MINDeSEA

Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials

Deliverable 7.4: Literature review report on present-day status of exploration for seabed mineral deposits around Europe

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This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Deliverable number	Short Title
7.4	Present-day status of exploration
Long Title	
D7.4: Literature review report on present-day status of exploration for seabed mineral deposits around Europe	
Short Description	
This document presents the status of exploration in the international and pan-European framework	
Keywords	
GeoERA Raw Materials, exploration, pan-European seas, CRM, Seabed mining	
Authors / Organisation(s)	**Editor / Organisation**
Luis Somoza *et al.*/ IGME, SGU, GSI, BGR, LNEG, HSGME, NGU, GIU, IGEO, IPMA, USGS, VNIIO	IGME
File name	
MINDeSEA_D7-4_WP7 – Present day status of exploration for seabed minerals.doc	
Deliverable due date	**Deliverable submitted date (WP leader)**
31 October 2021 (M40)	30 October 2021 (M40)

History				
Version	**Author(s)**	**Status**	**Date**	**Comments**
01	L. Somoza, I. Zalba, F.J. González, E. Marino, T. Medialdea, A. Lobato, I. Blasco (IGME), J. Nyberg & MINDeSEA Team	final	30 Oct 2021	

Dissemination level		
PU	Public	X
CO	Confidential, for project partners, GeoERA and the European Commission only	

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

This publication is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

How to cite this report: **Somoza, L., Zalba, I., González, F.J., Marino, E., Medialdea, T., Lobato, A., Blasco, I., Nyberg, J., and the MINDeSEA Team. 2021. Deliverable 7.4: Literature review report on present-day status of exploration for submarine mineral deposits around Europe. GeoERA-MINDeSEA project. 30 pp. https://GeoERA.eu/projects/mindesea2/**

D7.4: Literature review report on present-day status of exploration for submarine mineral deposits around Europe

Summary:

GeoERA is a Co-Fund ERA-NET action under Horizon 2020, towards "Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe". Its main objective is to contribute to the optimal use and management of the subsurface. The project “Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials” (MINDeSEA), materialized in the frame of the GeoERA Raw Materials Theme (Grant Agreement Nº 731166, project GeoE.171.001), resulted from the collaboration between eight GeoERA Partners and four Non-funded Organizations at various points of common interest for exploration and investigation on seafloor mineral deposits.

This document reports the research and compilation works produced by the MINDeSEA partners, led by the Geological Survey of Spain (IGME-Spain). Exploration licenses beyond the EU countries and national waters are introduced in the first part, with special emphasis in the cases of oceanic nations. The exploration regulations in Europe are considered in the second part of this report paying attention to the EU supported projects for seabed minerals: geological, technological and environmental research. Finally, using our MINDeSEA dataset, we present an analysis of the exploration cruises in the different European marine regions and their associated minerals.

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

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1. INTRODUCTION

The demand for metals such as manganese, copper, nickel, and cobalt are rising as the world's population and economy continue to expand, as well as the technological transition from fossil to renewable energy sources and the development of e-mobility. These metal resources are currently only mined on land. To satisfy rising global demand, ensure the raw materials supply of commodity-poor nations, and decrease their reliance on quasi-monopolists of specific metals, state-owned and private businesses have refocused their attention on deep-sea mineral resources such as polymetallic nodules (Hein et al., 2020).

Actually, polymetallic nodules, cobalt rich ferromanganese crusts and polymetallic sulphides are the three types of mineral deposits with a particular interest. They contain many of the metals required in significant amounts for the above-mentioned technological changes. These three are formed principally by iron and manganese oxides and are located in the world's oceans at depths between hundreds of meters to 6000 m. In addition to iron, manganese, nickel, copper, and cobalt, they contain substantial amounts of additional metals of commercial significance, such as gold, molybdenum, titanium, lithium, vanadium, and rare-earth elements. Not all these elements are concentrated in the three mineral deposits types and depending witch it will concentrate more some elements than others. By now the biggest and most commercially significant deposit is found in the Clarion-Clipperton Zone (CCZ) in the equatorial North Pacific, between Hawaii and Mexico, in the so-called manganese nodule belt (Hein et al., 2013).

A significant supply risk exists for certain metals, such as cobalt, vanadium, rare-earth elements, and gallium, whereas these metals have major economic significance for the European sector (European Commission, 2017). Maintaining value chains and the well-being of the European economy need reliable and unrestricted access to metal resources. This issue in not only affecting the European countries, according to the International Energy Agency (Bouckaert et al., 2021) the world's critical minerals demand will increase more than 400% from now to 2050. They emphasised in *"the growing dependence on critical minerals required for key clean energy technologies calls for new international mechanisms to ensure both the timely availability of supplies and sustainable production."*

In this context many countries and companies are making efforts to explore these minerals, both in its exclusive economic zone and in international waters. A license is required before beginning a deep-sea mining or exploration project. Depending on where the project is placed, marine exploration or mining licenses may be granted by the ISA or by national governments. National governments grant permits for operations that take place inside a country's EEZ. The EEZ extends up to 200 nautical miles from the territorial sea baseline. A coastal state has unique sovereign rights inside its EEZ to explore and exploit, conserve, and manage the natural resources (living and non-living) of the water column, seabed, and subsoil. The licenses for the Continental Shelf are also issued by national governments. The Continental Shelf (as defined by the UN Convention on the Law of the Sea) is the sea floor that extends beyond the territorial sea up to 200 nautical miles from the territorial sea baseline or beyond that to the continental margin's outer border. A coastal state has sovereign rights inside its continental shelf to explore and utilise mineral and other non-living resources of the seabed and subsoil, as well as sedentary live species (Sharma, 2017).

Currently, the initiatives under progress are exploratory projects. The North Pacific Ocean has the most licensed projects, accounting for a significant portion of the International Seabed Authority's (ISA) permitted regions in international seas. International seas in the East Pacific, the South and Central Atlantic, and the

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Indian Ocean are also being explored. Furthermore, nations such as Tonga, Nauru, Papua New Guinea, and Norway are exploring their seas for minerals.

2. EXPLORATION LICENCES BEYOND THE EEZ

The Area is defined as the seabed and subsoil outside the boundaries of national jurisdiction (i.e., all of the seabed beyond each country's continental shelf). The Area and its natural resources have been designated as "the common inheritance of mankind" by the United Nations Convention on the Law of the Sea. The ISA, an institutional entity created under UNCLOS, manages the Area's seabed resources on behalf of everyone. No nation may claim or declare sovereign rights over any portion of the Area or its resources. However, any UNCLOS member nation is allowed to conduct seabed mineral activities in the Area, subject to UNCLOS and ISA regulations. This implies that any exploration or mining operations in the Area must be conducted within the terms of a contract with the ISA (See **Deliverable D4.6**).

States Parties (signatories of UNCLOS), state businesses sponsored by States Parties, and natural or juridical persons with the nationality of States Parties and sponsored by States Parties are all eligible for ISA licenses. This aspect of sponsorship is essential to the international system because it ensures that a State Party to UNCLOS is ultimately responsible for the actions of contractors working with the ISA.

By 2010, the ISA had only awarded exploration contracts to eight countries: France, Russia, Japan, China, Korea, Germany, an Eastern European country consortium, and India. They're all for investigating polymetallic nodules. Interest in seabed mineral resources increased quickly after this year, and ISA had 25 exploration contracts for nodules, crusts, and sulphides in 2015. ISA has granted 31 exploration contracts by 2021 (19 for nodules, 7 for sulphides, and 5 for crusts) in the world oceans (**Fig.1**). Nineteen of these contracts are for polymetallic nodule exploration in the Clarion-Clipperton Fracture Zone, the Central Indian Ocean Basin, and the Western Pacific Ocean, 17, 1, 1 respectively. In the Western Pacific Ocean, there are four contracts for cobalt-rich crust exploration and one in the south Atlantic. There are seven contracts for polymetallic sulphide exploration in the South West Indian Ridge, Central Indian Ridge, and Mid-Atlantic Ridge.

Currently, taking into account all the contractors their exploration areas the summary of exploration surface appears in the next table (**Table 1**). More detailed information about the exploration areas and the contractors is recorded in **appendix I** and **appendix II**.

Table 1. Summary of the exploration areas for the polymetallic nodules, ferromangansese crusts and polymetallic sulphides in the 5 zones of the world ocean.

Ocean basin	Nº of areas	total extension of exploration areas (Km^2)
Polymetallic Nodules		
Pacific (CZZ)	57	1.238.883
North Pacific	4	74.088
Indian Ocean	2	76.022
Ferromanganese Crusts		
Atlantic Ocean	150	2.997
Pacific Ocean	600	11.875

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Polymetallic Sulphides		
Atlantic Ocean	300	30.123
Indian Ocean	400	39.934

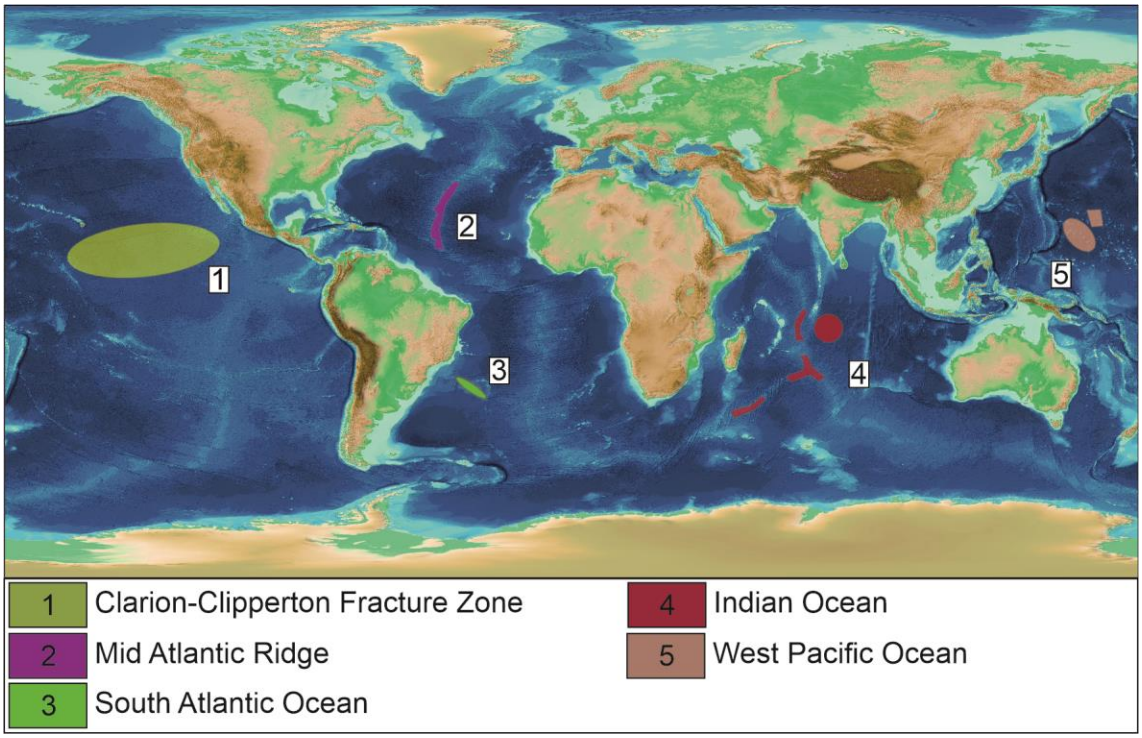

Figure 1. Main areas where the exploration areas of the exploration contracts awarded by ISA are located. Source: ISA (**ISA**) and GEBCO (**GEBCO**).

Exploration license case

In 2021, there are 31 exploration contracts for the three mineral deposits types into five zones from the oceans (**Fig. 1**). Each contract allows the contractor for exploration rights for 15 years and is supported by a national government (ISA, 2013). In Europe, seven countries are involved in exploration activities for polymetallic nodules and polymetallic sulphides principally. France, Germany, Belgium, United Kingdom, Russia, Czech Republic, Poland, Bulgaria and Slovakia are involved in deep sea exploration activities. More detailed data about the resource type, contract duration and exploration zone is available in **Appendix I and II**.

Belgium and Germany have made significant advances in exploration activities for polymetallic nodules in Clarion Clipperton Fracture Zone (CCFZ). Point out that Germany also has an exploration contract for polymetallic sulphides in the Indian Ocean. The contractor for Germany is the Federal Institute for Geosciences and Natural Resources of Germany (BGR), a research agency of the Federal Ministry for Economic Affairs and Energy of Germany. In the case of Belgium, the contractor is Global Sea Mineral Resources (GSR), a private company with support from the Belgian government. They already had made an Environmental Impact Assessment, which is publicly available (**BGR**, **GSR**), where it is possible to see the development of the research activities in the zone. A brief description of the BGR and GSR research is available in **Appendix III**.

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Nauru Ocean Resources case

Nauru Ocean Resources Inc (NORI) is based in Nauru, a small pacific island, and signed an exploration contract for polymetallic nodules in CCFZ under the sponsor of Nauru (**Fig.2**). This company is a subsidiary of *The Metals Company*, founded in 2021 through the merger of *Deep Gre*en and the *Sustainable Opportunities Acquisition Corporation* (NYSE: SOAC) and is based in Canada. *The Metals Company* also has agreements with Tonga and Kiribati for CCZ exploration rights.

In June 2021, Nauru has informed a United Nations agency of its intentions to begin deep-sea mining, giving the ISA two years to finish long-running discussions on regulations regulating the contentious new sector. Nauru President notified ISA about the mining plans to be carried out by *The Metals C*ompany. Nauru intended to use the so-called "two-year rule." This law would force the ISA to enable seabed mining to go forward within two years, effectively establishing a deadline for the organisation to approve mining rules (Reid, H. & Lewis, J., 2021). The ISA, in a statement, said it planned to begin by the end of 2021 the work on mining rules, which had previously been postponed owing to the pandemic (ISA, 2021).

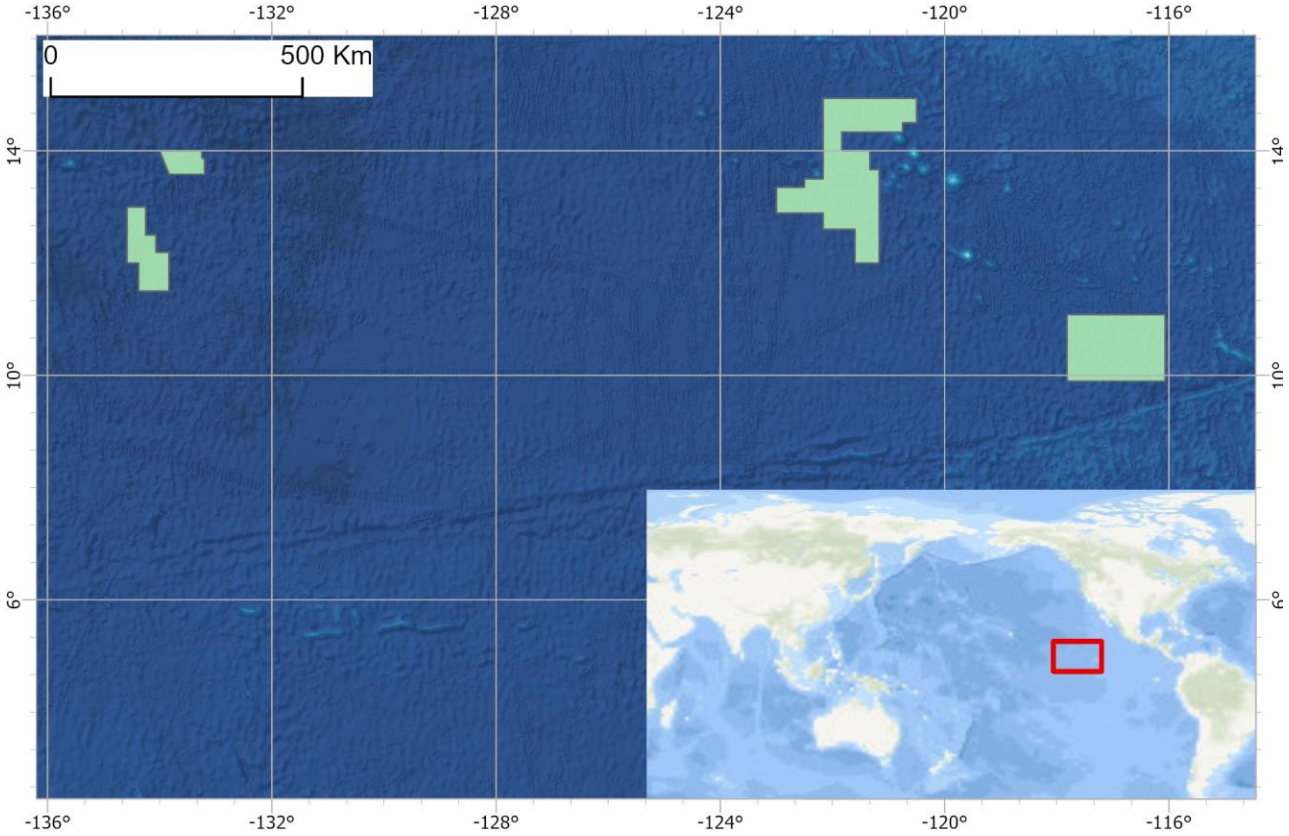

Figure 2. NORI exploration areas in Clarion Clipperton Fracture Zone. Source: **ISA**

3. EXPLORATION LICENCES WITHIN EEZ OUTER EUROPE

It is relevant to distinguish between seabed mining inside coastal states' exclusive economic zones and seabed mining in the high seas or "the Area," outside national authorities. Seabed mining in the high seas is established within the United Nations Convention on the Law of the Sea (UNCLOS) and is regulated by the ISA (See **Deliverable D4.6**). Seabed mining applications that lie inside a country's exclusive economic zone

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(within national jurisdiction) are governed by local legislation in that country. Several countries have granted exploration licenses in their waters in this context, although no explotation activity has yet taken place.

Actually, except for diamonds in Namibia's continental shelf, any deep sea mining operation extracts mineral resources from the seabed. There are very few seabed mining projects that have been granted a mining license. *Deep Sea Mining Finance Limited* (formerly *Nautilus Minerals*) in Papua New Guinea (Miller et al., 2018) and *Diamond Fields International* in the Red Sea (Petersen et al., 2018), but they have not started yet. Nautilus Minerals was into financial difficulties, and on 21 February 2019, the company filed for protection from creditors under the Canadian Companies' *Creditors Arrangement Act* (CCAA).

Other countries, primarily from the Pacific, such as New Zealand, Tonga, Japan, Fiji, Solomon Islands, and Vanuatu have also allowed studies to explore the mining feasibility of their national seafloors, but some of these permits have expired (Levin et al., 2020). Polymetallic nodules and cobalt crusts are also being explored in the Cook Islands and polymetallic nodules in Brazil (Marques et al., 2019). The following table summarises some of the exploration licenses in the EEZ worldwide (**Table 2**).

Some countries exploring deep sea mineral resources under their waters have opted for a caution approach to seabed mining. This has been accomplished via moratoria, permanent prohibitions, or the rejection of project proposals. While Namibia and Australia's Northern Territory have put a moratorium on phosphate mining and bulk seabed mining, the Environmental Protection Agency of New Zealand has rejected its first application for consent to conduct marine phosphate mining, and *Mexico's Secretary of Environment and Natural Resources* (SEMARNAT) has denied environmental authorisation for its first marine phosphate mine. In their exclusive economic zones, some other countries have imposed moratoria on oil and gas development and production (Roux & Horsfield, 2020).

Table 2. Deep Sea Mining projects have been developed or are being developed within the EEZ of some countries. Those projects currently active are shown in italics. PMS, Polymetallic Sulphides. Clicking on the source box, more available information is available.

Contract holder (country of registration)	Location	Type of mineral	Status (year awarded if known)	Source
Diamond Fields International (Canada)	Atlantis II Basin. Red Sea	PMS	*Mining contract, active (2010). Project currently on hold because of contractual issues with partnership company*	
Diamond Fields International (Namibia)	Namibia	Diamonds	*Mining contracts x4. active (2009. 2007 & 2007; 2000 is pending renewal: expected contract renewal as of November 2017)*	
Diamond Fields (South Africa).	Western Cape. South Africa	Phosphorites	Prospecting contract, active (2014)	
Trans-Tasman Resources (New Zealand)	South Taranaki Bight, west coast of North Island	Iron ore sands	*Three projects with an exploration permit, a mining permit and a prospecting permit.*	

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Trans-Tasman Resources (New Zealand)	Westland sands. Ross to Karamea, west coast of South Island	Iron ore sands	Prospecting contract, active (2016)	-
Chatham Rock Phosphate (New Zealand)	Chatham Rise, east side. South Island	Phosphorites	*Mining contract, active (2013). The company refused environmental mining consent approval (2015).*	↗
Bluewater Minerals (Solomon Islands) Ltd. (Solomon Islands)	Temotu and Western provinces. Solomon Islands	PMS	Prospecting contract, active (2007)	↗
Green Rash Trading 251 (South Africa)	Groen River to Cape Town. South Africa	Phosphorites	Prospecting contract, active (2014)	↗
Green Rash Trading 257 (South Africa)	Cape Town to Cape Infanta. South Africa	Phosphorites	Prospecting contract, active (2014)	↗
Namibian Marine Phosphate (Pty) Ltd. (Namibia)	Sandpiper Marne Phosphate Project. Walvis Bay. Namibia	Phosphorites	*Mining contract, active (2011). Project pending ElA approval (June 2017).*	↗

Papua New Guinea: Solwara 1 case

Papua New Guinea (PNG) has been the first nation in the world to allow a commercial seabed massive sulphide mining operation and participate in deep sea mining inside its EEZ. *Nautilus Minerals Inc.*, a Canadian-owned business established in 1987, has been searching for polymetallic sulphide deposits in PNG since 1997. The exploration license was situated 30 km off the coast of New Ireland Province at a depth of approximately 1600 m and a size of 59 km^2 (Lipton, 2008).

ROV films, high and low-resolution bathymetry, dredge surface sampling, and core drilling investigated the Solwara 1 location. In 2006 and 2007, ROVs equipped with robotic arms were utilised to gather chimney samples. The mapping work on SMS was done using a remotely operated vehicle (ROV) that was outfitted with sensors to scan the seabed. Several video cameras and two magnetometers are among them. Furthermore, the ROV's high-resolution mapping sonars were successfully utilised to detect real-time seabed objects in front of and to the sides of the ROV (Gena, 2013). *Nautilus* successfully tested and then installed an ocean bottom electromagnetic system across the research region during the 2007 campaign. A controlled source technique was used to detect electromagnetic fields associated with generated subsurface electrical currents. It was developed to identify locations on the seabed with near-surface huge sulphides (Lipton, 2008).

The company followed studying the Solwara 1 zone and evaluating the present resources, but in 2016, financial problems and disagreements with PNG government finished with the company in bankruptcy. This

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led to suspending the development of the seafloor production system and the Solwara 1 proje ct (Papua New Guinea Mine Watch, 2016).

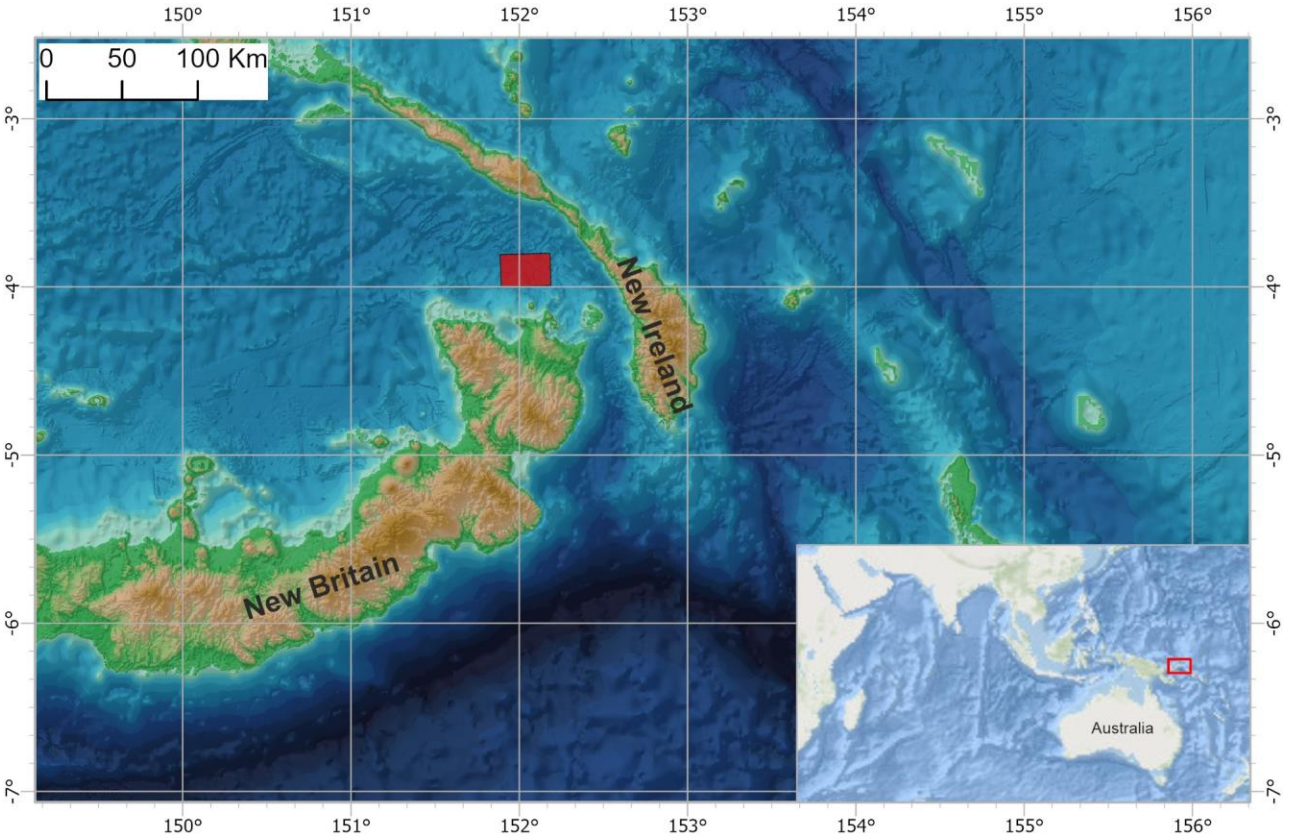

Figure 3. Location of the Solwara 1 project study area located in Papua New Guinea's waters.

4. STATUS OF EXPLORATION WITHIN EEZ IN EUROPE

High-tech metals are essential in the development of new "environmental technologies" that improve energy efficiency and reduce greenhouse gas emissions. As a result, they have the potential to play a key part in the overall move toward sustainable manufacturing and ecologically friendly goods, as well as the transition to a climate-neutral economy. In Europe, ensuring access to raw materials, such as Mn, Ni, Cu, and Li, has become an increasingly essential element for transitioning to a green energy society. In this context, The Raw Material Initiative, a plan for addressing the problem of secure access to sustainable raw materials for the EU, was approved by the Commission in 2008 (COM, 2008). In general, The EU Industrial Policy Strategy reaffirmed the raw materials policy, which recognises raw materials as critical components of industrial value chains (COM, 2017).

To achieve resource security, actions must be taken to diversify supply from primary and secondary sources and enhance resource efficiency and circularity, including sustainable product design. This is true for all raw materials, including basic metals, industrial minerals, aggregates, and biological materials, but it is especially important when it comes to EU-critical raw materials. (COM, 2020; European Commission, 2019).

Marine minerals, such as rare earth elements and cobalt, may help achieve the fast-increasing need for raw materials in the future. For ages, marine aggregates, minerals, and compounds dissolved in seawater have been exploited, such as marine salt. Moreover, in Europe, some countries like France have exploited those resources for use as agricultural fertilisers (European Commission, 2021). It is important to notice that deep sea mining has not yet occurred in European waters. However, numerous policy papers have been issued by

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the European Commission on seabed mining which shows the Commission's desire for the EU to be an active participant in utilising the seabed, such as deep seabed mining (Arneses et al., 2020).

In the European context, many countries are sponsoring DSM exploration contracts with the ISA. These countries are France, Germany, Belgium, Bulgaria, Czech Republic, Slovakia, Poland and the UK. Referring to deep sea mining in the continental shelve, EU law applies to marine regions over which the EU Member States have sovereignty. According to UNCLOS, each coastal State may control seabed mining in the marine areas within its national authority. Therefore, it follows that the national law of the EU Member States and EU law applies to seabed mining activities inside those maritime zones (Arneses et al., 2020). In many cases, terrestrial mining legislation simply applies to the continental shelf or EEZ rather than specific deep-sea mining legislation. By the present, no EU law has been established expressly to control exploration or extraction and exploitation of seabed mining either inside marine regions within the national authority of EU Member States or beyond, except for Norway.

France

The Mining Code, Law No. 68-1181 of 30 December, 1968, relating to the exploration of the continental shelf and the exploitation of its natural resources, as amended by Decree Nº 71-360 of 6 May, 1971, and Decree Nº 2006-798 of 6 July, 2006, relating to the prospecting, research, and exploration of mineral and fossil substances in France, is the legal framework that governs deep-sea mining in France. A new Mining Code was established and went into effect in 2011. The Mining Code was only partially reformed since it primarily addressed the legislative aspect. The provisions of Law No. 68-1181, enacted on 30 December, 1968, concerning the exploration of the continental shelf and the exploitation of its resources, have not been included into the new Mining Code. The new Mining Code contains rules for mineral and fossil material study and exploitation at sea, both on the continental shelf and in the exclusive economic zone (EEZ). DSM in areas within national jurisdiction is also included in Ordinance Nº 2016-1687 of 8 December 2016 about marine territories within the authority of France.

Italy

In Italy, there is no specific mention to deep sea mining in the law, is subject to Law No. 613 of 21 July 1967 on the exploration for and exploitation of liquid and gaseous hydrocarbons in the territorial sea and the continental shelf.

Germany

Germany has claimed an EEZ and enacted laws that control mineral exploitation from the EEZ and continental shelf. The Baltic and North Sea waters, on the other hand, are relatively shallow, with bottom depths of less than 200 meters. Since the 1980 Interim Regulation of Deep-seabed Mining, which was followed by the Seabed Mining Act on 6 June, 1995, DSM has been regulated in Germany (amended in 2010).

The Netherlands

Two regulations in the Netherlands govern mining operations at sea. The Earth Removal Act (Ontgrondingenwet) applies if the minerals are found at the surface or within 100 meters of the surface. The Mijnbouwwet (Mining Act) will apply if the minerals are found at a depth of more than 100 meters below the surface.

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Portugal

Furthermore, Portugal is the only EU Member State that has enacted explicit law regulating deep-sea mining in national waters, although not at the national level. The mineral resources of Portugal are public property, according to the Portuguese Constitution. The Portuguese legal framework for geological resource study and utilisation was completely overhauled in 1990, with Law Decree 90/90 on March 16, 1990 141, which applies to both state-owned and privately held geological resources.

In 2012, the Azores Autonomous Region enacted a unique legislative framework applicable to seabed mining, which provides economical control of the seabed's geological resources near the Azores archipelago. It is in addition to the legal framework for the exploitation of natural resources in the Azores approved by the Regional Legislative Decree (Portugal, Regional Legislative Decree 21/2012/A of 9 May 2012). It comprises a collection of regulations that govern the procedures for prospecting, exploration, exploitation, research, right allocation, and land occupancy and expropriation.

Spain

Spain lacks specific legislation on deep sea mining. In Spain, Law 22/1973, of 21 July, 1973, on Mines, establishes a legal framework for the discovery, research, and exploitation of mineral deposits and any other geological resource, regardless of origin or physical state. This law establishes that all-natural mineral deposits and other existing geological resources found in Spanish territory, including the territorial sea and the continental shelf, are public domain goods that can be explored, investigated, and exploited directly by the Spanish State or transferred following the procedures and conditions outlined in this law and other applicable provisions in force.

United Kingdom (UK)

Deep-sea mining in the United Kingdom is regulated under the Marine and Coastal Access Act 2009, which established a new and comprehensive system of marine management for the national marine area, including a marine spatial planning system, a comprehensive licensing system for marine activities, and the designation of conservation zones, rather than a general mining act, which does not exist under UK law.

Norway

In recent years, Norway has started initiatives related to deep sea mining on the deep ocean bottom of the Arctic region inside its sovereign territorial waters, emphasising Polymetallic Sulphides (Juliani & Ellefmo, 2018). In this respect, the Norwegian government has established law that governs activities related to natural resource exploration and exploitation on the seabed and its substrates in Norwegian-controlled waters, including the continental shelf (Norwegian government. Law No. 7 of 2019). Mineral resources in Norwegian internal waterways, marine territory, and the Norwegian continental shelf are governed by this Act. Companies that want to participate in any activity must first submit an environmental impact assessment to the Cabinet of Ministers for approval. Mineral activities must not obstruct shipping, fishing, aviation, or any other activity, nor may they injure or threaten pipelines, cables, or other subsea infrastructure. The Act emphasises the precautionary principle in order to protect the marine environment and the cultural riches of the bottom. It also considers the fishing industry and the possible repercussions it may face by paying those who are harmed by deep sea mining.

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5. EU SUPPORTED DEEP SEA MINING PROJECTS

The need to improve knowledge in deep sea mining in the EU framework has made that during the last years EU has funded projects on exploration, environmental impact assessment/conservation and technology development. An exhaustive list of those projects can be seen in **Table 3**. Some particular countries have founded national research programs. Norway's contributed with €13 million to DSM research to continue with the previous MarMine (2016) project (Norwegian University of Science and Technology) and the UK established a multi-million-pound MarineE-tech (2015) initiative.

In the Blue Mining project (2014-2018) (Blue mining, 2015), 19 research centres and companies from 6 EU countries have participated. Its field of work has been developing technology associated with the exploration and exploitation of mineral resources using technologies such as UAVs. The Blue Nodules project (2016-2020) (Blue nodules, 2016) has involved 14 research centres and has developed a technologically sustainable deep sea mining system to harvest polymetallic nodules from the seafloor. Within GeoERA Raw Materials program has developed Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials (MINDeSEA), between 2018-2021, due to the collaboration between 8 GeoERA Partners and 4 Non-funded Organisations (MINDeSEA, 2018). The project aimed to develop an integrative metallogenetic study of principal types of seabed mineral resources (hydrothermal sulphides, ferromanganese crusts, phosphorites, marine placers and polymetallic nodules) in the European Seas.

Environmental impact assessments have also become increasingly crucial as expectations for the development of seabed mineral resources. The EU has also launched the MIDAS ("Management of Impacts of Deep Seas Resources Exploitation") (2013-2016) programme as part of the Seventh Framework Programme (MIDAS, 2013). The goal was to minimise the environmental effect of mining of deep-sea mineral resources. Polymetallic nodules, seafloor hydrothermal deposits, ferromanganese crusts, and rare-earth mud were the main targets. The initiative brought together 32 partners from 11 European nations working in research, industry, social sciences, law, and non-governmental organisations. Not funded by the EU, the Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) (2015-2017) are supported by EU countries collectively (JPI Oceans 2015). One of the JPI Oceans research projects focuses on exploring deep sea resources, and its objectives include establishing deep-sea habitat maps for deep-sea mining areas. Mining Impact: Environmental impacts and risks of deep sea mining project (2018-2022), the second phase of the JPI Ocean project, is currently taking place with the coope ration of 30 partners from 11 different countries (JPI Oceans 2018). The objectives are to assess the large-scale environmental impact caused by the suspended sediment plume, (2) the regional connectivity of species and biodiversity of biological assemblages and their resilience to impacts, and (3) the integrated effects on seabed ecosystem functions.

In recent years, many studies have been carried out to understand the potential damage that underwater mining could cause to the environment. To this end, different variables have been studied, such as habitats or physical and chemical changes in the sediment. A study carried out in one of the nine Areas of Particular Environmental Interest (APEIs) implemented by the ISA in CCFZ shows that this particular area is partially representative of an exploration area nearby located (Jones et al., 2021). In the same area, another study using metazoan megafaunal data simulated a range of very low to severe disturbances to determine the effect on community-level metrics (Ardron et al., 2019). Also, in CCFZ, the seamounts habitats were studied to understand their distribution during a mining activity (Cuvelier et al., 2020).

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Table 3. International scientific research projects related to Deep Sea Mining

Programme Project initiative	Project type/EU program	Project Description
Minerals4EU	Funded by the EC	The Minerals4EU project is designed to meet the recommendations of the Raw Materials Initiative and will develop an EU Mineral intelligence network structure delivering a web portal, a European Minerals Yearbook and foresight studies.
EMODNET III Geology. WP7 Marine Minerals	Funded by the EC through the EMFF	The European Marine Observation and Data network (EMODnet) compiles environmental information on 7 themes, including geology. EMODnet III Geology continues to update and further develop a framework for mapping marine minerals across all European seas for work package 7 Marine minerals. 11 different types of occurrences and deposits are mapped, including raw materials and hydrocarbons.
The European MSP Platform	DG MARE	The European MSP Platform is designed to offer support to all EU Member States in their efforts to implement Maritime Spatial Planning (MSP).
Blue Mining	Funded by the EC (Seventh Framework Programme)	A European international consortium of 19 large industry and research organisations on various maritime fields of expertise, the “Blue Mining” consortium, will develop solutions that will bring sustainable deep sea mining a big step closer.
Blue Nodules	Funded by the EC Horizon2020	It is a research and innovation project to develop a deep sea mining system for the harvesting of polymetallic nodules from the sea floor with minimum environmental impact
Marine E-Tech	Funded by NERC	The scientific approach led by Marine E-tech is holistic and interdisciplinary. It assesses the complex interplay between key processes in seafloor ferromanganese-cobalt-rich deposit formation and the potential environmental impacts of recovery.
MIDAS	Funded by the EC (Seventh Framework Programme)	Managing impacts of deep sea resource exploitation
RMIS	Directorate-General (DG) Joint Research Centre (JRC)	The European Commission's (EC) Raw Materials Information System (RMIS).

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EGDI	Eurogeosurveys	EGDI is EuroGeoSurveys' European Geological Data Infrastructure. It provides access to Pan-European and national geological datasets and services from the Geological Survey Organizations of Europe.
The INSPIRE "Geology and Mineral Resources"	The European Commission	-
Minventory	The European Commission	Large scale harmonisation project
InterRidge	International cooperative organization	Interdisciplinary, international studies of oceanic spreading centres
ASMWG & AORA	International working group EU, USA, Canada	Interdisciplinary (Atlantic seabed mapping, ecosystems, aquiculture)

6. MINDESEA DATABASE FOR MINERALS EXPLORATION

The MINDeSEA database contains 32 research/exploration cruises including data on expedition geographical information and legs duration; contractor; seismic, bathymetric, underwater video or sampling data, including navigation tracks and sampling sites location. This first compilation is promoted from the incorporation of the datasets from IGME and SGU. The dataset should be completed and updated in the future integrating the information from other sources like the references for the listed WP3 to WP6 occurrences and other public and EGS repositories.

According to the data collected in the MINDeSEA database is possible to establish potential exploration areas and gaps of information in pan-European seas, linked to the different CRMs, the mineral deposits and the morphotectonic environment that are present in each of them. This map on potential exploration areas for each mineral deposit is dependent on the occurrence, metallogenic, potential and predictivity maps produced under MINDeSEA (see deliverables for WP3 to 6).

MINDeSEA database along European sea regions

During the project, an extensive database including **1194 sample occurrences** for all the mineral deposits in the seabed was developed (**Table 4**). Those are distributed in European marine regions adopted by the EU Marine Strategy Framework Directive (**MSFD**). A summary of this sample location is available. These areas are classified in Arctic Ocean, Baltic Sea, Macaronesia, the Bay of Biscay and the Iberian Coasts. Together with these regions in the MINDeSEA project are the Norwegian Sea, Greenland Sea, Iceland Sea, Barents Sea, and White Sea subregions that are part of the Arctic Ocean; and the Black and Mediterranean seas. However, additional investigation and exploration would be necessary to estimate reserves for all these marine deposits in Europe.

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The MINDeSEA database recorded 490 polymetallic nodules records, 260 ferromanganese crust records, 310 hydrothermal sample records, 45 phosphorite sample records, and 89 placer deposits records (**Table 4**). The region with more records is Macaronesia, with 255 closely followed by the Arctic Ocean and the Baltic Sea, with 232 records. Following, the Bay of Biscay, with 133 records, Central-NE Atlantic, with 131 records, and a Mediterranean sea with 103 records. Less samples are available in the Aegean Sea, the Black Sea, and the Norwegian Sea, with 26, 26 and 21 records respectively. Finally, the Celtic, Adriatic, and Great North Sea are regions with less occurrence record, with 18, 16 and 6 respectively.

Table 4. Occurrence records in European marine regions for the different deposits

Marine region	Polymetallic Nodules	Ferromanganese Crusts	Hydrothermal deposits	Phosphorites	Placer deposits	TOTAL
Arctic Ocean	66	24	133	-	9	232
Baltic Sea	223	-	-	-	9	232
Black Sea	14	-	-	-	12	26
Bay of Biscay and the Iberian Coasts	91	20	1	13	8	133
Great North Sea	-	-	-	-	6	6
Celtic Sea	1	1	-	-	4	6
Aegean Sea	-	-	26	-	-	26
Macaronesia	30	174	51	-	-	255
English Channel	-	-	-	-	4	4
West Coast of Scotland	-	-	-	-	7	7
Irish Sea	-	-	-	-	1	1
Central-NE Atlantic Ocean	65	23	11	32	-	131
Adriatic Sea	-	-	-	-	16	16
Norwegian Sea	-	16	-	-	-	16
Mediterranean Sea	-	2	88	-	13	103
TOTAL	**490**	**260**	**310**	**45**	**89**	**1194**

Total of samples	***1194***

Polymetallic Nodules data

Polymetallic nodule samples are the most abundant mineral deposits within the MINDeSEA database, with 490 records analysed and 296 occurrences and from all of them 220 samples were analysed to obtain their geochemistry. Samples were recovered during 16 cruises (E.g. SGU cruises as K 414, K 510, or IGME cruises ANASTASYA/1999, ANASTASYA/2000, etc.). Polymetallic Nodules samples have been discovered in 7 of the Marine regions and in water of 16 countries (Germany, Denmark, Estonia, Spain, Finland, France, United

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Kingdom, Ireland, Latvia, Norway, Poland, Portugal, Romania, Russia, Sweden, Ukraine). Polymetallic Nodules contain several critical (Ba, Bi, Co, HREE, LREE, Nb, P, Sc, W, V, Li, Ti) and strategic elements (Mn, Ni, Cu, Mo, Zn) in different contents.

Ferromanganese Crusts data

Fe-Mn crusts samples counts 260 records divided in 141 occurrence sites distributed in seven of the 15 marine regions, between all these samples 181 of them were analysed. Samples were recovered in the EEZ of seven countries and within international waters (Denmark, Spain, Portugal, Iceland, Norway, Russia, United Kingdom, International waters), most of the samples were recovered during several cruises like DRAGO0511, SUBVENT1, ASV, DIVA ARTABRIA II, etc. In Fe-Mn crusts is possible to find a great number of the critical (Bi, Co, HREE, LREE, Nb, P, Sc, W, V, Li, Ti, PGM) and strategic elements (Mn, Ni, Cu, Mo, Zn).

Hydrothermal deposits data

Hydrothermal deposits are represented by massive sulphides, Fe and Mn oxyhydroxides and metalliferous sediments with a total of 310 (173 were chemically analysed) sample records located in 153 occurrences. Samples were recovered in 6 marine regions and in the EEZ of 8 countries (Cyprus, Spain, Greece, Greenland, Iceland, Italy, Norway, Portugal) and International Waters. The database show only one cruise (SUBVENT2) in which have been reported hydrothermal samples. Depending on the type of the minerals that constitute the hydrothermal deposit the strategic (Ni, Cu, Mo, Zn) and critical elements (Sb, Ba, Bi, Co, Ga, Ge, HREE, LREE, In, Nb, Sc, Ta, W, V, Li, Ti) concentrated are different.

Phosphorites data

Phophorites data of the MINDeSEA database only have been reported in two marine regions and two countries (Spain and Portugal) with a total of 45 samples and 12 occurrences, 35 samples were analysed. Samples we recovered during the DIVA ARTABRIA I and II cruises as well as DRAGO0511 and JC142 cruises. Phophorites concentrated few critical (F, HREE, LREE, phosphate rock, P, Ti) and strategic elements (Mn).

Placer deposits data

Placer deposits collect 89 samples each of which represent a singular occurrence but none of them were chemically analysed yet. Placers have been localized in waters of 14 countries (Albania, Bulgaria, Cyprus, Denmark, Spain, France, United Kingdom, Ireland, Italy, Latvia, Poland, Romania, Russia, Ukraine). Depending on the mineralogy of the deposit the strategic and critical elements could be different (eg., gold, cassiterite, rutile, magnetite…).

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

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8. APPENDIXES

APPENDIX I: ISA Contractors exploration areas

Zone 1: Clarion Clipperton fracture zone

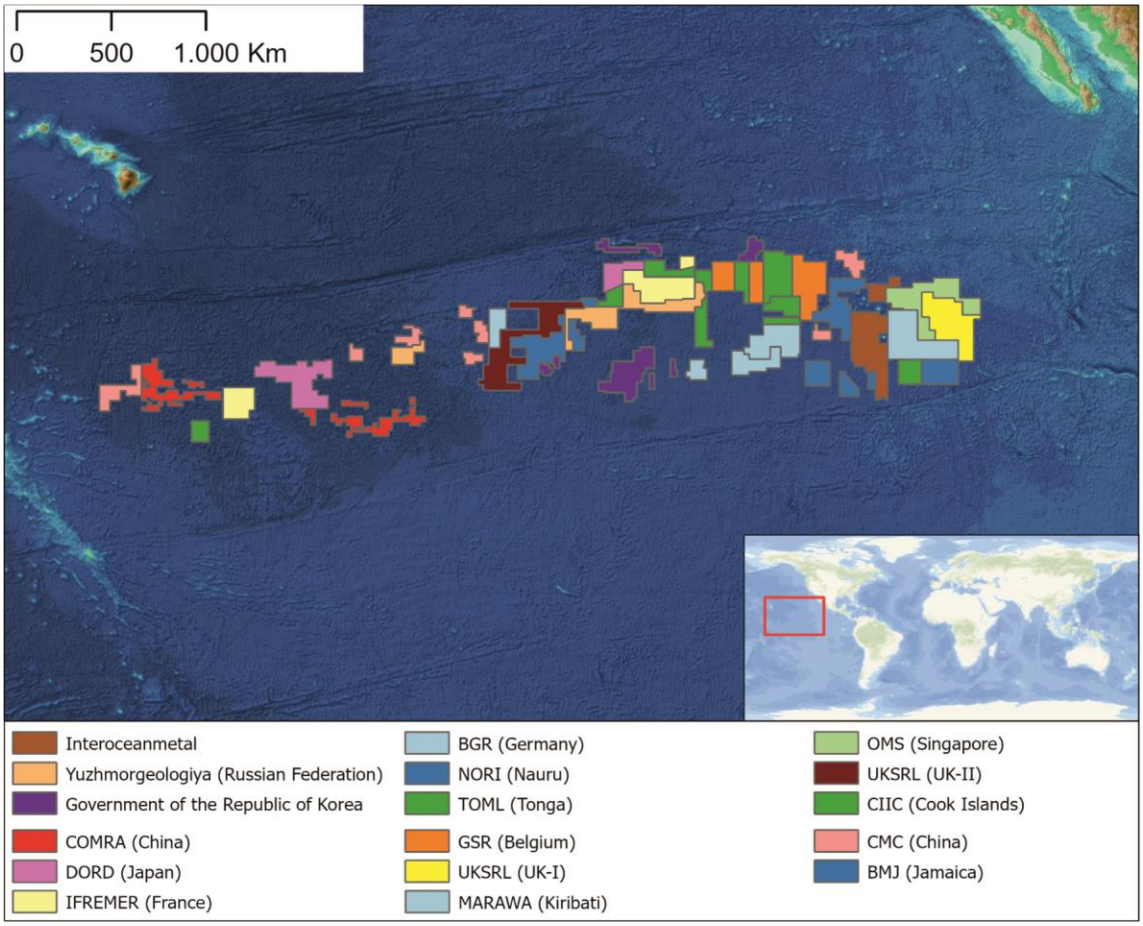

Figure 1. Areas allocated by ISA to contractors in the Clarion-Clipperton Zone. All zones refer to Polymetallic Nodules. Source: ISA (ISA).

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Zone 2: Mid Atlantic Ridge

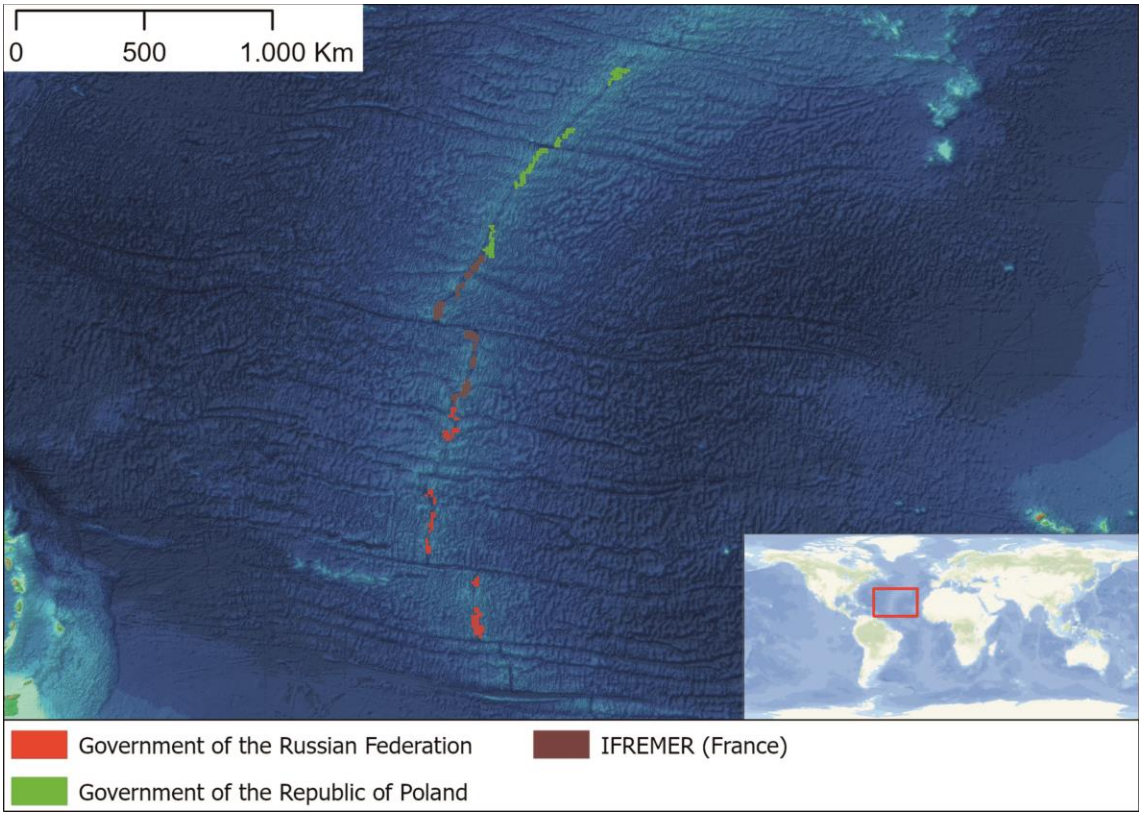

Figure 2. Areas allocated by ISA to contractors in the Mid Atlantic Ridge zone (**Fig.2**, zone 2). All zones refer to Polymetallic Sulphide. Source: ISA (ISA).

Zone 3: South Atlantic Ocean

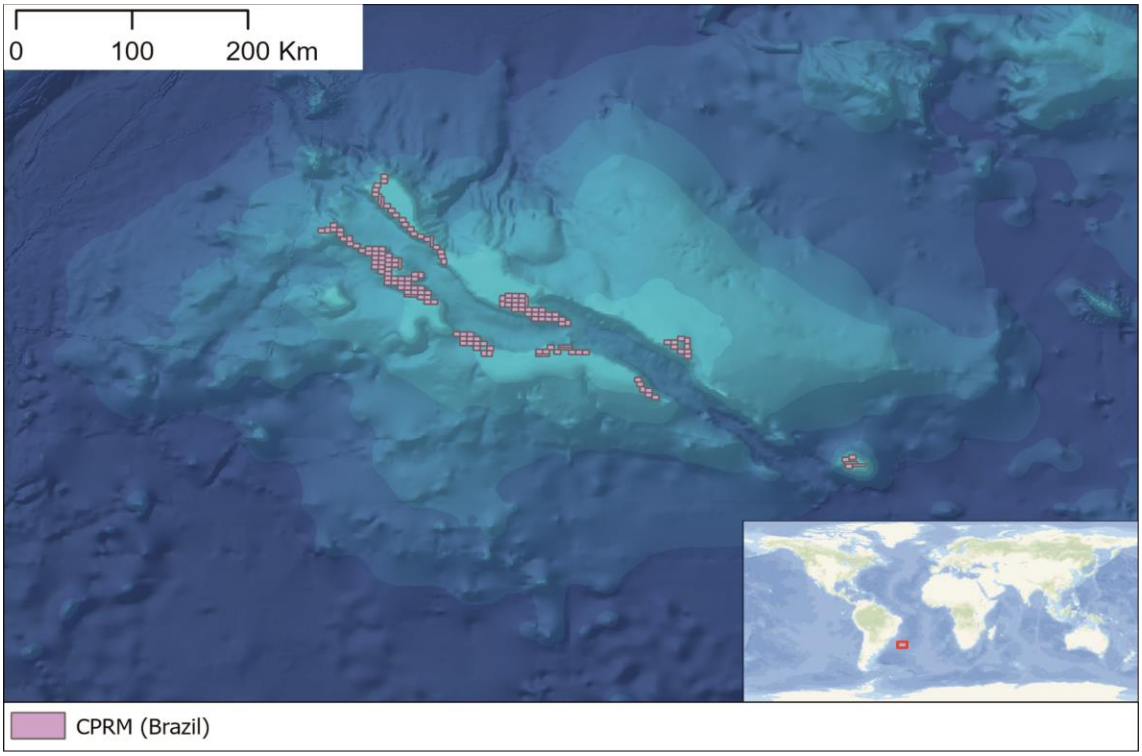

Figure 3. The Area allocated by ISA to the contractor in the South Atlantic Ocean (**Fig.2**, zone 3). All zones refer to Ferromanganese Crusts. Source: ISA (ISA).

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Zone 4: Indian Ocean

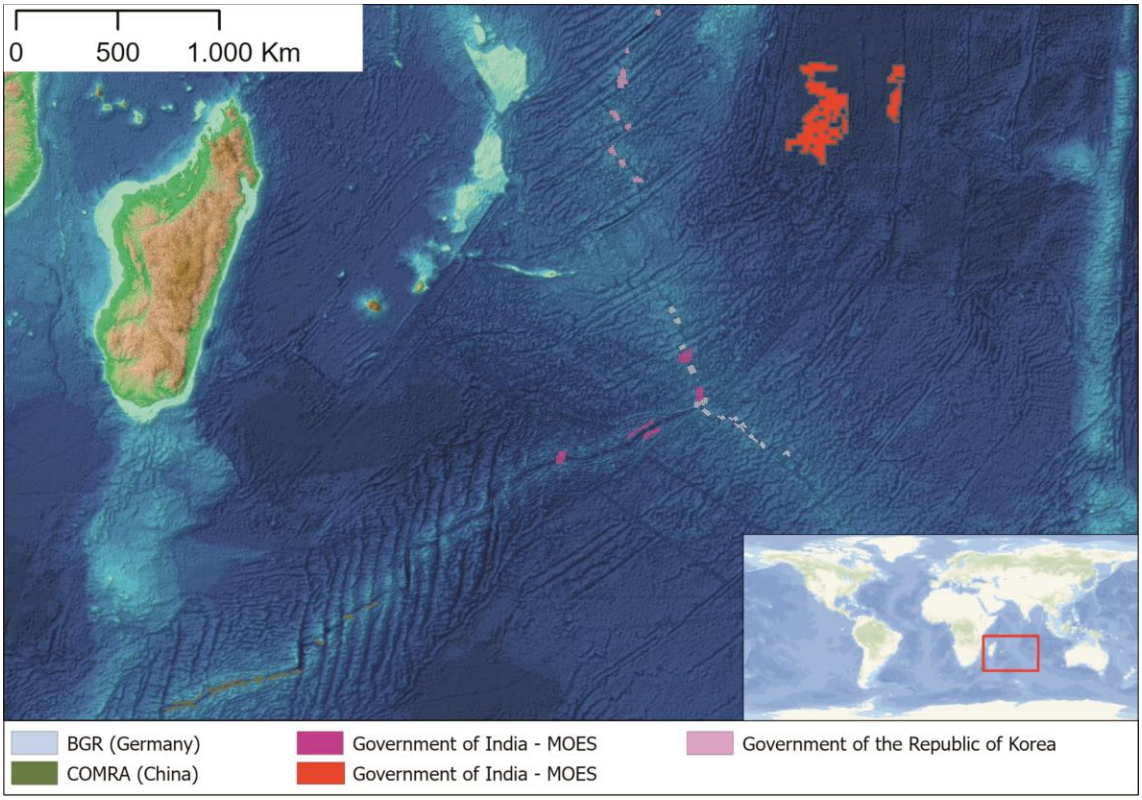

Figure 4. Areas allocated by ISA to contractors in the Indian Ocean (**Fig.2**, zone 4). All zones refer to Polymetallic Sulphide except two zones referred to Polymetallic Nodules (MOES, red). Source: ISA (ISA).

Zone 5: West Pacific Ocean

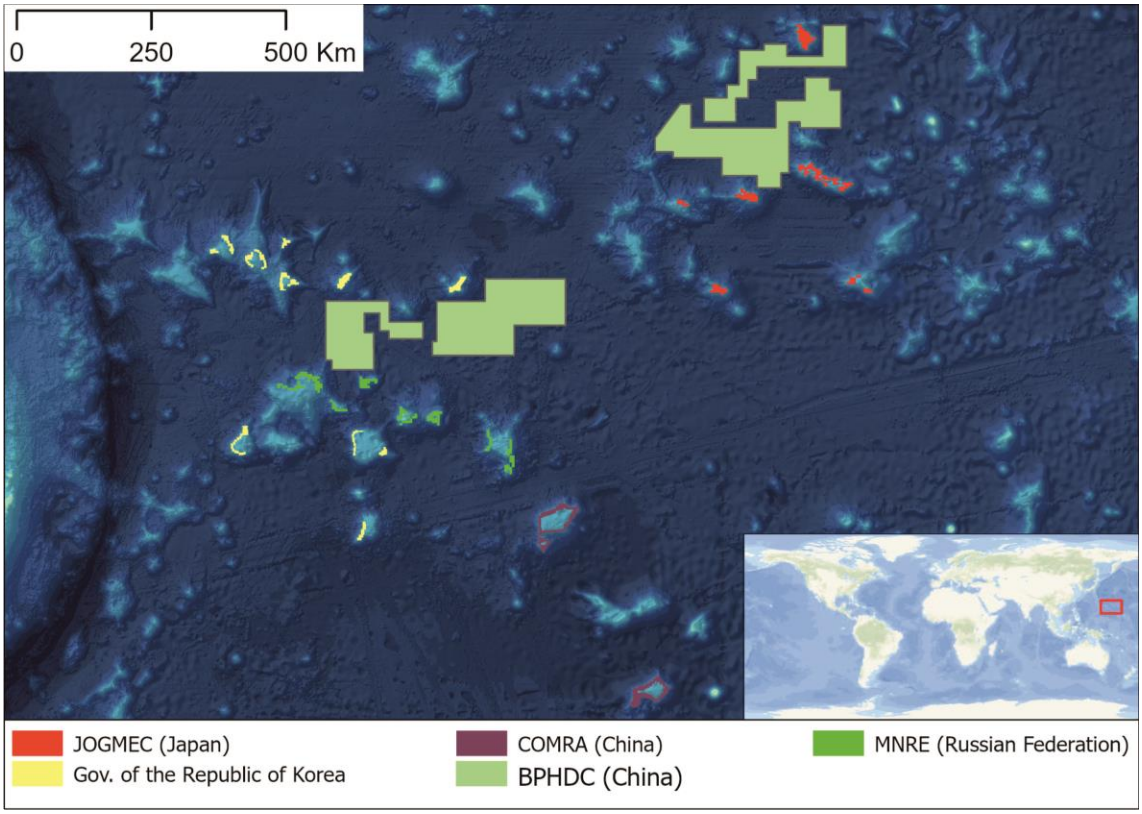

Figure 5. Areas allocated by ISA to contractors in the West Pacific Ocean zone (**Fig.2**, zone 5). All zones refer to

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Ferromanganese Crusts except four zones referred to as Polymetallic Nodules (BPHDC, light green). Source: ISA (ISA).

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APPENDIX II: ISA Contractors

The tables below list all contractors who have signed an exploration contract with the ISA to date, 2021.

Table 4. Polymetallic Nodule exploration Contracts issued by the ISA. There is more information by clicking on the "contractor" and "contract" boxes. Information given in the column called "Location" is referred to **Fig.1**.

Polymetallic Nodules exploration contracts					
Contractor	**Contract Date**	**Expiration Date**	**Sponsoring State**	**Location**	**Contract**
Interoceanmetal Joint Organization	29/03/2001	28/03/2021	Bulgaria, Cuba, Czech Republic, Poland, Russian Federation and Slovakia	Zone 1	
JSC Yuzhmorgeologiya	29/03/2001	28/03/2021	Russian Federation	Zone 1	-
Government of the Republic of Korea	27/04/2001	26/042021	Korea	Zone 1	
China Ocean Mineral Resources Research and Development Association (COMRA)	22/05/2001	21/05/2021	China	Zone 1	
Deep Ocean Resources Development Co. Ltd.(DORD)	20/06/2001	19/06/2021	Japan	Zone 1	
Institut Français de recherche pour l'exploitation de la mer (IFREMER)	20/06/2001	19/06/2021	France	Zone 1	
Government of India	25/03/2002	24/03/2022	India	Zone 4	
Federal Institute for Geosciences and Natural Resources of Germany (BGR)	19/07/2006	18/07/2021	Germany	Zone 1	
Nauru Ocean Resources Inc. (NORI)	22/07/2011	21/07/2026	Nauru	Zone 1	
Tonga Offshore Mining Limited (TOML)	11/01/2012	10/01/2027	Tonga	Zone 1	
Global Sea Mineral Resources NV (GSR)	14/01/2013	13/01/2028	Belgium	Zone 1	
UK Seabed Resources Ltd. (UKSRL UK-I)	08/02/2013	07/02/2028	United Kingdom	Zone 1	
Marawa Research and Exploration Ltd.(MARAWA)	19/01/2015	18/01/2030	Kiribati	Zone 1	
Ocean Mineral Singapore Pte Ltd.	22/01/2015	21/01/2030	Singapore	Zone 1	

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(OMS)					
UK Seabed Resources Ltd. (UKSRL UK-II)	29/03/2016	28/03/2031	United Kingdom	Zone 1	↗
Cook Islands Investment Corporation (CIIC)	15/07/2016	14/07/2031	Cook Island	Zone 1	↗
China Minmetals Corporation (CMC)	12/05/2017	11/05/2032	China	Zone 1	↗
Beijing Pioneer Hi-Tech Development Corporation (BPHDC)	18/10/2019	17/10/2034	China	Zone 6	-
Blue Minerals Jamaica Ltd. (BMJ)	04/04/2021	03/04/2036	Jamaica	Zone 1	-

Table 5. Cobalt-rich Ferromanganese Crusts exploration contracts issued by the ISA. There is more information by clicking on the "contractor" and "contract" boxes. Information given in the column called "Location" is referred to **Fig.1**.

Cobalt-rich Ferromanganese Crusts exploration contracts					
Contractor	**Contract Date**	**Expiration Date**	**Sponsoring State**	**Location**	**Contract**
Japan Oil, Gas and Metals National Corporation (JOGMEC)	27/01/2014	26/01/2029	Japan	Zone 5	↗
China Ocean Mineral Resources Research and Development Association (COMRA)	29/04/2014	28/04/2029	China	Zone 5	↗
Ministry of Natural Resources and Environment of the Russian Federation (MNRE)	10/03/2015	09/03/2030	Russian Federation	Zone 5	-
Companhia De Pesquisa de Recursos Minerais (CPRM)	09/11/2015	08/11/2030	Brazil	Zone 3	↗
The Republic of Korea	27/03/2018	26/03/2033	Republic of Korea	Zone 5	↗

Table 6. Polymetallic Sulphides exploration contracts issued by the ISA. There is more information by clicking on the "contractor" and "contract" boxes. Information given in the column called "Location" is referred to **Fig.1.**

Polymetallic Sulphides exploration contracts					
Contractor	**Contract Date**	**Expiration Date**	**Sponsoring State**	**Location**	**Contract**

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China Ocean Mineral Resources Research and Development Association(COMRA)	18/11/2011	17/11/2026	China	Zone 4	
Government of the Russian Federation	29/10/2012	28/10/2027	Russian Federation	Zone 2	-
Government of the Republic of Korea	24/06/2014	23/06/2029	Republic of Korea	Zone 4	
Institut français de recherche pour l'exploitation de la mer (IFREMER)	18/11/2014	17/11/2029	France	Zone 2	
Federal Institute for Geosciences and Natural Resources of the Federal Republic of Germany (BGR)	06/05/2015	05/05/2030	Germany	Zone 4	
The Government of India	26/09/2016	25/09/2031	India	Zone 4	
Government of the Republic of Poland	12/02/2018	11/02/2033	Poland	Zone 2	

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APPENDIX III: Short description of exploration activities in CCFZ

Federal Institute for Geosciences and Natural Resources (BGR)

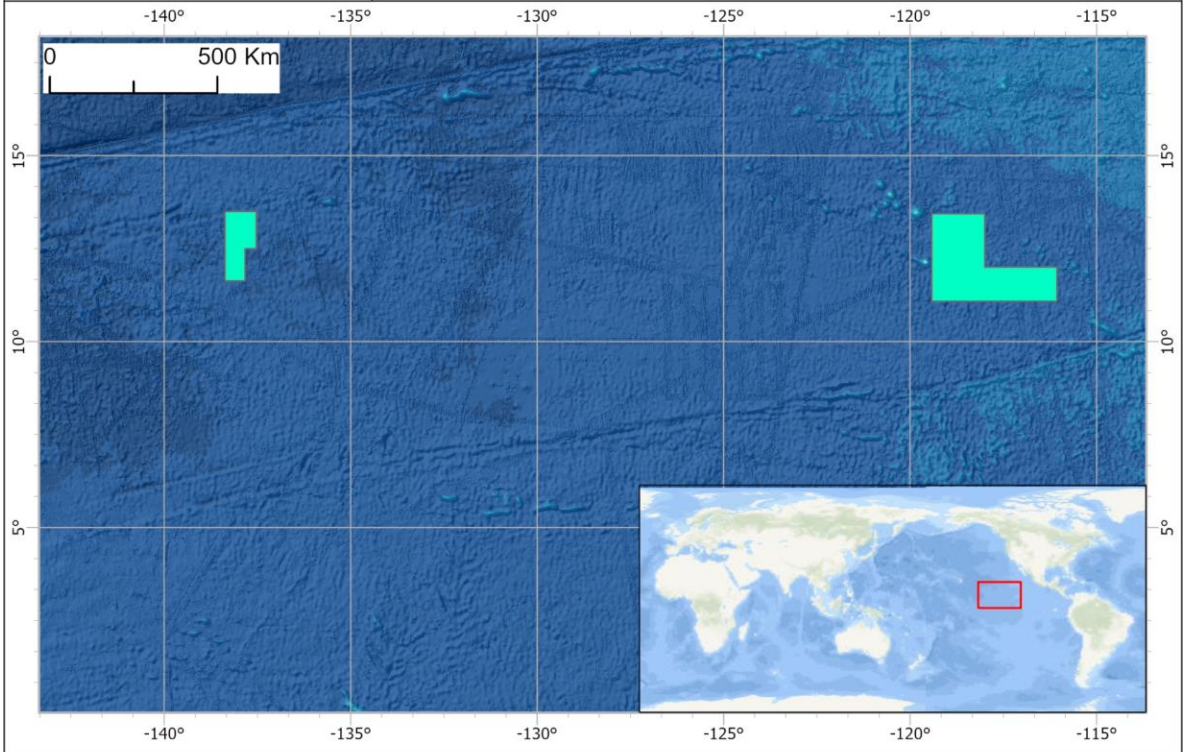
Location: Clarion Clipperton Fracture Zone (CCFZ)

Latitude: 12:17°N **Longitude**: -122:-128°E

Exploration areas: two exploration area in total covers 75000 km²

Nº of zones: 2

Type of contract: Exploration license



Company : BGR is the geoscientific center of excellence within the federal government and part of its scientific and technical infrastructure. One of the goals of BGR is research and develop new exploration methods, such as Deep Sea Mining , looking for critical resources.

Government support : Germany	**Licence timeline:** 2006-2021
Type of resource : Polymetallic nodules	**Water depth :** 4000-6000 m

The resource assesment made in the exploration zone is based on hydracoustic and box-corer data for the entire license area . A predictive model based in neural network approach was used to analyse the entire license area and typical geostatistics (variography as well as ordinary and universal kriging) were carried out to analyse prospective areas.

SOURCE:

International Seabed Authority (ISA): https://www.isa.org.jm/map/federal-institute-geosciences-and-natural-resources-germany

GSR Environmental Impact Statement: https://www.isa.org.jm/files/files/documents/EIA_BGR_0.pdf

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).

Global Sea Mineral Resources (GSR)

GSR
Global Sea Mineral Resources

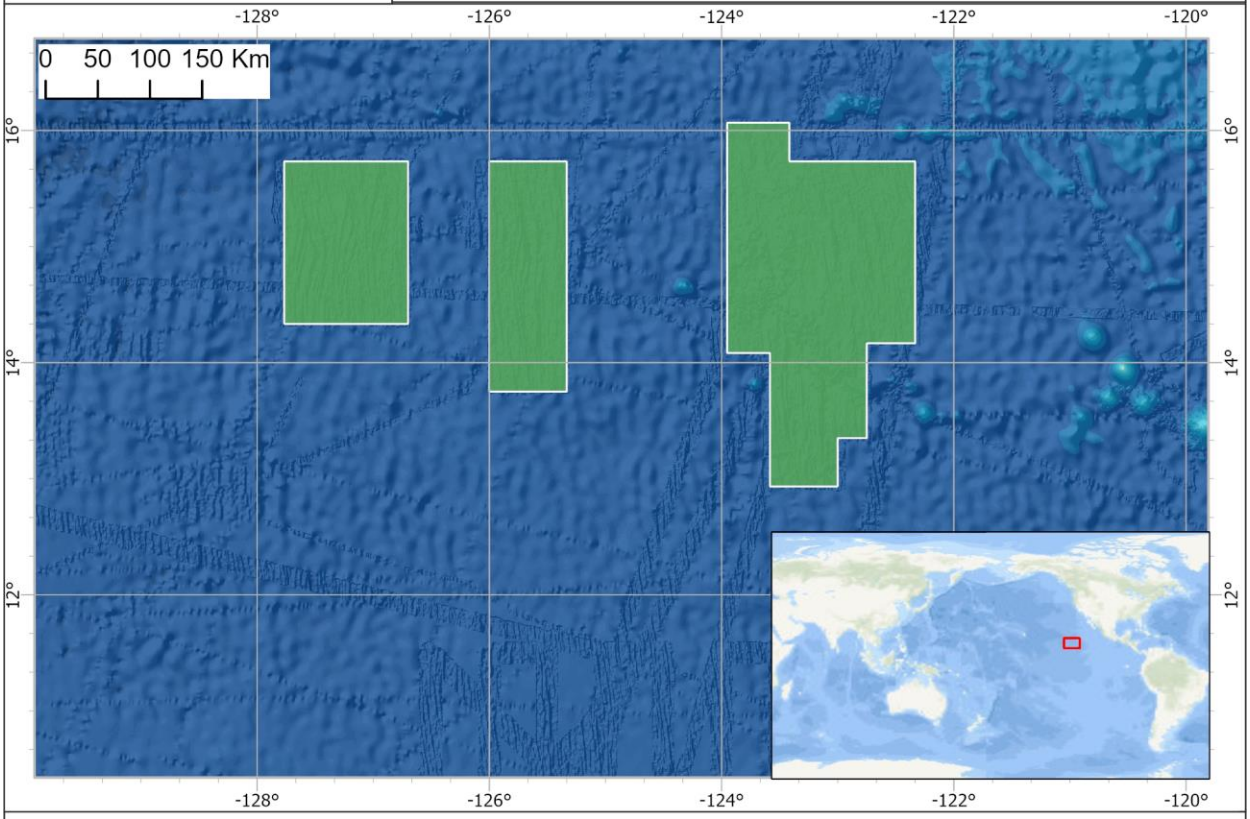
Location: Clarion Clipperton Fracture Zone (CCFZ)

Latitude: 12:17°N **Longitude**: -122:-128°E

Exploration areas: three exploration area in total covers 76728 km²

Nº of zones: 3

Type of contract: Exploration license



Company : GSR is a is a subsidiary of the DEME Group, a Belgium company, focused on the development of sustainable ocean mineral resources

Government support : Belgium	**Licence timeline:** 2013-2028
Type of resource : Polymetallic nodules	**Water depth :** 4000-5000 m

During the surveys, the company has obtained a large number of samples of sediment, flora and fauna, nodules and water column. In addition, they have obtained abundant high and low resolution geophysical data as well as detailed photographs of the seabed. Combining all this information, they have elaborated models from which they have obtained an approximation of the amount of resources and areas with potential to be exploited

SOURCE:

International Seabed Authority (ISA): https://www.isa.org.jm/map/global-sea-mineral-resources-nv

GSR Environmental Impact Statement: https://www.isa.org.jm/files/files/documents/GSR-EIS-compact.zip

This project has been supported by the European Union's Horizon 2020 research and innovation programme, GeoERA (Grant Agreement Nº 731166, project GeoE.171.001).