Deep Sea Mining

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As land-based mining industries face increasing complexities, e.g., diminishing return on investments, environmental degradation, and geopolitical tensions, governments are searching for alternatives. Following decades of anticipation, technological innovation, and exploration, deep seabed mining (DSM) in the oceans has, according to the mining industry and other proponents, moved closer to implementation. The DSM industry is currently waiting for international regulations that will guide future exploitation.

Keywords: deep seabed mining (DSM) ; International Seabed Authority (ISA) ; environmental impacts ; sustainability ; governance

1. General context

Following decades of anticipation, technological innovation and exploration, deep seabed mining (DSM) in the high seas may no longer be a science-fiction-like vision, but according to the mining industry and other proponents, it may be a possible reality in the coming years [1][2]. While the global economy is concerned over an eventual decline in key metal ore-grades on land alongside increased environmental and social concern tied to terrestrial mining, a new 21st century ‘Klondike gold rush’ is on the horizon; a race to the bottom that, while alarming to many marine scientists, aims to exploit the vast and highly unknown tracts of the deep seabed [1][3][4].

The debate on DSM often emanates from the notion that modern society depends on an ever-increasing steady flow of metals and minerals; as alongside future global population growth, the demand for metals is expected to rise [1]. Economic growth, green technology, and the production of electronic goods are driving the mining industry into new frontiers. Land-based mining industries have a harder time discovering high-grade ores, a trend fuelling the exploitation of lower-grade sites and mining in new distant areas at greater depths. Terrestrial mining is already causing social conflict and environmental harm ridden by issues such as land grabbing, toxic waste, and the destruction of natural habitat [3]. Many scholars assume that the recycling potential of already existing ‘hibernating’, urban metal stocks is significant. So called urban mining would help slow the mining of virgin materials [5]. According to a World Economic Forum (WEF) 2019 report, only around 20% of global metals are recycled from scrap and electronic waste [6]. The anticipated intensifying trend towards ‘peak minerals’ could spur new political clashes as available land for mining increasingly becomes a scarce commodity, one that pits giant mining firms against food production, safe environments, and housing for future populations [7] (pp. 183–210). The interest in exploiting deep sea minerals, such as polymetallic nodules containing nickel, copper, cobalt, and manganese is driven by the rapidly increasing demand for metals used in, for example, batteries to power electric cars, making smartphones, or for storing solar and wind energy. Hence, governments are now searching to diversify supply to secure future profits and production [1]. This demand is a key driving factor behind interest in the deep seabed, an interest that has awoken from its slumber after a loss of attention in the 1980s [8]. As metal demand surges, WEF writes in a 2020 report directed at manufacturers that the time to get involved into the DSM process is now. They foresee DSM minerals to enter the metal market within a decade and call for all relevant stakeholders to engage in the technical, environmental, and social sustainability aspects of it [9].

No commercial-scale mining of the deep sea (approximately 200 to 6000 metres below sea level) has yet taken place, even though there are several existing projects on shallower seabeds within nation-states’ jurisdictional waters [4]. Nevertheless, the International Seabed Authority (ISA), the UN body responsible for regulating the deep sea beyond national jurisdiction, have to date awarded 30 exploration contracts with 21 different contractors. In accordance with UNCLOS, actors comprise of state enterprises and private corporations that have sponsoring from their state of nationality. The contracts span over 15 years and have been agreed upon by nations such as China, Japan, Germany, Russia, France, and the United Kingdom [8][10]. The ISA has for the last 25 years been the sole deciding authority on exploration licenses, reviewing environmental impact assessments, and ensuring sufficient monitoring of the mining activities in the Area. The ‘Area’ is defined as ‘the seabed and ocean floor and the subsoil thereof, beyond the limits of national jurisdiction’ [11].

The DSM industry is waiting for the ISA to finalise the ‘Mining Code’, a code that sets out to be an overarching legal document with guidelines for future exploitation. Currently delayed, the ISA was anticipating a finalised document in 2020, and appears to be pushing towards a faster, rather than slower, consensus decision to commence exploitation, according to some observers at the expense of scientific robustness [1][12][13].

2. Historical Overview

Manganese nodules (described as the most feasible deep sea resource for exploitation) were, until after the Second World War, described almost in the same mysterious fashion as moon rocks. However, during the era of modernist beliefs guided by technological advancements during the 1950s and onwards into the 1970s, governments began envisioning the potential of harvesting resources firstly from outer space, and secondly, from the deep sea [8][10]. United Nations General Assembly (UNGA) Resolution 1348 from 1958 illustrates the visions of nations: ‘to promote the fullest exploration and exploitation of outer space for the benefit of humankind energetically’. A few years later in 1966, a similar message was agreed upon in UNGA Resolution 2172, stating that the exploitation of the deep ocean would be an effective way to raise the resources and financial means needed for global development and prosperity [10]. In 1965, Dr. John L. Mero, an American engineer, published the book “The Mineral Resources of the Sea”. In it, Mero painted a picture of an infinite and easily obtained metal resource; nodules were growing at a faster rate than any possible exploitation effort could harvest them [8].

Following the end of the colonial era, recently independent developing countries were promised by developed UN nations that future exploitation of the seabed (and space) would help address inequality gaps between the Global North and the Global South. Concerns for potential environmental impacts were brought up at the time, however, these remained generally ignored due to the vastness of the ocean [10]. With support from their respective governments, companies in the West began exploring the possibilities of mining the ocean. Several multinational consortia were created to overcome financial and technical risks. The global spending on DSM peaked at the end of the 1970s only to see a dramatic drop in the coming decade [8]. Technical constraints that remained unsolved, alongside the potential for regulations, resulted in several nations shifting focus back to land [14]. However, the interest never entirely ceased, and governments in China, India, and South Korea, to name a few, continued exploring manganese nodules and two other types of deep-sea resources, seafloor sulphides and cobalt-rich crusts [8].

The revived interest in all three deep sea resources from the millennial turn and up until the present day can be tied to their revamped financial viability, technological innovations, and the political economy of the global metal market. Price volatility, the control of essential resources, and growing demand for metals linked to green technology and sustained economic growth instill vulnerability and concern for continued development [8][10][15].

3. Resources of the Deep

Each mineral deposit differs from the other in terms of unique surrounding ecosystems, connections to biogeochemical cycles, and technical difficulties in obtaining them. A fourth resource related to DSM, phosphorite deposits found on continental margins, is left out of this review as the other three are considered to be more feasible for extraction.

3.1. Manganese Nodules

Manganese nodules, also referred to as polymetallic nodules, are most easily described as potato-sized rocks found on the abyssal plains approximately 3000–6000 m below sea level [13][16]. Covering approximately 70% of the ocean seafloor, these plains, despite the name, are not flat but have varied topography, which not only diversifies the fauna, but also makes potential mining more difficult. Even though most of the deep sea plains remain unexplored, they are believed to be the largest ecosystems on earth boasting a vast species richness and undocumented taxa [16]. Nodules may contain high grades of manganese minerals, nickel, cobalt, copper, zinc, and traces of other attractive metals such as lithium, which are enticing to mining companies. The nodules form very slowly, and it is estimated that they grow at a rate of merely 2–10 mm per million years. They can be found in the abyssal plains of three large ocean basins; the Indian, Pacific, and Atlantic Oceans. Nodules provide the nearby benthic life with a heterogeneous environment and hard substrate—a limited habitat in the deep that otherwise mostly consists of sediment [17][18].

The majority of exclusive exploration licenses awarded by ISA for nodules are within the CCZ—an area of high biodiversity and species richness [19]. The exact role the nodules play is still not yet fully understood, and [16] it has been concluded that the sample sizes aimed to define appropriate areas to mine are too few, and a substantial comparison across the CCZ is still missing. Calculations roughly estimate that the CCZ could hold over 21 billion tonnes of nodules, which collectively would hypothetically contain 6000 million tonnes of manganese, 270 million tonnes of nickel, and 44 million tonnes of cobalt [4]. The extraction of these nodules is planned to be managed remotely, controlling nodule harvesters that plough or scrape the seabed and sediment. Harvested nodules and underlying sediment will be pumped up to the surface and sorted, and sediment water will likely be returned to the ocean on-site [17].

3.2. Seafloor Massive Sulfides

Part of the new interest in DSM is in the findings of seafloor massive sulfides (SMS). SMS are deposits found around so-called active or inactive hydrothermal vents [17]. Hydrothermal vents are small unique structures found along the deep-ocean floor ridges where tectonic plates pull apart. These vents, also called black or white smokers, are best described as small underwater volcanoes or chimneys. The vent areas may contain rich concentrations of sulfides as well as other metals and minerals such as copper, zinc, gold, barium, and silver [4]. At depths between 1000–4000 m, where the vents are generally located, no light penetrates, and life is dependent on chemically produced energy (chemosynthesis)

When tectonic plates pull apart, cold water seeps in. This cold water is rapidly heated by the magma beneath and re-emerges as alkaline (high pH) vent fluids containing hydrogen. The fluids may then precipitate metals and sulphides when they meet the cold bottom sea water. The minerals form chimneys, and as each chimney collapses and rebuilds around the vent, minerals and metals are compounded over time [20].

The active vents host unique ecosystems that are home to endemic species that rely on the chemical reactions between hydrogen and carbon dioxide facilitated by the 400 C vent fluid [20]. These places are, as Van Dover et al. [20] puts it, libraries necessary for deepening our knowledge on the connections between the processes of the Earth and life itself. To date, there are approximately 400 known active vent fields around the globe. Inactive vents were for a long time considered to be relatively devoid of life, however, findings in the recent decade shows inactive vents along ridges hosting lively populations of barnacles, corals, and sponges [17].

3.3. Cobalt-Rich Crusts

Cobalt-rich crusts (CRC), also referred to as ferromanganese crusts or polymetallic crusts, are found on the seamounts rising 1000 m or more above the seafloor. The crust layer of these mounts contains iron, manganese, and trace metals such as copper, cobalt, and nickel [4]. The thin crust takes millions of years to form through the precipitation of minerals from the surrounding seawater. The thickest parts of the crust are estimated to be around 25 cm and occur on top of the mountain summits or flanks. Seamounts, or knolls, can be found in all oceans, but the most pronounced area of the highest industrial interest lies in the Pacific Ocean with more than 55,000 mounts and smaller so-called knolls [17]. The international areas around the central equatorial Atlantic or within the EEZs of Pacific island states such as Kiribati, French Polynesia, Tuvalu, and Samoa Islands, are highlighted in the literature as hotspots for potential CRC exploitation. CRCs may pose a more challenging mining procedure as (a) the entire crust must be removed from rock substrate and (b) the steep and rugged landscapes where machinery must operate makes the technological obstacles harder to overcome than the other two DSM resources [4][17].

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