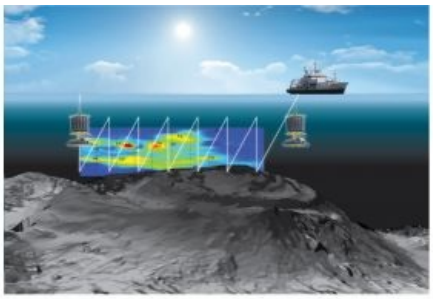
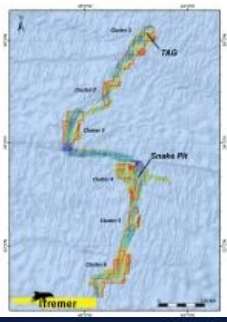
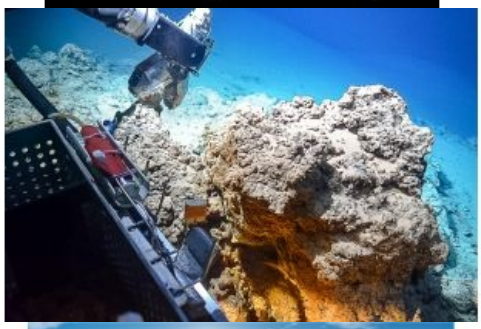
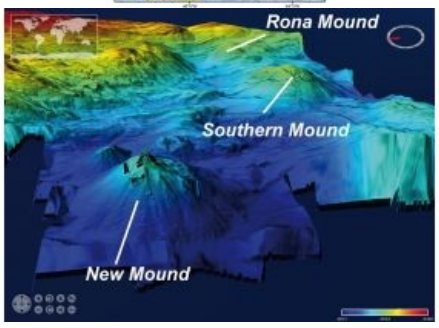
IFREMERÂ€™S EXPLORATIONS AND RESEARCH

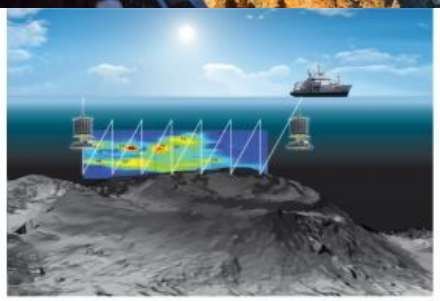
Understanding Deep-sea Minerals and Ecosystems











France and Ifremer have long been involved in the discovery and study of deep-sea mineral resources and their associated ecosystems. With a rather unique position in the marine research landscape, Ifremer is actively involved in the deep sea, both as a contractor with the ISA and an integrated marine science research institute. The HERMINE 2017 exploration cruise on the French polymetallic sulphides exploration contract is an example of combined mineral exploration and scientific investigations.

In the seventies, France was amongst the pioneer nations that discovered the metal-bearing hydrothermal sources and explored the polymetallic nodule deposits in the Clarion Cliperton Fracture Zone (CCFZ) located in the northern central Pacific. A strong commercial interest for these potential sources of minerals initially triggered an important exploration activity by countries such as China, Germany, India, Japan, Korea, France, etc. Then, in the 1980s, unfavourable market conditions halted this exploration.

The last two decades have seen a renewed interest for these potential sources of minerals sparked by factors such as the rise of metal prices, the development of low-carbon technologies increasing the demand for some minerals and geopolitical issues. Exploration of the three types of deep-sea mineral resources - polymetallic nodules, in abyssal plains; polymetallic sulphides (PMS), along mid-ocean ridges and in back-arc basin context; and cobalt-rich ferromanganese crusts, on seamounts - has therefore been an item of increasing interest on the international agenda.

Figure 1: Diversity of polychaetes families in the CCFZ area : (a) Amphinomidae, (b) Travisiidae, Travisia sp., (c) Poecilochaetidae, Poecilochaetus sp. (d) Flabelligeridae, (e) Cirratulidae, Chaetozone sp. (f) Sabellidae, (g) Syllidae, Anguillosyllis sp. et (h) Lumbrineridae, Lumbrinerides sp. Â©Ifremer

As an integrated marine science research institute, Ifremer plays a particular role in the French national strategy for the exploration and exploitation of the deep seabed minerals. Under the sponsorship of France, Ifremer has signed two exploration contracts with the International Seabed Authority (ISA), which regulates the activities related to deep-sea minerals exploration and exploitation in the Area. The institute also conducts fundamental and applied research related to both the geological and environmental aspects of deep-sea minerals as well as technology developments.

Ifremer’s Exploration Contracts with the ISA

The exploration contract for polymetallic nodules, signed in 2001, covers an area of 75,000km² in the CCFZ and was extended for five years in 2016. Investigations conducted so far have resulted in a first estimate of the mineral resources and a better understanding of the benthic ecosystem. For instance, studies led within the JPI Oceans pilot action have highlighted the diversity and importance of the epifauna associated with the nodules and found that recovery of the fauna from previous small experimental mining simulations, up to 37 years old, was very slow (Vanreusel et al., 2016). Despite this progress, our knowledge about the functioning of these ecosystems and their resilience remains too limited to evaluate the potential impact of the exploitation of nodules. These questions are therefore the focus of our current activities.

Figure 2: Map of the French exploration contract for polymetallic sulphides on the Mid Atlantic Ridge with its six clusters containing the 100 exploration blocks. Â©Ifremer

The exploration contract for PMS was signed in 2014, for a period of fifteen years, and covers an area located on the Mid-Atlantic Ridge, spreading from 21°N to 26°N at an average depth of 3,400m. The activities, planned as part of the exploration programme, aim at locating hydrothermal vent fields and extinct seafloor massive sulphides, estimating the mineral resources in the contract area and assessing the biodiversity and environmental parameters at a regional and local scale over the sites of potential mining interests.

Research Activities

In addition to the activities performed as an ISA contractor, Ifremer also conducts fundamental and applied research on the deep-sea, which is one of the institute's strategic themes, with the following objectives:

- To understand the geo-biological processes controlling the creation of the mineral resources;
- To develop technologies and methodologies for innovative and multi-scale exploration, observation, analysis and monitoring;
- To describe and understand the composition, structure and functioning of deep-sea ecosystems.

A collective scientific assessment group, led by the CNRS (Centre National de la Recherche Scientifique), provided a summary of the international scientific knowledge available on the environmental impacts of exploration and exploitation of deep-sea mineral resources. It also identified the scientific barriers and research and development activities required to break them (Dyment et al. 2014). Although recent studies and projects have partly improved our knowledge and filled some of the gaps identified, this knowledge remains inadequate.

The JPI Oceans pilot action 'Ecological aspects of deep-sea mining', led by Geomar, has shed some light on the CCFZ ecosystems composition (Figure 1) and on the potential impacts of polymetallic nodules exploitation by assessing the biodiversity and recovery of sites that had seen small experimental mining simulations over decadal timescales. However, the size of these experiments is not representative of future commercial scale operations and does not allow for a proper assessment of their impacts. To overcome these limitations, a new JPI Oceans project, named 'Mining impact', has started. This project will set up a comprehensive monitoring programme to ensure an independent scientific investigation of the environmental impacts of an industrial nodule collector components trial, planned by the Belgian contractor DEME-GSR in 2019.

Figure 3: Sampling of an inactive hydrothermal chimney by the Nautileâ€™s arm during the exploration cruise Hermine 2017. Â©HERMINE 2017, Ifremer

Ifremer, in collaboration with the Sorbonne University, the MNHN and the Mediterranean Institute of Oceanography, currently leads a research project on the hydrothermal vent ecosystems. The data collected during two scientific cruises (BICOSE 1 in 2014 and BICOSE 2 in 2018)

Recent Exploration on Polymetallic Sulphides: the HERMINE Cruise, R/V *Pourquoi Pas?*

The HERMINE cruise is part of Ifremer's programme of activity under its exploration contract for PMS with the ISA. The cruise, held from 13 March to 28 April 2017, targeted the exploration of active and inactive PMS and the quantification of natural chemical input of the hydrothermal plume to the water column. The cruise strategy was built around three objectives: (i) regional exploration including the detection of plume anomalies and the research of PMS deposits, (ii) local exploration of a PMS district and (iii) integrated study of a natural hydrothermal plume. This '3-in-1' cruise required us to optimize the various operations with the daytime being devoted to dives, on board the Human Occupied Vehicle (HOV) *Nautile*, and the nights being mostly dedicated to CTD/Rosette operations.

The preliminary results of the HERMINE cruise are:

- Regional Exploration. About half of the campaign was dedicated to the objective to complete the mapping of the six clusters and search for new active hydrothermal sites along the 800km of the contract area (Figure 2). Targets included recent volcanic ridges and areas with potential exhumed mantle (i.e. oceanic core complex). Based on the relatively short time spent on such a large area (~10,000km^2), the results are very positive since two very different types of mineralization were discovered. Very old and oxidized sulphide deposits were identified off-axis in cluster 4, and the mineralized quartz veins (Fe, Cu) discovered in cluster 6 represent an unusual type of mineralization in the ocean. In addition, at least seven new active hydrothermal fields were detected.
- Local exploration of TAG district. One of the objectives was to identify and sample mineralization on inactive areas (Figure 3). More than twenty hydrothermal mounds ranging from a few tens to 400m in diameter were studied (Figure 4). The mineralization was concentrated on a relatively small area of 4x6km, which makes it, with the exception of the Red Sea, the highest local density of hydrothermal mineralization currently known in the oceans. This mineralized district might represent a potential for several tens of millions of tons of ore. Additional studies are necessary to discuss the meaning of this unusual density of PMS. Biological and microbiological studies were also conducted to understand biodiversity and ecosystems functioning on the active and inactive sites.
- Integrated study of the TAG hydrothermal plume. In-situ analysis and sampling of the rising plume was carried out with the HOV *Nautile*. Sampling of the non-buoyant plume involved the deployment of CTD/rosette sampling equipment as shown in Figure 5.

The objective was to study the metals, gas and larval dispersion, the microbial diversity and metabolic activity in the hydrothermal plume. Hydrothermal fluids and water samples collected will allow us to (i) understand the dynamics of the natural plume, (ii) quantify natural chemical input in the water column, and (iii) evaluate the dissolved and particulate trace metal dispersion of the TAG plume. Eventually the findings on the natural plume will contribute to future deep-sea PMS mining impact studies.

Figure 4: Map of inactive mounds in the TAG district area from high resolution ROV based bathymetric surveys. Â©HERMINE 2017, Ifremer

Conclusion

Ifremer continues its long-standing involvement related to the deep-sea by providing public policy support, and as such, holding the two French exploration contracts with the ISA under the auspices of and sponsored by France, and by pursuing its contribution to major scientific research. Research themes span from understanding the processes that control the formation of the deep-sea mineral resources to the functioning of the different ecosystems. With the renewed interest in these potential sources of raw material, it is of paramount importance to expand our knowledge of these ecosystems and to assess their resilience and the impact that exploitation would have. This research, often conducted in the context of international collaborative projects (JPI Oceans Mining Impact, EU FP7 MIDAS, H2020 MERCES etc.), also provides information for the development of the legal framework, the Mining Code, that is currently being drafted by the ISA to regulate exploitation of the deep-sea minerals in the Area.

References

Auguste M., Mestre N. C., Rocha T. L., Cardoso C., Cueff-Gauchard Valerie, Le Bloa Simon, Cambon-Bonavita Marie-Anne, Shillito B., Zbinden M., Ravaux J., Bebianno M. J. (2016). Development of an ecotoxicological protocol for the deep-sea fauna using the hydrothermal vent shrimp Rimicaris exoculata. Aquatic Toxicology, 175, 277-285. http://doi.org/10.1016/j.aquatox.2016.03.024

2014. Dyment, F. Lallier, N. Le Bris, O. Rouxel, P.-M. Sarradin, S. Lamare, C. Coumert, M. Morineaux, J. Tourolle (coord.), 2014. Les impacts environnementaux de l'exploitation des ressources minérales marines profondes. Expertise scientifique collective, Synthèse du rapport, CNRS – Ifremer, 110 p. environ

Vanreusel, A., Hilario, A., Ribeiro, P.A., Menot, L., Arbizu, P.M., 2016. Threatened by mining, polymetallic nodules are required to preserve abyssal epifauna. Scientific Reports 6, 26808.

Figure 5: Theoretical Â« Tow-yo Â» profile of the CTD deployment and data interpretation to identify the hydrothermal plume. Â©HERMINE 2017, Ifremer