DEEP-SEA MINING: AN EMERGING MARINE INDUSTRY – CHALLENGES AND RESPONSES

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SYNOPSIS

Deep-sea mining is an emerging marine industry that presents particularly complex challenges due to its multi-faceted political, economic, technological, scientific, environmental, social, industrial and legal aspects, all of which must be addressed to achieve commercially viable results. Furthermore, these aspects are either governed by or must take into account the burgeoning regulatory regime promulgated by the International Seabed Authority, with consequent effects on operating conditions. This paper describes the three principal deep-sea metal-bearing hard mineral deposits that are of the most immediate interest to the deep-sea mining industry, i.e., ferro-manganese nodules, cobalt-rich ferro-manganese crusts and polymetallic sulphides, and their distinctive biogeophysical marine environments (abyssal sediments, seamount flanks, and hydrothermal vents, respectively), and presents an overview of their resource interest, extraction technologies, technical and environmental issues, international regulatory context, and innovative responses to these myriad challenges. It suggests that experience gained in the deep-sea mining industry could inform the responsible development of other new deep sea industries, such as those related to marine genetic resources.

INTRODUCTION

Deep-sea mining is an emerging marine industry that presents particularly complex challenges due to its multi-faceted political, economic, technological, scientific, environmental, social, industrial and legal aspects, all of which must be addressed to achieve commercially viable results. Furthermore, these aspects are either governed by or must take into account the burgeoning regulatory regime promulgated by the International Seabed Authority (ISA), with consequent effects on operating conditions. This paper describes the three principal deep-sea metal-bearing hard mineral deposits that are currently of the most immediate interest to the deep-sea mining industry, i.e., ferro-manganese (Fe-Mn) nodules, cobalt (Co)-rich Fe-Mn crusts and polymetallic sulphides, and their distinctive biogeophysical marine environments (abyssal sediments, seamount flanks and hydrothermal vents, respectively), and presents an overview of their resource interest, extraction technologies, technical and environmental issues, international regulatory regime, and innovative responses to these myriad challenges. It suggests that the experience of the deep-sea mining industry could inform the responsible development of other new deep sea industries, such as those related to marine genetic resources. The author aspires to convey a flavor of the nature, variety, complexity and fascination of the challenges facing this bold new marine activity.

THE RESOURCES

Fe-Mn Nodules

The oceanic Fe-Mn nodules of interest here are sediment-hosted, moveable, hydrogenous deposits found at abyssal depths between 3,500-5,000 m. They form very slowly (~5-15 mm/million years) around a solid nucleus, primarily on or in sediments by precipitation of their constituent elements from the water column and sediment interstitial waters. Depending on which metal source predominates during their formation, nodules are classified as mainly hydrogenetic or diagenetic, respectively. Their formation environment largely determines their relative metal concentration and growth rate. For example, primarily hydrogenetic nodules are enriched in Co and nickel (Ni), and depleted in copper (Cu) and zinc (Zn), with a Mn/Fe ratio of <2.5. Their principal mineral phase is vernadite (delta-MnO_2). Primarily diagenetic nodules are enriched in Ni, Cu and Zn, and relatively depleted in Co, with highest Ni and Cu concentrations found at Mn/Fe ratios ranging between 2.5 and 5. Their principal mineral phase is todorokite. Mixed-type nodules have a hydrogenetic (vernadite) component on top where the nodule is exposed to the water column and a diagenetic (todorokite) component where it is buried in the sediment, with the relative element concentration varying concomitantly as described. Nodule metal content is related to the mineralogy. The composition of hydrothermal nodules is distinctively different, not of current resource interest, and not addressed. Metals of commercial interest are Cu, Ni, Co, Zn, Mn, Bismuth, Lithium, Molybdenum, Niobium, Tellurium, Titanium, Tungsten, Yttrium, Zirconium and Rare Earth Elements (REE).

Co-rich Fe-Mn Crusts

The oceanic Co-rich Fe-Mn crusts of interest here form even more slowly than Fe-Mn nodules (~1-5 mm/million years) by precipitation of their constituent elements from the water column on hard, sediment-free surfaces of seamounts and other submarine topographical elevations exposed to currents. Crusts are classified as almost entirely hydrogenetic and are not sediment-hosted. They are particularly enriched in Co, and depleted in Cu and Zn. The Mn/Fe ratio ranges between 0.91 and 1.56. Their principal mineral phases are ferruginous vernadite (Fe-rich delta-MnO_2) and amorphous Fe oxyhydroxide; the latter is usually finely intergrown with vernadite. The highest Co concentration is usually found in crusts at depths between 1500-2500 m, although prospectively interesting crusts can be found at depths ranging between 1000-3000 m. The composition of hydrothermal crusts is distinctively different, not of current resource interest, and not addressed. Metals of commercial interest are Co, Ni, Mn, Platinum, Bismuth, Niobium, Molybdenum, Tellurium, Thorium, Titanium, Tungsten, Yittrium, Zirconium and REE.

Polymetallic Sulphides

The polymetallic sulphide minerals of interest here, also known as sea-floor massive sulphides (SMS), form on and below the sea floor through the interaction of seawater with magma. In seismically active areas, especially at divergent and convergent plate boundaries, cracks in the sea floor facilitate cold seawater reaching hot magma located many kilometers down at the mantle, where it is heated to 350-400°C. This hot seawater leaches metals from the rock and magmatic fluids, and the resulting buoyant and expanding metal-enriched heated fluid rises back up to the seafloor. Here much of it is ejected back into the overlying cold seawater, where the dissolved metals precipitate and are deposited as polymetallic sulphides in the form of chimneys. SMS ore bodies, the most prospectively interesting form of this resource, form immediately below the seafloor under the chimneys. Metals in solution are entrained in the hydrothermal plumes emitted from the chimneys (the color of these plumes depends on their composition and temperature and gives the chimneys their common names – black, white, grey, and yellow smokers). These plumes can be detected at considerable distances from their original site of emergence into the overlying seawater. Although the chimneys themselves can grow quickly, SMS are not a renewable resource. Many thousands of years are needed to produce a commercially attractive SMS deposit. Polymetallic SMS are the only prospectively interesting hydrothermal mineral deposits discussed in this paper. Metals of commercial interest are Cu, Gold, Silver, Zn, Antimony, Bismuth, Cadmium, Gallium, Germanium, Indium, Tellurium, Thallium and Selenium.

MINING CYCLE AND TECHNICAL CHALLENGES

Overview

The three principal stages in a commercial mining cycle are:

1) Exploration: Resource Location and Assessment
2) Exploitation: Mining and Processing
3) Closure: Site Remediation and Monitoring

The three resources addressed here represent three different types of metal-bearing mineral deposits from three distinctive biogeophysical deep-sea environments. Each type of deposit presents individual technical challenges at each stage of the mining cycle at the mining site. The technical challenges derive from:

1) The deposit itself (nodule, crust, polymetallic sulphide)
2) Its biogeophysical environment (abyssal sediments, seamount, hydrothermal vent system)
3) Regulatory requirements (these are mostly environmental and they differ for each deposit).

One challenge that all three deposits share is their location on and below the seabed far offshore: at least 25 nautical miles (nm) from land (i.e., outside the 12-nm territorial sea) and usually much further out to sea, i.e., beyond 100 nm in the Exclusive Economic Zone (EEZ; this extends 200 nm from a fixed baseline, which under current international law is usually the low-water line along the coast as marked on official charts of the relevant coastal state) and on the (outer) continental shelf (which may under certain circumstances, not addressed here, extend out to 350 nm or 100 nm from the 2,500-m isobath), and including sea areas beyond any national jurisdiction, i.e., the so-called high seas. These deposits are found in the Pacific, Indian, and Atlantic Oceans, listed here in best prospectivity order based on current knowledge. So far, most of the most immediately prospective resources have been found outside national jurisdiction, which under international law triggers application of the regulatory regime of the international community (see further below), with concomitant consequences for commercial operations..

Current marine industries are major sources for deep-sea mining equipment and technology; these include: offshore oil and gas, dredging, cabling, and "wet" diamonds. Most crucially, and of particular interest, is the creative adaptation of these existing technologies necessary to suit the specific needs of each deposit. Deep-sea mining requires the multi-disciplinary skills offered by, e.g., engineers, scientists, technologists and naval architects. All have essential contributions to make, as do the deep-sea mining regulators and legal advisers, who will ideally also be equipped with sufficient relevant engineering, scientific and technological knowledge to know when and where to seek further information, to consult widely with stakeholders, and to proceed cautiously.

Exploration: Resource Location and Assessment: Selected Technical Challenges

a) Nodules: abyssal plains; deposit extent, sediment depth and type, metal content and consistency of that content; topography (e.g., slope – abyssal plains have hills)

b) Crusts: (old, e.g., at least pre-Miocene) seamounts; deposit thickness, grade and extent (e.g., obscured by sediment cover); mining feasibility (topography and seamount substrate)

c) Polymetallic Sulphides: (in)active vents, deposit size (seabed and sub-surface), metal content; mining feasibility (topography); drilling technology (e.g., for sampling in seismically active areas)

The full portfolio of currently available and creatively adapted sophisticated exploration techniques and equipment is required (e.g., bathymetric mapping tools, water samplers, photo and video cameras, seabed samplers (e.g., corers, dredges, grabs, drills), remotely and/or autonomously operated devices), together with appropriately adapted vessels from which to deploy them that are also able to stay at sea for the long periods required to conduct these surveys (30-60 days), and the multi-disciplinary personnel qualified to operate these systems and interpret the results. The continuous reliable availability of and access to global positioning and satellite-based data-gathering systems, at the highest level of resolution, are fundamental.

Exploitation: Mining and Ore Preparation: Selected Technical Challenges

One basic mining concept with four major components applies to all three deposits.

a) Seafloor mining device
b) Vertical transport system
c) Ore preparation
d) Mining support vessel

Seafloor mining devices will differ substantially for each deposit. The current approach to polymetallic sulphide mining most closely resembles terrestrial mining, conceptually and practically, as it involves extraction of surface and subsurface massive ore bodies that require bulk and auxiliary cutters. Furthest advanced in this context at present is Nautilus Minerals, whose seafloor mining tools, built in the United Kingdom by Soil Machine Dynamics, are shown on the Nautilus website (www.nautilusminerals.com). Ore disaggregation is a major technical challenge for polymetallic sulphide mining. At present it is expected that the mining tools will be remotely operated and attached by umbilical to the mining support vessel.

Prototype nodule-mining systems have been deployed for several decades. Three concepts are under consideration: hydraulic, continuous line bucket, and shuttle. Of these the first at present seems to be gaining the most attention. If a hydraulic approach is used, the mining tool, as with polymetallic sulphides, will be remotely operated and attached by umbilical to the mining support vessel. Its operation has been likened to that of a terrestrial combine harvester. Technical challenges include: operability at very low temperature (~2^{o}C), very high pressure (~400 bar), and on soft surfaces (sediments); minimizing sediment collection with the nodules; turbidity generation overall; long-term reliability and very low maintenance (repairs will be very difficult).

Crust mining is considered to be the most technically challenging of the three, especially with regard to removing crusts from the underlying substrate with minimal collection of that substrate, and with regard to operating mining tools on the complex, steep topography of seamounts. Early conceptual designs exist in the literature, but the most current approaches are proprietary. Of the three resources considered here, crusts are likely to be mined last.

Vertical transport systems are likely to be the most similar for the three resources. These will probably include some form of flexible jumper to convey the ore in a seawater slurry to a vertical riser that is attached to the mining support vessel. The slurry will be conveyed up the riser to the vessel via a lifting mechanism, for which hydraulic and airlift approaches are under consideration. Fully enclosed riser and lifter systems are preferred; environmentally these have particular advantages (e.g., miminization of sediment dispersal in the water column). Offshore oil and gas industry experience with riser and lifting technology is informing deep-sea mining riser design.

Ore Preparation addressed here is only the initial at-sea preparation of the ore on the mining support vessel for on-land processing, as further at-sea processing is not currently considered to be commercially viable. At present, this preparation is confined to ore dewatering and removal of fines. As much seawater as possible must be removed from the slurry before the ore is transported to land. Dewatering will most likely occur on board the mining support vessel itself, or on an auxiliary vessel, moored alongside the mining support vessel, to which the ore is transferred and that will transport the ore to land. Fines are likely to be retained as well; they have value, and if treated as a waste, their environmentally responsible disposal, both at sea and on land, is difficult. The de-ored seawater under current designs for both nodules and polymetallic sulphides is currently likely to be disposed of at sea. The depth at and method by which this disposal occurs, the quality of seawater to be disposed (e.g., temperature, composition), as well as the disposal-at-sea option itself, are the subject of extensive debate, and involve a variety of environmental, engineering, technical and commercial considerations.

Mining Support Vessels must provide a large, stable platform on and from which all the mining operations will be conducted. They must be able to remain at sea continuously for up to a year and accommodate a large, multi-disciplinary team, comprising, e.g., the ship's own officers and crew, and the mining company's engineers, technicians and other specialists. Efficient top-side vessel design is critical; it is likely to include, e.g., A-frames, general and specialist cranes, the dewatering system, a derrick/moon pool and on-deck storage for, e.g., risers and umbilicals. If it operates sufficiently close to shore (unlikely for CCZ nodules), a helicopter landing pad is likely to be included. The Nautilus SMS mining vessel, commissioned in November 2014, with completion currently expected in 2017, will provide useful insights.

Closure: Site Remediation and Monitoring: Selected Technical Challenges

For all three resources: long-term (at least 10 years) monitoring of mined and control sites is necessary, because biological processes in the slow deep-sea are usually very slow. The two principal disturbances, of the sediment and hard-substrate communities at the seafloor, are likely to be irremediable. Monitoring is extremely costly. Therefore considerable attention is being given to designing the deep-sea mining systems to minimize and mitigate the effects of these disturbances *ab initio*. Extensive consultation with scientists specialized in deep sea ecology is ongoing.

ENVIRONMENTAL ASPECTS

Overview

An extensive and rapidly growing body of scholarly literature, far too voluminous to discuss in detail here, addresses the potential and actual effects on the marine environment of deep-sea mining. The effects are usually addressed in three contexts that common to all three resources addressed in this paper: at the surface, in the water column, and at and below the sea floor. The surface and water column effects are likely to be similar for all three resources. The most extensive effects, i.e., those with the most potentially long-term consequences, are likely to occur at the seafloor. The most environmentally problematic effect in this context is the permanent removal of hard substrate for which certain organisms and communities are obligatorily specialized. This is a particular issue for sessile (permanently affixed, at least as adults) biota found on nodules and crusts. These organisms cannot live on soft substrata (i.e., sediments). The effects of sedimentation, sediment compaction, and crushing of sediment-hosted organisms by the seafloor mining tools are also considered to be likely to have particularly problematic environmental consequences (the latter two effects may be less severe for SMS and crusts as these resources, although usually covered by some sediment, are not sediment-hosted). The principal environmental issues are summarized below, as are the principal environmental advantages, because it must be emphasized that deep-sea mining, considered both on its own and in the context of the overall global stressors on the health of this planet, has much to offer that is environmentally constructive. For further detail, please see the section on further reading and selected references at the end of this paper.

Summary of Principal Environmental Issues

- Permanent removal of hard substrate for which certain organisms/communities are specialized
- Sedimentation (bottom and surface/mid-water)
- Noise
- Vibration
- Light
- Leaks, spills, effects of corrosion
- Operational discharges from the surface vessels (governed by IMO treaties and regulations)
- Slow and different biological regeneration (especially sessile communities); remediation potential (e.g., with tailings) but probably unlikely to be successful
- Vessel traffic for ore transport to shore for land-based processing
- Vessel-source air pollution
- Surface and mid-water marine community disturbance, especially if mining vessels remain on location for many months

Summary of Principal Environmental Advantages

- Little or no overburden to remove (on land the overburden can be 75% of the mined material)
- Much less ore is needed to provide same amount of metal (ore grades at sea can be up to 7 times higher than on land)
- Three or more metals can be obtained at one site
- No local human populations to disrupt
- No permanent infrastructure.

INTERNATIONAL LEGAL AND REGULATORY CONTEXT

United Nations Convention on the Law of Sea (LOSC)

Overview

The LOSC is our world's "Constitution for the Oceans" (Koh, 1982). Negotiated over nearly ten years, it entered into force on 16 November 1994; it has 167 parties (out of - currently - 193 members of the United Nations) as of 1 September 2015. Comprised of 320 Articles and 9 Annexes, it is one of the longest and most complex multi-lateral treaties concluded to date. Furthermore, it is the most powerful and comprehensive treaty governing human activities on this planet extant so far. No terrestrial (land-based) equivalent exists. The LOSC aims to have an all-inclusive scope with regard to law of the sea issues (see Preamble, first chapeau). Because it applies also to land-based and atmospheric activities when the marine environment is or may be adversely affected, its remit in this context spans the planet. The concern of the drafters of the LOSC for the marine environment permeates the treaty. In addition to an entire chapter (Part XIII, see further below) being dedicated to this subject, the very first Article of the LOSC already addresses the marine environment by setting out an all-encompassing definition of 'pollution of the marine environment'. Note that this definition applies to anthropogenic CO_2 emissions, regardless of their source. In the environmental context, note the extensive use of the precautionary words 'may' and 'likely' in provisions designed to establish circumstances under which action to protect and preserve the marine environment is required.

An essential source of the LOSC's power is that its provisions are usually mandatory, unqualified, and without exceptions. The mandatory nature of its provisions is demonstrated by the extensive use of the mandatory verb 'shall', employed in international treaty parlance to establish binding obligations on the parties to the treaty. In this context, 'shall' may be considered as being synonymous with the verb 'must' in English. The unqualified nature of its provisions is illustrated by the virtual absence of phrases such as 'in accordance with capabilities', 'as appropriate', 'as far as possible', 'as far as practicable,' whose use in treaties, even when coupled with 'shall', unfortunately tend to negate in practice these treaties' obligatory intentions. Exceptions in the LOSC usually apply only to "warship[s], naval auxiliary[ies], other vessels or aircraft owned or operated by a State and used…only on government non-commercial service" (LOSC Art. 236), but even in that context States must ('shall'), albeit weakened with qualifications, ensure that these vessels act consistently with the Convention. Furthermore, LOSC Art. 309 explicitly prohibits reservations or exceptions, and LOSC Art. 310 reinforces this prohibition for States becoming parties to the LOSC. Finally, many of its provisions are now considered to have codified, or to have become, customary international law, thereby making it exceedingly difficult under international law for non-parties to act inconsistently with those provisions.

The LOSC and Deep-Sea Mining

With regard to deep-sea mining, this paper focusses on the LOSC provisions applicable to the mineral resources found in areas beyond national jurisdiction. Of these, the most important in the present context are LOSC Part XI, LOSC Annexes III and IV, and the 1994 Implementing Agreement (IA; in force 28/07/1996; 147 parties as of 1 September 2015. The IA is interpreted and applied as a single instrument with the LOSC. Note the LOSC definition of the 'Area', 'activities in the Area', 'resources of the Area': these definitions all relate only to the seabed/subsoil and solid, liquid, or gaseous minerals found in areas beyond national jurisdiction, and thereby set the jurisdiction of the International Seabed Authority (ISA; see further below), the body set up under the LOSC (Part XI Section 4) to administer activities in the Area and the resources of the Area.

Legal Status of the Area and Its Resources

Both are the common heritage of mankind, a status which entails that no state may exercise sovereignty or sovereign rights over the Area or its resources and that rights in resources of the Area (i.e., minerals) are "vested in mankind as a whole", on whose behalf the ISA acts (LOSC Art. 137(2)), but only for those specific rights. The legal status in the Area of non-mineral resources, such as, e.g., marine genetic resources, is unclear.

Selected LOSC Provisions Relevant to Environmental Aspects of Deep-Sea Mining

<u>Part XI (Area), Annex III (Basic Conditions of Prospecting, Exploration and Exploitation), Part XI Implementing Agreement (IA)</u>

- Part XI (Art. 145): prevent/reduce/control pollution and other hazards to and interference with ecological balance of the marine environment; protect and conserve <u>*natural*</u> resources of the Area and prevent damage to flora and fauna of the marine environment
- Part XI (Art .147(1)&(3)): conduct other activities in the Area *and in marine environment* with reasonable regard for mineral activities and *vice-versa*
- Annex III Art. 17 – sets out what ISA must regulate: Marine environment: (1)(b)(xii) & 2(f)
- Annex III Art. 14(2): Marine environmental data are not proprietary
- IA: Preamble; Section 1(g),(h,)(i),(k)

<u>Part XII (Protection and Preservation of the Marine Environment)</u>

- Art. 192: "States have the obligation to protect and preserve the marine environment."
- Art. 194(5): measures required to protect and preserve rare or fragile ecosystems [and] depleted, threatened or endangered species and other forms of marine life
- Arts. 204 & 206: require both environmental impact assessment and monitoring

- Art. 209: marine environmental protection requirements specifically for the Area; includes flag states
- Art. 215: enforcement of marine environmental protection rules in the Area (see also Art. 153(5) Part XI)

Part XIII (Marine Scientific Research)

- Art. 240(d): Marine scientific research is subject to Part XII (marine environmental protection) rules (see also Art. 87(1): on high seas freedoms, which include marine scientific research; their exercise is not unrestricted, All high seas freedoms must be exercised with due regard for activities in the Area (Art 87(2)).
- Art. 256: Marine scientific research may be conducted in the Area (see also LOSC Art. 87(2) & LOSC Part XI Art. 143) by the ISA, States Parties and other competent international organizations
- Arts. 242 and 243: International cooperation in general and between ISA, States Parties and Contractors in particular on marine scientific research is encouraged, especially on the marine environment and related research (see also LOSC Art. 143 on marine scientific research in the Area). This cooperation is essential for developing and implementing *cumulative* environmental impact management systems.

International Seabed Authority (ISA)

Overview

The ISA implements the LOSC and the IA on deep-sea mining. It is headquartered in Kingston, Jamaica (www.isa.org.jm). All LOSC parties are ISA members. It holds annual meetings in Jamaica in July. The ISA has the exclusive right to manage seabed minerals in the Area, and the exclusive right to issue exploration and exploitation licenses (contracts) for minerals in the Area. It is not empowered to exclude other (non-mineral) activities in the Area, even in areas for which it has issued an exploration license. It is not empowered to issue licenses for activities related to other (non-mineral) resources in the Area. The UN General Assembly follows ISA activities closely.

The ISA develops internationally legally binding regulations. So far the ISA has issued regulations governing the exploration for nodules, crusts and sulphides. The exploitation regulations are now being developed, for which the ISA is making extensive use of an innovative international consultation process. The mineral resources of the Area are the common heritage of mankind, and the ISA is consulting mankind on how these resources are to be exploited and how the proceeds are to be allocated (see, e.g., ISA Report to Stakeholders (ISBA/Cons/2015/1) and the Center for International Law/National University of Singapore/ISA Joint Workshop held in June 2015; https://www.isa.org.jm/sites/default/files/files/documents/bp4-final-web.pdf). All the responses to the ISA consultations are available on the ISA website. Other innovative ISA initiatives, similarly developed, include requiring preservation reference zones and impact reference zones in contract areas proposed for mining and the development of an Environmental Management Plan for the six-million-km^2 Clarion-Clipperton Zone (CCZ) in the Northeast

Pacific Ocean ISBA/17/LTC/7 (13 Ju1y 2011).The CCZ, named for the two E-W-trending fracture zones it lies between, covers the currently most prospective known nodule resource region in the world's oceans.

The ISA observes the LOSC Art.169 requirement to consult and cooperate with intergovernmental organizations (IGOs) and with non-governmental organizations (NGOs) recognized by the UN Economic and Social Council (ECOSOC), all of whom may express their views, even in the annual meetings of the ISA Council and Assembly, according to procedures established by the ISA. Procedures to express views directly, rather than through their sponsoring state, in these latter meetings have not yet been established for contractors.

Pursuant to LOSC Arts. 208 and 209, ISA Regulations operate to also set minimum environmental standards for national (*within* EEZ) deep-sea mining regulations. The ISA environmental regulations are already extensive (see references). National deep-sea mining regulations are still quite rare but increasingly more states are promulgating them, especially within the last five years; so far it appears* that Belgium, Cook Islands, Fiji, Tonga, New Zealand, Papua New Guinea, United Kingdom have adopted specific environmental regulations for deep-sea mining. *(*I have not myself read all this national legislation.)* The ISA Regulations have also informed the development in July 2012 of the Secretariat of the Pacific Communities (SPC) and European Union (EU) Pacific-ACP States Regional Legislative & Regulatory Framework for Deep Sea Minerals Exploration and Exploitation (available from the Applied Geoscience and Technology Division (SOPAC) of the SPC at www.sopac.org).

The ISA sponsors research, workshops, and publications. The results are freely available on the ISA website. Much of this technical activity is channelled through the ISA's Legal and Technical Commission (LTC). Composed of 25 scientists and lawyers, it has a heavy workload. For example, the LTC reviews draft regulations, examines and recommends actions by the ISA Council on applications for work in the Area, monitors and comments on the contractors' work in the Area through the annual reports the latter are required to submit, and deals with the implementation of the extensive marine environmental protection duties imposed by the LOSC for deep-sea mining activities. Every year the LTC holds two week-long meetings in Jamaica (2015: February and July).

ISA Environmental Impact Assessment (EIA) Requirements

Contractors must collect oceanographic and environmental data for:

- Baselines to assess natural change and likely effects of activities
- Monitoring and evaluation methodologies and programs
- Designation of Impact and Preservation Reference Zones

The Reference Zones must be representative of the site to be mined with regard to its environmental characteristics and biota (e.g., species composition). The Preservation Reference Zone must be of an appropriate size and in a location where it will be unaffected by mining, including sediment plumes. It is used to identify natural variations in environmental conditions.

The ISA environmental data requirements are extensively set out. All relevant data (including hydrographical, chemical and biological data), data standards and inventories, cruise reports, and raw environmental data**,** in the format established by the ISA, are to be made freely available for scientific analysis within four years after completion of a research cruise. An inventory of the data holdings from each contractor is to be accessible on the World Wide Web. Metadata describing analytical techniques, error analyses, descriptions of failures, techniques and technologies to avoid, comments on sufficiency of data and other relevant descriptors must be included with the actual data. To answer certain questions on the environmental impacts of mining, specific experiments, observations and measurements must be conducted. In this context, even if the LOSC did not already do so, collaborative research by contractors would have been, and is, strongly encouraged by the ISA. It stresses that all contractors need not execute the same studies, and it encourages, advises, and assists in identifying cooperative research opportunities between contractors and other research communities. Such collaborative research is needed to, e.g.:

- Minimize and possibly mitigate the effects of the loss of hard substrate (e.g., in the CCZ: nodules)
- Enhance natural recolonization of the seabed
- Develop methods to minimize effects of the direct disturbance of the sea floor and of material carried in, and deposited from, the operational plume.

This requires detailed, <u>long-term</u> (at least ten years, and in the deep sea that may not be long enough) regional *and* local baseline and operational research, including experiments and models. The major challenges are to first minimize and then, if possible, mitigate and remediate the effects of mining with regard to, in particular, sedimentation and the removal of hard substrate.

The ISA needs all this information because it must engage in <u>*regional*</u> environmental management, which includes assessment and management of cumulative and local impacts of mining activities, biodiversity conservation, and facilitation of benthic recolonization. For an area the size of the CCZ, and with (as of 1 September 2015) 16 different contractors from 20 different countries, this is a daunting challenge. Nevertheless, the CCZ is the area where these requirements are going to be first set out and tested. This is because the CCZ is the only region in the deep sea that has been subject to ongoing research in all the oceanographic and some of the engineering disciplines since the 1960s, and because its nodules are the closest to exploitation of the three categories of resources located in the Area. All 20 countries, except India, which focuses on the Indian Ocean, have exploration licenses for nodules in the CCZ.

The ISA has now (2015) decided to embark on its LOSC-mandated (Art. 154) operational review, as its current structure, staffing, and budget are under increasing strain from the burgeoning number of exploration licenses under its management (26 as of 1 September 2015, for all three categories of resources, in the Pacific, Atlantic and Indian Oceans.) The exploration licenses are for fifteen years; seven of these licenses, all for the CCZ, will expire in 2016 (6) and 2017 (1). No exploitation licenses have yet been applied for. As of 1 September 2015 the ISA is dealing with 16 contracts for nodules; all in the CCZ except India, whose concession is in the Indian Ocean; six for sulphides and four for crusts.

International Tribunal for the Law of the Sea (ITLOS)

Established pursuant to LOSC Art. 287(1)(a) and operating according to its statute under LOSC Annex VI, the International Tribunal for the Law of the Sea (ITLOS; www.itlos.org), based in Hamburg, Germany, has 21 Judges who serve nine-year (re-electable) terms and are appointed by vote of the LOSC parties at the latter's annual meeting. LOSC Article 186 provides for a Seabed Disputes Chamber, which has 11 Judges. On 1 February 2011, the Chamber issued a pioneering Advisory Opinion (pursuant to LOSC Art. 191) on responsibilities and liabilities of states engaging in marine mining (LOSC Art. 139), especially with regard to the marine environment, holding that all countries, regardless of their developmental status and financial and technical capabilities, must comply with LOSC/ISA mining environmental regulations (see: http://www.itlos.org/fileadmin/itlos/documents/cases/case_no_17/adv_op_010211.pdf). For an excellent and concise scholarly overview of this opinion, see the analysis by Professor David Freestone, www.asil.org/insights110309.cfm.

International Maritime Organization (IMO)

Headquartered in London, the International Maritime Organization (IMO; www.imo.org) has promulgated and continues to develop and update a suite of environmental and safety treaties for the global shipping community, on topics including (for environmental aspects) air pollution, anti-foulants, ballast water, chemicals, garbage, greenhouse gas emissions, noise, oil, pollution response, sewage and ship recycling. The scope of the IMO's safety treaties is equally extensive. The IMO hosts >30 IGO meetings annually; usually they are one week each. The IMO's rules are usually legally binding and set minimum national standards. The IMO treaties govern the operation of ships that will engage in deep-sea mining. Cooperation between the ISA and IMO is formalized in a Memorandum of Understanding (MoU).

Although its Secretariat is hosted by IMO, the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its 1996 Protocol (known as the London Convention and Protocol; LC/LP) constitute a separate and powerful treaty system, which also has a dedicated scientific group that meets annually, usually in the spring, for a week, that is relevant to deep-sea mining operations. Although the LC/LP exclude "the disposal {or storage – LP} of wastes or other matter directly arising from, or related to the exploration, exploitation and associated off-shore processing of seabed mineral resources is not covered by the provisions of {these treaties}", the LC/LP and the ISA share environmental concerns with regard to deep-sea mining that will benefit from cooperative approaches; an MoU between them is under discussion. Also important to watch is the work of the LC/LP on the disposal at sea of land-based mining tailings; see, e.g, the outcome of the June 2015 GESAMP workshop, hosted by Peru (http://www.dicapi.mil.pe/taller/en/down_workGesamp.html). The LC/LP parties meet annually in London for a week, usually in the autumn).

***Ad Hoc* Open-ended Informal Working Group [on] ….. Conservation and Sustainable Use of Marine Biological Diversity Beyond Areas of National Jurisdiction (BBNJ Working Group)**

After nine meetings (1st in 2006 and the last in January 2015, this group, set up by the UN General Assembly (UNGA) to recommend means of regulating in areas beyond national jurisdiction marine genetic resources (including benefit sharing); area-based management tools, e.g., marine protected areas, environmental impact assessments, capacity-building, and transfer of marine technology, agreed to recommend to the UNGA the development of a LOSC implementing agreement for conservation and sustainable use of marine biological diversity in BBNJ (http://www.un.org/Depts/los/biodiversityworkinggroup/). The UNGA approved this recommendation by UNGA Resolution A/RES/69/292 (currently available as A/69/L.65) on 19 June 2015.

The BBNJ discussed deep-sea mining in 2008 and 2011. The latter meeting was addressed by the ISA Secretary-General, who also advised the BBNJ of a pioneering large-scale environmental research project conducted under ISA auspices, whose results are reported in the document entitled: "Biodiversity, species range and gene flow in the abyssal Pacific nodule province: predicting and managing the impacts of deep seabed mining (ISBA/14/C/2)." The BBNJ's work will overlap with the ISA's remit; for example, the ISA cannot exclude, e.g., activities related to marine genetic resources in the Area, even in areas for which it has granted exclusive rights to for mining activities.

European Union Regulatory and Technical Initiatives

EU MIDAS | Managing Impacts of Deep Sea Resource Exploitation

The European Union (EU) is becoming increasingly involved in this topic as well. In addition to the ACP template legislation described above, MIDAS, a multi-disciplinary EU-funded research program to investigate environmental impacts of extracting mineral and energy resources from the deep sea, is to develop recommendations for best practice in the mining industry and develop legislation accordingly. Set up in November 2013 for 36 months, MIDAS has 32 European partners of scientists, industry, social scientists, lawyers, NGOs and SMEs **(http://eu-midas.net/)**.

***EU Technical Mining Development Projects* (as of 1 September 2015)**

- **http://www.bluemining.eu/**: develop key technologies for exploration (discovery and assessment) and exploitation of deep sea mineral resources up to system/subsystem model or prototype demonstration
- **Blue Atlantis:** https://ec.europa.eu/eip/raw-materials/en/content/innovative-mining-marine-mineral-resources-%E2%80%93-european-pilot-mining-test-atlantic-tools: deep-sea mining test facility in the Azores
- **http://vamos-project.eu**/: To develop a prototype underwater, remotely controlled, mining system with associated launch and recovery equipment.

Selected International NGO Initiatives

International Marine Minerals Society's Code for Environmental Management of Marine Mining (IMMS Code)

Only one international learned professional society, the International Marine Mineral Society (IMMS), is dedicated exclusively to marine mining. The IMMS is a non-profit organization founded in 1987 (www.immsoc.org). It runs the Underwater Mining Institute (UMI), the first and longest-running (UMI held its first conference in 1970) annual conference series solely on marine mining. As befits an international body, the UMI holds its conferences all over the world (e.g., 2011: Hawai'i; 2012: China; 2013: Brazil; 2014: Portugal; **2015: Florida – St. Petersburg – 1-4 November.** Korea, Germany and Norway will be the host countries in 2016, 2017 and 2018, respectively. Major players in marine mining from all relevant countries, companies and organizations, as well as from academia, are represented in its membership. The IMMS newsletter, Soundings, provides regular overviews of the latest deep-sea mining developments.

The IMMS developed the first and so far only full-cycle international environmental marine mining code. Initiated in 2000 at UMI 30 and adopted in 2001, the Code was fully revised after an extensive consultation process, including presentation for comments to the ISA's LTC and Council in 2010, and the revised version was adopted in 2011(www.immsoc.org/code). The Code is intended to:

- Complement/improve existing and supplement incomplete/absent international/national environmental regulations from exploration to post-closure
- Provide framework to appraise actual and proposed environmental practices by companies/entities
- Establish a consistent environmental 'playing field'
- Set transparent environmental reporting standards
- Use active, up-to-date industry expertise and experience

The Code is voluntary, not legally binding and designed to be dynamic, with a feedback and review process. It is increasingly cited in scholarly and grey literature, and is used by countries, the EU, the UN, and the ISA in their own regulatory developments. The present author coordinated the revision of the Code.

INTERRIDGE: http://www.interridge.org/

- promotes interdisciplinary, international studies of oceanic spreading centers by creating a global research community, planning and coordinating new science programs that no single nation can achieve alone, exchanging scientific information, and sharing new technologies and facilities
- ~2500 member researchers and 30 member nations

INDEEP: International Network for Scientific Investigations of Deep-Sea Ecosystems: http://www.indeep-project.org/

- develop and synthesize understanding of deep-sea global biodiversity and functions and provide a framework to bridge the gap between scientific results and society to aid in the formation of sustainable management strategies

VentBase**:** a forum to aid effective management of deep-water hydrothermal vent seafloor massive sulphide deposits (www.indeep-project.org/ventbase).

CONCLUSIONS

1. Commercially and environmentally responsible deep-sea mining is feasible.

2. The LOSC mining provisions and their implementation by the ISA are central to useful developments in law of the sea and international law for all emerging – and existing – marine activities.

3. Particularly useful aspects include:
- Innovative approach to treaty 'amendment'
- Definition and applicability of 'precautionary'
- Elaboration of State responsibility and liability rules, especially their equal applicability to all states
- Strengthening of environmental protection requirements
- Wide-ranging consultations with stakeholders

4. International law requirements remain to be translated into consistent, effective and fully enforced national and international legislation

5. Early, sustained, pro-active and constructive engagement by all stakeholders is essential.

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