DEEP SEA MINING

A policy brief from The Geological Society

The Challenger Expedition, a four-year circumnavigation of the globe by a British naval vessel (1872-1876), was a key turning point in the history of oceanography. It established the foundation for the modern study of the oceans, collecting extensive data on marine life, ocean floor composition, and water properties at various depths. As part of this notable national investment in scientific research and understanding, we first learned of the existence of polymetallic nodule deposits.

Now, almost 150 years on from that discovery, nodules are one of the three types of deep sea mineral deposits under the subject of intense political interest and scientific investigation worldwide, due to our growing global demand for resources to support the energy transition. We owe our knowledge of the existence of these deep sea mineral deposits to a significant British investment in exploratory science. Continued support for, and investment in, our scientific understanding of the deep sea and other maritime environments will ensure that both resources and environments are managed in line with the best available scientific evidence.

Summary for Policymakers

Our global demand for minerals is increasing, driven largely by the drive to meet Net Zero and the associated transition to low-carbon, mineral-intensive sources of energy.

Declining accessibility and grade of terrestrial mineral deposits is encouraging frontier exploration e.g. in the deep-sea, where less is known about environments, habitats and the long-term implications of mining activity.

Exploration is already taking place for deep-sea mining prospects, with a focus on a region called the Clarion-Clipperton Zone (CCZ), collecting environmental baseline data, characterising resources, and conducting tests of mining equipment.

Coastal nations regulate and license exploration within 200km of their coastlines, while exploration in international waters more than 200 km from the coast is regulated by the International Seabed Authority (ISA).

The ISA has been developing governance for mineral exploitation in international waters under the UN since 2014, and published draft regulations in 2019. Final regulations are anticipated in 2025.

Advances in recovery technology and processing of sea floor mineral deposits have made the exploitation of these deposits potentially more accessible than ever before, expanding commercial interest worldwide.

Exploratory, and some large-scale, test projects have taken place to assess the viability and effectiveness of equipment and processes; however, no commercial deep-sea mining has taken place yet (despite a few countries having approved licences to explore within their exclusive economic zones).

An emerging picture of the environmental impacts of potential deep-sea mining is arising based on a significant investment from industry and government contractors, as well as academic research projects. These include:

- Ecological disturbance to deep-sea ecosystems (e.g. seafloor disturbance in mined regions from mining machines or plumes of sediment generated by them)
- Broader-scale impacts, for example loss of biodiversity or ecosystem function
- Impacts on surface and mid-water ecosystems that would be dependent on how ore is processed at sea - an area of uncertainty

Over the last 20 years, scientific investigation led by UK and USA researchers has contributed to the development of a protected area system in the CCZ, with the first areas approved by the ISA in 2012 and revised in 2021, to protect a region of approximately 2 million square kilometres (roughly 30 % of the total area of the CCZ.).

Deep-sea mining could support global long-term materials demand, if it takes place in a well-regulated environment, and environmental impacts are understood, measured, managed and risks mitigated.

Deep-sea mining carries different risks than terrestrial mining (although all resource extraction has environmental impact) and must be carried out with environmental, social and governance considerations at the forefront or planning and operations.

There is no shortage of geological supply of terrestrial materials and minerals to meet our projected future demand. However, scaling up mining responsibly and sustainably is a challenge that must be met regardless of where mining takes place.

Making more from less, reducing waste, increasing reuse and recycling as well as moving towards circularity of materials will be critical to our future sustainable relationship with materials and minerals.

Emerging technologies and alternative technologies have the potential to influence our dependence on certain minerals and metals and potentially reduce our reliance on minerals of particular interest in the deep-sea.

Deep-sea mineral resources

There are three main types of actively forming mineral deposits in the deep-sea.

1. Hydrothermal **polymetallic sulphide deposits** (sea floor massive sulphide deposits)

These form on or below the seabed at volcanically active plate boundaries. They contain localised high concentrations of Copper, Zinc, Lead, Silver and Gold. Currently known deposits occur at depths up to 5000 m below sea level. These deposits are not a target for mining battery metals such as Nickel or Cobalt.

2. Polymetallic (manganese) **nodules**

These form in sediment-covered deep abyssal plains more than 3000m below sea level and are typically between 1-20 cm in diameter. These nodules grow at a rate of 1-10 mm every million years, and around 5 % are exposed while 95 % are under seafloor sediment. Nodules with the highest concentration of minerals of minerals of interest are found between 4000-6000 m below sea level. They contain quantities of battery metals such as Nickel and Cobalt.

3. Cobalt-rich (ferromanganese) **crusts**

These precipitate on to nearly all sediment-free rock surfaces in the deep-sea such as seamounts, ridges, and guyots at around 400-7000 m below sea level. Around 75 % of these deposits grow at a rate of 1-5 mm per million years. Crusts with the highest concentration of minerals of interest are between 800-2500 m below sea level. As with nodules they contain quantities of battery metals such as Nickel and Cobalt.

Type of Deposit	Global Permissive Area*	Location**
Polymetallic sulphide deposits	3.2 million km^2	42% in EEZ / continental shelf extensions
Polymetallic nodules	>51 million km^2	19% in EEZ / continental shelf extensions
Cobalt-rich crusts	23 million km^2	54% in EEZ / continental shelf extensions

*A "permissive area" is a region with geological characteristics favourable for the extraction of specific mineral resources. These areas are identified based on the potential presence of valuable resources and the term highlights the suitability of the area for mining activities, but it doesn't guarantee economic viability or the absence of environmental risks.

**A key factor influencing our understanding of the scale and location of sea floor mineral deposits is data availability. For example, data on the location of polymetallic sulphide deposits is focused 20 km either side of active neovolcanic ridge axes, and data for cobalt-rich crusts only spans 80 °N to 70 °S.

Licensing and regulation

Deep-sea mineral exploration can take place in two maritime zones; international waters (any part of the seabed which is outside of national jurisdiction >200 miles from coastline) and economic exclusive zones or EEZs (areas within <200 miles of coastline). The International Seabed Authority issues exploration licences for the three main deep-sea mineral resources in international waters. Licences have a duration of 15 years or more.

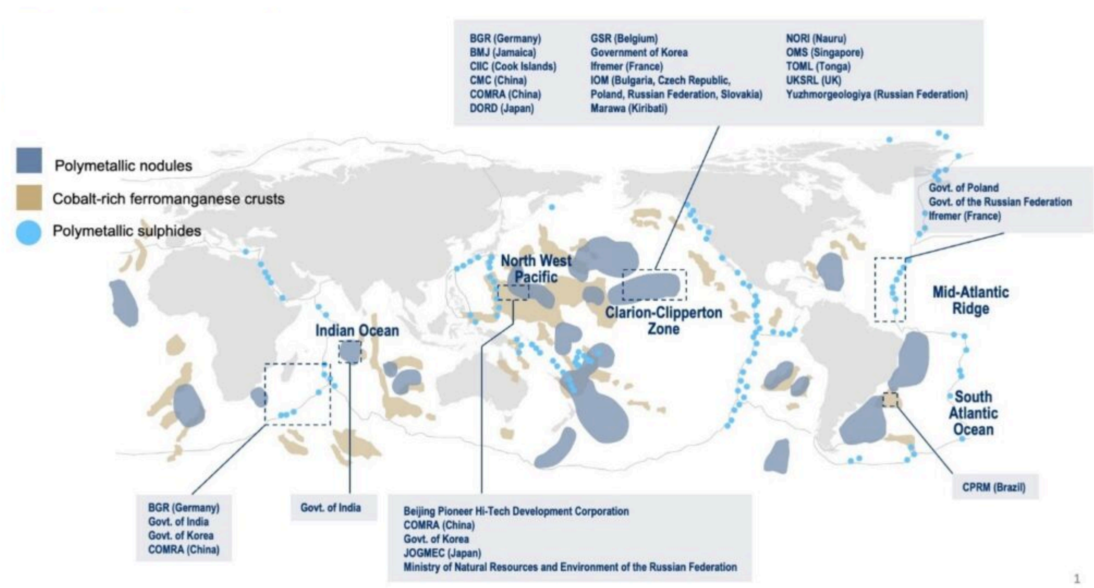

Figure 1 - Distribution of critical mineral resources in the deep-sea. Source: International Seabed Authority.

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Coastal nations control regulation and licensing to explore, exploit, conserve, and manage marine resources within their EEZs. The United Nations Convention on the Law of the Sea seeks to ensure that regulation of seabed activities within EEZs must be at least effective as the international rules, standards, and practices and procedures being developed internationally with respect to preventing, reducing and controlling pollution of the marine environment.

The International Seabed Authority has been developing governance in this area under the UN since 2014. It published draft regulations in 2019 and intends to adopt regulations for the exploitation of deep-sea mineral resources in international waters in 2025.

Based on a series of scientific workshops and papers, in 2012 the ISA adopted a system of protected regions called Areas of Particular Environmental Interest (APEIs). Revised in 2021, these represent 1.97 million square kilometres of the Clarion Clipperton Zone region of interest, roughly 30 % of the total area of 6 million square kilometres. This action by the ISA was the first protected area system in the High Seas, well before the development of the current High Seas Treaty (BBNJ Treaty) that is currently being ratified by nation states.

Why deep-sea mining?

Some key driving forces of deep-sea mining are:

- Decarbonisation / demand for minerals for green technologies
- Resource efficiency
- Higher grade deposits than are widely accessible on land
- Unstable security of land-based supply
- Low resource diversity
- Geopolitical influence and competition
- Resource nationalism
- Resource poor, high use countries
- Potentially reduced environmental or social impact compared to terrestrial mining (in some scenarios)

Metal production is one of the most energy intensive industrial sectors. Primary metal production accounts for ~8 % of global energy consumption.

At the same time as metal demand is increasing, the rate of discovery of accessible, high grade metal ore deposits is decreasing. The average grade of copper ore mined in 2019 was 0.6 % which is 25 % lower than the average grade mined in the previous ten years.

Lower grade deposits require more energy to process, and create more waste, meaning higher demand for metals comes hand in hand with higher demand for energy across the sector and greater carbon emissions per ton of metal produced.

This puts greater demand on exploring new frontiers of metallic and mineral deposits, not yet exploited, such as in the deep-sea.

Deep-sea deposits also have higher concentrations of some minerals and metals that are particularly important for the energy transition e.g. Copper, Platinum, Rhenium, Tellurium and Rare Earth Elements.

All current alternative energy technologies are dependent upon metals such as Nickel, Copper, Manganese, and Cobalt and a successful energy transition and solvency of our future green economy will not be possible without an increase in the supply of these materials (even with significantly increased recycling and reuse).

A sustainable future will include creating more from less, reuse, re-manufacture and recycling, as well as low-carbon extraction and processing of materials.

In terrestrial mining, removal of the rock above a mineral deposit can make up as much as 75 % of the waste. In contrast, many of the deep-sea mineral deposits are exposed on the sea bed or under limited sediment cover, removing the need to use as much energy to process, or create as much waste, as in terrestrial mining.

Cobalt-rich crusts contain a significant amount of the metals most valuable to current society; however they are the deep-sea deposits we know the least about – further reinforcing the extensive need for further research on these deposits and their environments.

The deep sea is the largest habitable environment on Earth. Although the deep-sea is low in the abundance of animal life, biodiversity can be relatively high, and many species are undescribed. Recent experimental studies have shown both the short and long-term impacts of deep-sea mining at a local ecological scale. It is currently not possible to accurately predict the degree of biodiversity loss from deep-sea mining, which is important given nation states' obligations to the Convention on Biological Diversity.

Deep-sea mining is not a solution to short-term challenges such as depleted or inaccessible terrestrial mining deposits, and scientific research must assess the impacts of its practice for us to be able to make informed decisions. Ensuring scientific evidence and expertise is integral to the development and evolution of policy and long-term management of these resources and their host environments is not optional.

Key outstanding scientific questions:

What is the risk of biodiversity loss (or extinction) from deep-sea mining given our obligations to the Convention on Biological Diversity?

What is the timescale of recovery of ecosystems impacted by deep-sea mining, and what restoration processes would be suitable when mining stops?

What is the value of deep-sea biodiversity and critical conservation requirements?

What is the carbon footprint for metal production of seabed minerals in comparison to terrestrial mining?

Can we develop low carbon extraction of metals from deep-sea mineral resources that are financially and environmentally viable?

Can advances in technology allow us to minimise or mitigate the environmental impacts of deep-sea mining?

Can a more circular economy reduce our demand for raw materials?

Key developmental challenges:

- Limited knowledge of the seafloor and deep-sea resources, particularly crusts and polymetallic sulphide deposits located >20 km from neovolcanic axes
- Limited knowledge and understanding of environmental impacts to the deep ocean environment from deep-sea exploitation
- Depth of potential mining
- Social license and public perception
- Development of geophysical exploration tools
- Financial; CAPEX, OPEX and investment
- Overly complex or unclear approval processes
- Lengthy or unspecified timeframes
- Duplicate or irrelevant documentation requirements
- The use or application of unrealistic or inappropriate standards
- Overly burdensome financial, insurance or indemnity requirements

Global policies & positions on deep sea-mining

The United Kingdom

"We will find out more about deep-seabed minerals and assess the challenges and opportunities of extracting them.

- Continue to contribute to discussions on deep sea-bed mining at the International Seabed Authority (ISA), pressing for the highest environmental standards in relation to existing exploration activity, and possible future commercial exploitation should that be approved by the ISA in the future.

- Proactively build our research base on deep-seabed minerals and the potential impact on deep-sea ecosystems should any deep-seabed mining be approved in future. Through the work of UK Seabed Resources, under the existing licences issued, we will deepen our understanding of the opportunities, challenges and potential impacts of deep-seabed mining to be able to contribute to the broader international discussions in this regard, allowing us to take any future decisions informed by the widest possible evidence base."

"The UK has agreed not to support the issuing of any exploitation licences for deep-sea mining projects unless or until there is sufficient evidence about the potential impact on deep-sea ecosystems."

The UK sponsors two deep-seabed mining exploration licences for UK Seabed Resources (UKSR) to explore a total of 133,000 square kilometres of the Pacific seabed. This project is working closely with UK government departments and research institutions on environment regulatory and industrial considerations of deep-seabed mining.

Note: In April 2025 Loke Marine Minerals (owner of UK seabed Resources) declared bankruptcy, and the future of UKSR remains uncertain.

Europe

The position of the Commission on deep-sea mining, as defined in the Joint Communication "Setting the course for a sustainable blue planet - Joint Communication on the EU's International Ocean Governance agenda" adopted in June 2022 is:

"There is a broad consensus in the scientific community and among States that knowledge related to deep-sea environment and the impacts of mining are not comprehensive enough to enable evidence-based decision-making to allow for proceeding safely with exploitation. The EU will continue to advocate for prohibiting deep-sea mining until these scientific gaps are properly filled, that it can be demonstrated that no harmful effects arise from mining and, as required under the UNCLOS, the necessary provisions in the exploitation regulations for the effective protection of the marine environment are in place."

This position is reflected in recital 18 of the Regulation (EU) 2024/1252, adopted by the European Parliament and the Council:

"In line with the precautionary principle, the Commission should not recognise deep-sea mining projects as Strategic Projects before the effects of deep-sea mining on the marine environment, biodiversity and human activities are sufficiently researched, the risks are understood and technologies and operational practices are capable of demonstrating that the environment is not seriously harmed."

The United States of America

On 24 April 2025, President Trump issued an executive order aiming to "accelerate the responsible development of seabed mineral resources". In addition, the order requests that the Secretary of Commerce will "expedite the process for reviewing and issuing seabed mineral exploration licenses and commercial recovery permits in areas beyond national jurisdiction".

Elements of this order have received scrutiny for their potential to contravene the international regulations in development by the International Seabed Authority.

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China

In 2016, China adopted the first piece of national legislation for deep-sea mining in international waters. The Deep-seabed Area Resource Exploration and Exploitation Law (China's Deep-seabed Law) covers exploration and exploitation.

China has made significant progress in developing and testing deep-sea mining equipment at depths below 4000 m in international waters. These advancements, made by state-owned mining companies, intent to collect environmental data alongside performing operational tests. Beijing Pioneer Hi-Tech Development Corporation (BPHD) assert that their activity in the Pacific Ocean will form "a basis for formulating regulations for future deep-sea mining activities and the development of environmentally friendly technologies."

On 15 February 2025 China signed an MOU with the Cook Islands to collaborate on research and potential exploitation of minerals in the deep Pacific.

Japan

Japan, the world's largest importer of critical minerals, is pursuing deep-sea mining within its own EEZ, with plans to begin commercial-scale mining by 2027. Further testing is set to commence in 2025, with a focus on polymetallic nodule deposits. Japan has been investing in deep-sea mining and processing technology in preparation.

Japan's Ocean Policy Master Plan (2023) set out Japan's intentions to commercialise their deep-sea activities in the late 2020s, while the National Security Strategy (2023) re-emphasised the importance of these activities to secure resource independence in an increasingly tense geopolitical environment.

Norway

On 9 January 2024, the Norwegian Parliament (Stortinget) endorsed the government's proposal to allow exploration for the possible extraction of seabed minerals on the Norwegian continental shelf. Extraction licences for businesses would still further parliamentary approval.

The aim of this action was to permit the mining of important raw materials that are increasingly needed for the green and digital transitions, and the defence and aerospace sector. Although permits would only be made available after more environmental research was made available, concerns were raised within Norway and across Europe due to the potential risk to the deep-sea ecosystem, the fishing industry and coastal communities.

A cited motivation for this activity was to reduce Norway's dependence on China for their materials and to develop new exportable commodities to replace offshore oil and gas.

In December of 2024, licensing plans were paused following significant political opposition from Norway's Left Socialist Party, who refused to support the government's budget until these plans were ceased for the 2025 licensing round.

In response, the EU Parliament re-established its position "prohibiting seep-sea mining until: the scientific gaps are properly filled, it can be demonstrated that no harmful effects arise, and the necessary and effective environmental protection provisions are in place in the exploitation regulations."

Countries who hold exploration licences for deep-sea mining (as of July 2024)

Chile, Brazil, South Africa, Papua New Guinea, American Samoa, Saudi Arabia, India, Namibia, Sweden China, japan, Norway, and the Cook Islands have issued or have expressed an interest in licensing deep-sea mining within their EEZs.

The ISA has entered into 15-year contracts for exploration in international waters with 22 contractors.

Countries calling for some form of a pause or moratorium or ban on deep-sea mining in international waters (as of August 2024)

Type of measure	Country or state
Precautionary pause	Austria, Brazil, Costa Rica, Chile, Kingdom of Denmark, Dominican Republic, Ecuador, Federated States of Micronesia, Fiji, Finland, Germany, Greece, Guatemala, Honduras, Ireland, Malta, Monaco, Palau, Panama, Portugal, Spain, Samoa, Sweden, Tuvalu, Vanuatu
Moratorium	Canada, Mexico, New Zealand, Peru, Switzerland, United Kingdom
Ban	France

Source: "A Pause or Moratorium for Deep-seabed Mining in the Area? The Legal Basis, Potential Pathways, and Possible Policy Implications"

About The Geological Society

The Geological Society of London is the UK's national society for geoscience, providing support to over 12,000 members in the UK and overseas. Founded in 1807, we are the oldest national geological society in the world.We provide professional support to our members, as well as impartial scientific information and evidence to policy makers and the public.

Scientific advice and review for this briefing was provided by Dr Tracy Shimmield, Marine Geochemist. Dr Adrian Glover, Merit Researcher, Natural History Museum, Dr Hannah Grant, Marine Geologist, British Geological Survey, and Dr Daniel Jones, Head of the Ocean BioGeosciences Research Group & Honorary Professor, University of Southampton.