nodules; and
- Cobalt-rich Ferromanaganese Crusts.

Each of these deep sea mineral resources are found across distinct environments, with SMS deposits occurring at hydrothermal vents, polymetallic nodules typically being found on the abyssal plain and cobalt-rich ferromanganese crusts usually found on the flanks of sea mounts. There is interest in exploiting each of these resources, with progress across the three resources at different stages.

Presently, the greatest levels of activity are being directed towards exploiting SMS and polymetallic nodules, with Nautilus Minerals gearing up to exploit SMS deposits in the Bismarck Sea [3] and numerous entities engaged in the exploration of nodule concessions found in the international waters of the Clarion-Clipperton Fracture Zone [4]. To date there has been lesser interest in the exploitation of cobalt-rich ferromanganese crusts, however, activity in this area is beginning to grow [5].

Despite increasing interest and activity within the sector, the industry remains in a nascent state. We do not yet live in a world in which deep sea mining

Figure 1



is a reality. Hence, there is much that we do not yet know about how this industry will interact with marine environmental resources. However, there is a great deal that we do know, or which we can reasonably assume, through looking at analogous industrial activities

... industry remains in a nascent state ...

undertaken within shallower waters.

In essence, the fundamental principles which will support the deep sea mining industry represent an extrapolation of those used within other marine extractive industries which rely

Gardline's Ocean Reliance, a multirole survey vessel

on dredging techniques to extract materials from the sea floor, be it for the purposes of extracting sand and gravel for cement manufacture or the creation and maintenance of shipping channels. Such activities have been well studied by companies such as Marine Ecological Surveys Limited [6] and the ways in which these activities affect the environment are comparatively well understood.

Figure 1 provides an outline of the physical impacts which marine extractive industries typically impose upon the marine environment. The physical environmental impacts of dredging-related industries comprise both primary and secondary effects. Primary physical impacts are those associated with the removal of the substrata from the seabed and are restricted to the immediate footprint of the active operational zone. Secondary impacts comprise those which can be devolved further afield and include the following;

- The creation of sediment plumes within the water column;
- The deposition of any sediments mobilised within any plumes;
- Acoustic effects;
- Toxic effects caused by the mobilisation of toxic substances.

Each of the above can affect the environment in different ways, depending on the environmental sensitivities of the area concerned. For example, in shallow, low turbidity

... mobilisation of toxic substances ...

environments plumes have greater potential to impact adversely on the environment than plumes created in deeper waters in areas of greater turbidity. This is because of the importance of light in shaping the ecosystems found in shallower, low turbidity environments compared to deeper, higher sediment environments.

The above example indicates that to be able to predict the impacts of marine extractive projects it is vital that, in addition to understanding the physical impacts of such projects, one possesses an understanding of the environmental resources. In traditional marine extractive industries such environmental resources have been comparatively well studied, hence scientists have a correspondingly strong ability to predict their environmental impacts.

As the environmental resources of the deep sea have

... the majority of animals which are found in the deep ...

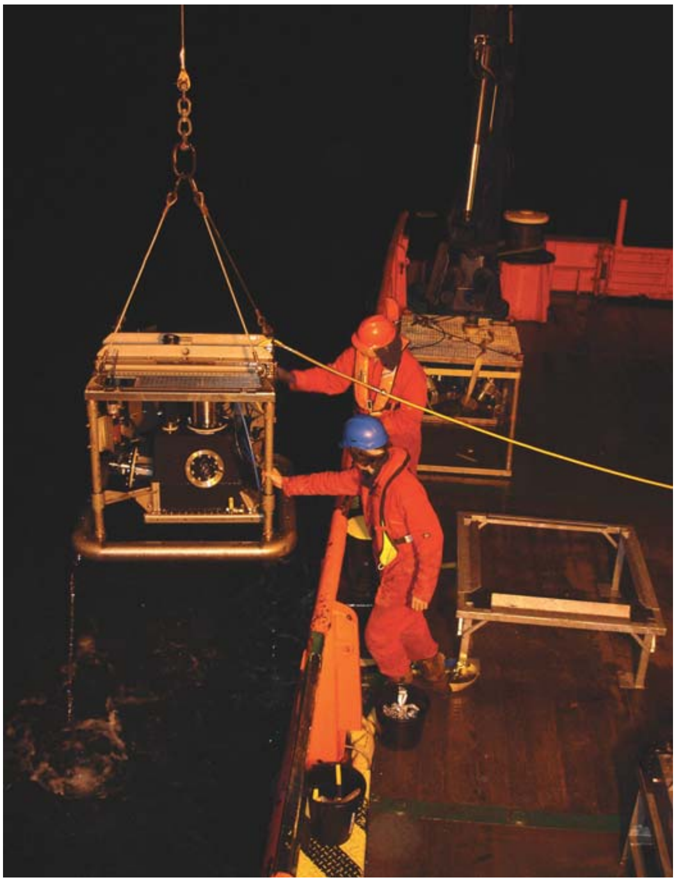
been less well studied our ability to predict the impacts of deep sea mining activities is less robust. We are unfamiliar not only with the majority of animals which are found in the deep, but with their life histories, their distributions, and their ecology. Hence, our ability to understand how they might respond to anthropogenic disturbance is limited.

Our present lack of knowledge of the potential ecological impacts of deep sea mining has led to the development of a view within certain quarters of the prospective industry as controversial. Notable anti-deep sea mining campaigns, including the Out of Our Depth Campaign and Greenpeace's Deep Seabed Mining campaign, have been launched in response to growing industry activity.

In the light of these sensitivities and the unknowns pertaining to deep sea mining, it is vital that the industry operates in an open manner, and that operators seek a collaborative approach to working with scientists, industry regulators and the general public.

Developing a robust understanding of the environmental impacts of deep sea mining will necessitate making direct investments into research into specific issues by a range of organisations, separately and collectively, at a range of different levels. For example, companies may be required to undertake Environmental Impact

Emptying a 0.1m2 Hamon Grab During a Research Cruise



Retrieving a seabed camera

Assessments (EIA) on a project by project basis and may need to commission detailed research into specific areas. At higher levels industrial operators may wish to collaborate in order to progress strategic research programmes, the results of which may help to overcome industry-wide barriers. Regulators may wish to commission research to inform the decision-making processes.

It is encouraging that efforts are being made to address knowledge gaps pertaining to the environmental impacts of the industry at numerous different levels. For example, within Europe programmes such as the Managing Impacts of Deep Sea Resource Exploitation (MIDAS)[7] project have been established to examine the industry from a variety of perspectives, whilst Nautilus have established the Nautilus Cares[8] programme and seek to work with teams of experts to address stakeholders' concerns about their activities.

Whilst these early efforts at developing a better understanding of the composition, structure and function of the ecosystems which will be affected by the deep sea mining industry are to be applauded it is important that research is not only continued, but accelerated and co-ordinated. This will ensure that funds are used effectively, allowing our understanding of the environmental impacts of the industry to keep pace with the industry, ensuring that environmental issues do not act as an unnecessary brake on progress. The Marine Aggregates Levy Sustainability Fund[9] model developed in the UK to administer research into the environmental impacts of marine aggregates extraction would serve as a fine example to follow in terms of progressing strategically valuable research in this space.

The nascent deep sea mining industry represents an opportunity to gain access to the mineral resources required for economic development. There is much that we can assume about the industry in terms of the way in which it will impact the marine environment based on our knowledge of other industries. However, it is evident that the industry must work hard to ensure that the right knowledge of the environments within which it will operate is developed through commissioning primary research, with the results disseminated across all appropriate stakeholders. This will allow the industry to demonstrate its credentials for responsible development whilst contributing to the reduction of the uncertainties pertaining to consenting and licensing processes providing developers with greater certainty in terms of the likely acceptability of their proposals to decision-makers and increasing the potential for making successful investments.

Separating Infauna from Seabed Deposits

References:

1 J. L. Mero (1965). The Mineral Resources of the Sea. Elsevier, Amsterdam, The Netherlands.
2 http://www.isa.org.jm/files/documents/EN/ Brochures/ENG6.pdf
3 http://www.nautilusminerals.com/s/Projects-Solwara.asp
4 http://pang.org.fj/wp-content/uploads/2013/03/CCZ_Sep_2012_offcial_withAPEIs.pdf
5 http://www.isa.org.jm/en/node/914
6 www.seasurvey.co.uk
7 www.eu-midas.net
8 www.cares.nautilus minerals.com
9 www.cefas.defra.gov.uk/ alsf.aspx

The MESL Macrofaunal Lab Identifying Benthic Fauna