Deep ocean Mining
Kotlinski, Rybár

The principle of freedom of the seas, applied universally since the 17th century and limiting the rights of coastal states to a narrow belt of water adjacent to their shoreline, was abandoned during the first half of the 20th century. The reasons for a change in the legal status of the seas were both economic and political. The change resulted, on the one hand, from the concern for rational management of living resources, the concern stemming from increasing pollution of inshore waters, used more and more often for recreation. On the other hand, the change was brought about also by political and military reasons. After 1960, exploration and exploitation of marine deposits was systematically growing, more and more diverse resources being retrieved from increasingly greater depths, at increasingly longer distances from the shore.

The group of deep-sea polymetallic resources, encompassing polymetallic sulphide ores as well as deep-sea nodules and cobalt-rich crusts, is at present intensively studied. Particularly important commercially, due to their high concentrations in sulphide and manganese oxide ores, are such metals as **Ni, Cu, Co, Ag, Au, Mn, Mo, Zn, and Pt**. A comparison between the estimated magnitude of the deep-sea deposits of those metals and their terrestrial resources shows the first, particularly those of **Mn, Ni, Mo, Co** and **Ag** to be several times higher than the other ***/Fig. 1/.***

In 1987, based on the new international legal order and in accordance with the principles and procedures of application and claim registration, the pioneer investor status was granted to: DORD, acting on behalf of the government of Japan; IFREMER/AFERNOD, acting on behalf of the government of France; YUZHMORGEOLOGIYA, acting on behalf of the government of the Soviet Union (and later on behalf of the government of Russia), and India. The remaining investors registered their claims within the Clarion-Clipperton field in the Pacific, ***/Fig.2/*** the area housing also claims of a number of consortia, the so-called potential investors: OMA, OMI, and LMS, representing interests of developed western countries. In 1990 and 1991, the pioneer investor's status was granted to COMRA (acting on behalf of the government of China) and to

IOM, respectively, their claim areas being situated in the Clarion-Clipperton field as well KORDI, acting on behalf of the government of Republic of Korea, was granted the pioneer investor's status in 1994. During XI ISA session in 2005 the Germany registered their claim area in western part of C-C ore field (German Federal Institute for Geosciences and Natural Resources). In addition to the registered pioneer areas assigned to the pioneer investors, the Clarion-Clipperton field encompasses also mineable areas under the United Nations jurisdiction

Since 1994, after the Convention on the Law of the Sea treats mineral resources on the sea floor and in the subsoil thereof in the high seas had entered into force, activities of the registered pioneer investors within the so-called International Seabed Area have been coordinated by the International Seabed Authority (ISA).

Location of most of the registered pioneer areas in the Clarion-Clipperton field (France, Japan, Russia, China, Interoceanmetal Joint Organization, Korea) is the consequence of a unique character of that field, illustrated by the fact that it is only there that the high abundance of nodules is correlated with high grades of major metals: manganese, nickel, copper, and cobalt.

Interoceanmetal Joint Organization (IOM), ***/Fig.3/*** established in 1987, is an intergovernmental body created to carry out exploration of oceanic deep-sea polymetallic nodules. Since its establishment, IOM has been carrying out comprehensive geological, geophysical, and oceanographic studies in its area of interest in order to prepare a sound basis for registration of its claim to an area of nodule deposits. The Organization focused its interest on the Eastern Area of the Clarion-Clipperton Region, an area most interesting from the economic point of view. IOM, certified by the governments of Bulgaria, Cuba, Czech Republic, Poland, Russian Federation, and Slovak Republic, received its Certificate of Registration in 1992; in 1995, IOM was granted the Certificate of Compliance.

Using the results of its comprehensive research and analysis of regional geological and geophysical data, IOM selected, within 1987-1990, a prospecting area of about 553 thou. km^2 within which to conduct multi-faceted geological and geophysical studies. The studies carried out in the eastern part of the Clarion-Clipperton nodule region were aimed at narrowing an application area down to 300,000 km^2 and

to collect data necessary for IOM to apply to the Preparatory Commission of the International Seabed Authority (ISA) and International Tribunal for the Law of the Sea for registration and allocation of a 150,000 km^2 *pioneer area*.

As a preliminary to the actual exploration, the IOM pioneer area was – in 1999 - surveyed by means of a SIMRAD multibeam echo sounder. The survey resulted in compilation of 1:200 000 maps of bottom relief, slope angles, and bathymetry; side-scan sonar images of the bottom were collated as well.

In 2001 and 2004, IOM embarked upon implementation of the first stage of its "Plan of Work for Exploration" by launching a cruise to its pioneer area on board RV Yuzhmorgeologiya. During the cruise, a B-2 area was surveyed. The cruise was intended to acquire data with which to identify areas most suitable for more detailed geological exploration aimed at mapping potentially valuable nodule deposits as well as at assessing spatial variability in nodule coverage and base metal contents in the deposits .

The manganese deposits formation encompasses deep-sea nodules and cobalt-rich manganese crusts. The formation is identified based on the presence of nodule-forming processes at the sediment-water interphase, affected by specific environmental factors ***/Fig.4/.***

Conditions determining forming of the nodules are shaped depending on the following factors:

-dominant processes delivering material (including metals, i.e. Mn, Ni, Cu, Fe, Co), such as hydrothermal, volcanic-vent and infiltration ones;

-distance from the active magmatic centers;

-depth of occurrence, i.e. location in relation to the CCD and SCD levels;

-physic-chemical properties of near-bottom waters and pore waters.

The seafloor sediment vertical profile is topped by clays and siliceous oozes of the geochemically active (2-12 cm thick) layer on which nodules are formed and in which they are partly embedded. ***/Fig.5/ /Fig.6/.***

According to the most recent data, the polymetallic nodule resources in the richest field, the Clarion-Clipperton, are estimated at

about 34 billion tones, the estimated resources of the major metals being 7,500 million tones of Mn; 340 million tones of Ni; 265 million tones of Cu; and 78 million tones of Co.

Characteristics of polymetallic nodules in the IOM exploration area by depth and the distributions of the nodule abundance in dependence on depth are on ***Fig. 7 and Fig 8***.

Within the IOM exploration area, sediment samples were collected (with a 0.25 m^2 box corer equipped with a photo-camera) from a total of 371 sites; nodules were present at 324 (87.3%) of them, while at 154 (47.5%) of them the nodule abundance (wet weight-based) exceeded 10 kg /m^2 ***/Fig.9/.***

No regular pattern could be observed in the distribution of polymetallic nodules in the area surveyed; in other words, no single morphological element of the seafloor relief tended to be more amenable to nodule aggregations than the remaining ones. Both nodule-rich and nodule-depleted patches of the seafloor could be found on the undulating abyssal plain, on tops and slopes of ridges (horsts), and on the walls of grabens.

Mining system

To be deemed minable, a nodule deposit should bear enough nodules to guarantee commercial exploitation of $1.5 – 4 \times 10^6$ tones of nodules for 20-25 years, the metal grades being 1.25-1.5% for Ni, 1.0 – 1.4% for Cu, 27-30% for Mn, and 0.2-0.25 for Co.

A deep ocean mining system is an integration of a seafloor miner (or collector) system, hoist pipe system, ship system and transportation system. The technologies should be compatible for systems integration.

Nodule miner or collector

Reliability, mobility, safety and collection efficiency of the miner or collector system are the most important parameters in the mining system. The ocean mining consortia have been developing different concept systems of unmanned, seafloor nodule miners. There is no new miner system evolved since the ‘70’s. ***/Fig.10/***.