interoceanmetal
JOINT ORGANIZATION

30 YEARS OF DEEP SEABED EXPLORATION

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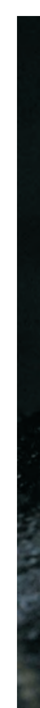


The Interoceanmetal Joint Organization, established in 1987, celebrates today its 30th birthday. It gives us great pleasure to commemorate this anniversary. The organization and its exploration activities are exceptional for many reasons. As the pioneer investor, the organization actively participated in the very early stages of deep sea mining development. Outcomes of regional exploration phases has been delivered to the International Seabed Authority within the system of relinquishments of registered exploration areas that currently are the genuine accomplishment of the UNCLOS principle of common heritage of mankind.

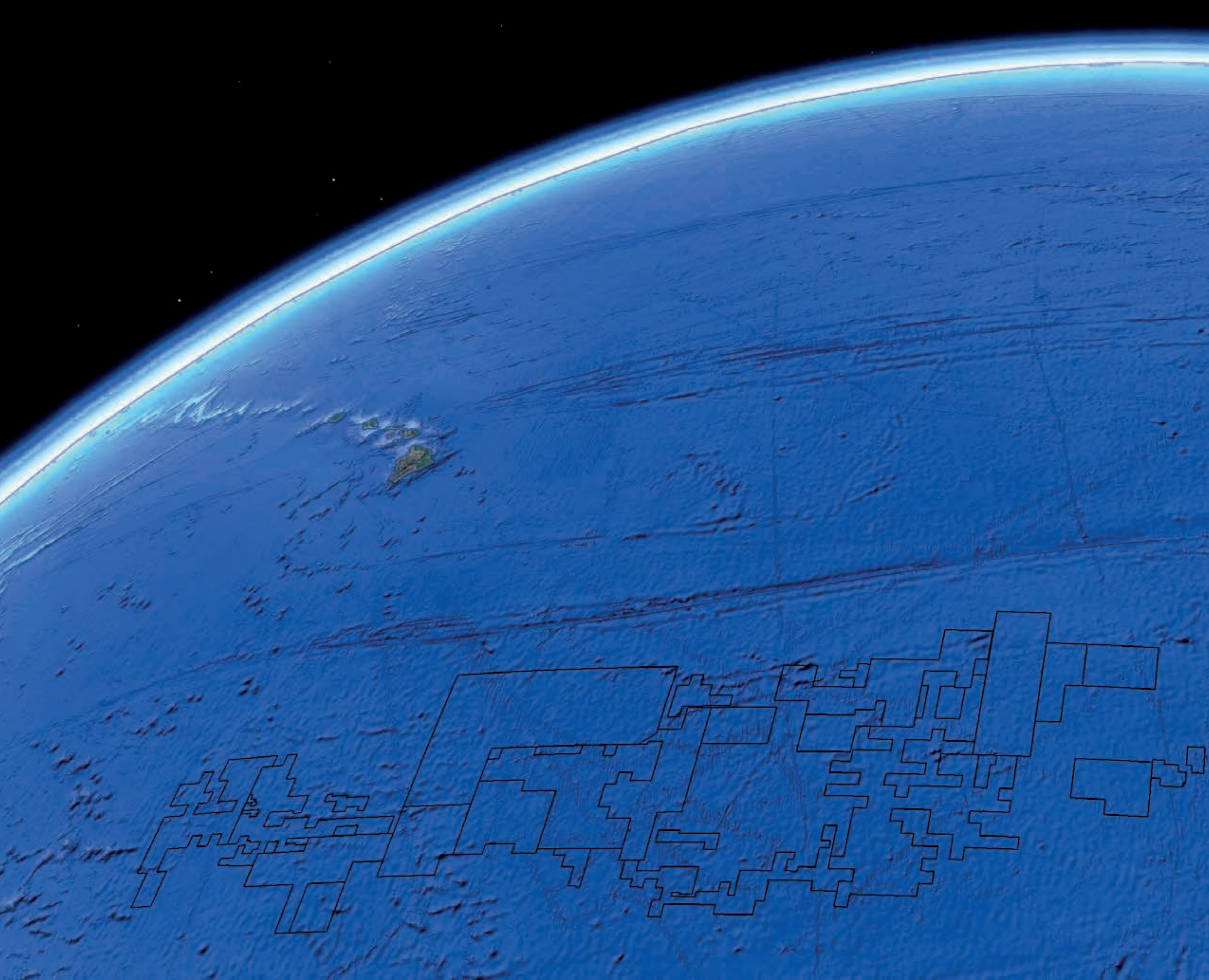
In 2001, the organization signed a contract for exploration for polymetallic nodules with the International Seabed Authority and in 2016 the application for the contract extension for the further 5 years was approved by the Authority Council. Interoceanmetal is the only international organization among other contractors for deep sea minerals exploration and it signed the very first contract for exploration within the framework of the UNCLOS system.

Over the 30 years of exploration, the organization has confirmed the importance of the polymetallic nodule deposit for the economy and supply of raw materials. Through its exploration activities, Interoceanmetal has increased the level of geological and environmental knowledge and confidence in deep sea mining minerals. The resource of polymetallic nodule within the registered exploration area has been estimated and reported to the Authority according to the international business and geological standards.

The challenging nature of the deep sea mining requires however, to put even more effort in future. Transition from the confirmed exploration results to the sustained exploitation will, in that case, require substantial investment, not only as the capital type but also organizational, legal and the technical one. The potential benefits of the deep sea mining for the mankind are obvious. This is now our chance and responsibility to provide reassurance to the industry, investors, and the scientific community that the Interoceanmetal Joint Organization cooperates with in order to ensure that seabed mining moves ahead.

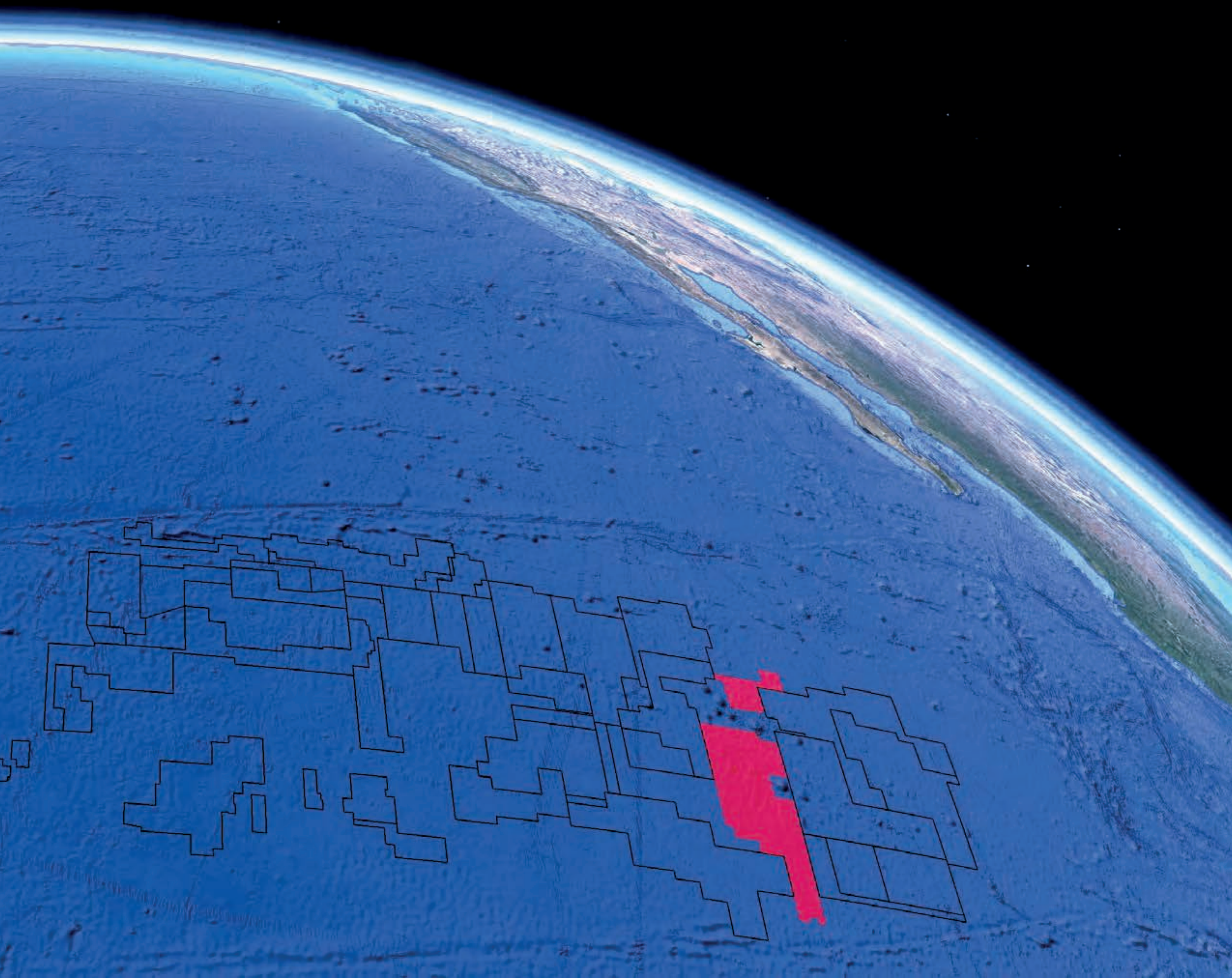
Tomasz Abramowski
Director General of the Interoceanmetal Joint Organization

Over 70% of the Earth is covered by waters. About half, exceeds the depth of 3,800 m. Majority of waters are outside the jurisdiction of any individual country. Under the United Nations Convention on the Law of the Sea, the mineral resources of the ocean floor and its subsoil, which are beyond the national jurisdiction, constitute the common heritage of mankind.



Over the past 30 years, the subject area has become one of the main mineral exploration targets. The deep seabed is, potentially, one of the most rewarding frontiers challenging the mankind. Mineral resources found in the deep seabed area represent an enormous contribution to the world resource base.

For the past 30 years, Interoceanmetal has belong to an exclusive group of pioneer explorers challenging the deep seabed area.



Introduction

The Interoceanmetal Joint Organization (IOM) is an intergovernmental consortium established to conduct exploration, evaluation and exploitation of polymetallic nodules in the Clarion-Clipperton Zone (CCZ) in the north-east Pacific. All activities are performed in accordance with the Contract (exploration licence) between IOM and the International Seabed Authority (ISA), the 1982 United Nations Convention on the Law of the Sea (UNCLOS) and the relevant ISA regulations.

The following states are the present IOM's members: Bulgaria, Cuba, the Czech Republic, Poland, the Russian Federation and Slovakia. The organization's core activity is to make research, employ technical potential of its member states and cooperate with other organizations and potential investors. The research and exploration works are conducted in accordance with the "Programme of activities for exploration of deep sea polymetallic nodules" approved by the ISA.

IOM staff in front of organization's headquarters in Szczecin, Poland (2017)

History

The Interoceanmetal Joint Organization was established on 27 April 1987 on the basis of the Intergovernmental Agreement. The Agreement was signed by Bulgaria, Vietnam, the German Democratic Republic, Cuba, Poland, the USSR and Czechoslovakia, and the operation started in December 1987. In 1989, Vietnam withdrew from the Organization and Germany, in the wake of the unification, left in 1991. In January 1992, the Russian Federation took over the responsibilities of the former USSR. In December 1992, Slovakia and the Czech Republic became sovereign states and therefore, divided the responsibilities of the former Czechoslovakia between themselves.

The aim of IOM for the initial years was to carry out regional geological and geophysical surveys in the CCZ in the Pacific Ocean. IOM carried out a preliminary study of the Prospecting area (546,000 km^2). In that period also the perspective Application area of 300,000 km^2, with the highest rate of nodule abundance, was selected.

In 1991, IOM submitted an application for the assignment and registration of the 150,000 km^2 area as their exclusive plot to the Preparatory Commission for the International Seabed Authority (PREPCOM), which worked under the regulations of UNCLOS. The PREPCOM registered the area requested by IOM on 22 August 1991.

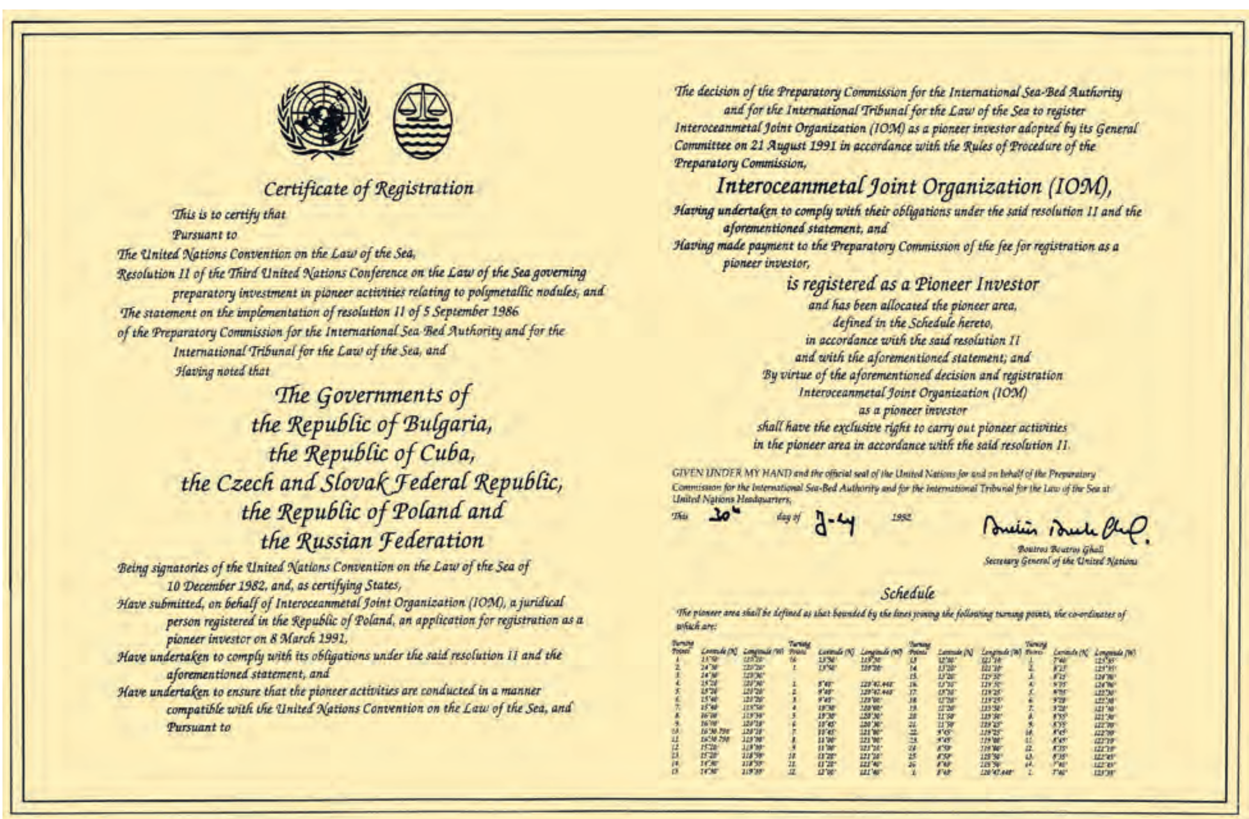
The Agreement was signed by representatives of Bulgaria, Vietnam, the German Democratic Republic, Cuba, Poland, the USSR and Czechoslovakia on 27 April 1987

History

On 30 July 1992, the General Secretary of the United Nations awarded IOM the Certificate of Registration, whereby IOM became the Pioneer Investor. The registered pioneer area covered 150,000 km². On 14 March 1995, IOM received the Certificate of fulfilling its commitments to the United Nations. The document constituted the basis for the development of the 15-year plan for deposit exploration in the area of 75,000 km².

The contract for polymetallic nodules exploration in the area of 75,000 km² was signed on 29 March 2001 by IOM and the ISA. Within that period, the most prospective exploration blocks were recognised and assigned. The results of the comprehensive research, which included geological documentation, technology of nodule extraction and processing as well as research on the marine environment in the Exploration area, were obtained.

In 2016, the contract was extended for the following 5 years. The current IOM's activities aim at fulfilling the approved 5-years' exploration plan. They include seabed geological survey, mining development and testing, technologies processing, environmental research, economy and other appropriate studies necessary to commence the nodule exploitation.



Certificate of Registration

This is to certify that

Pursuant to

The United Nations Convention on the Law of the Sea,

Resolution II of the Third United Nations Conference on the Law of the Sea governing preparatory investment in pioneer activities relating to polymetallic nodules, and

The statement on the implementation of resolution II of 5 September 1986 of the Preparatory Commission for the International Sea-Bed Authority and for the International Tribunal for the Law of the Sea, and

Having noted that

The Governments of the Republic of Bulgaria, the Republic of Cuba, the Czech and Slovak Federal Republic, the Republic of Poland and the Russian Federation

Being signatories of the United Nations Convention on the Law of the Sea of 10 December 1982, and, as certifying States,

Have submitted, on behalf of Interoceanmetal Joint Organization (IOM), a juridical person registered in the Republic of Poland, an application for registration as a pioneer investor on 8 March 1991,

Have undertaken to comply with its obligations under the said resolution II and the aforementioned statement, and

Have undertaken to ensure that the pioneer activities are conducted in a manner compatible with the United Nations Convention on the Law of the Sea, and

Pursuant to

The decision of the Preparatory Commission for the International Sea-Bed Authority and for the International Tribunal for the Law of the Sea to register Interoceanmetal Joint Organization (IOM) as a pioneer investor adopted by its General Committee on 21 August 1991 in accordance with the Rules of Procedure of the Preparatory Commission,

Interoceanmetal Joint Organization (IOM),

Having undertaken to comply with their obligations under the said resolution II and the aforementioned statement, and

Having made payment to the Preparatory Commission of the fee for registration as a pioneer investor,

is registered as a Pioneer Investor

and has been allocated the pioneer area, defined in the Schedule hereto, in accordance with the said resolution II and with the aforementioned statement; and

By virtue of the aforementioned decision and registration Interoceanmetal Joint Organization (IOM) as a pioneer investor shall have the exclusive right to carry out pioneer activities in the pioneer area in accordance with the said resolution II.

GIVEN UNDER MY HAND and the official seal of the United Nations for and on behalf of the Preparatory Commission for the International Sea-Bed Authority and for the International Tribunal for the Law of the Sea at United Nations Headquarters,

This 30th day of J-y 1992

Boutros Boutros Ghali
Secretary General of the United Nations

Schedule

The pioneer area shall be defined as that bounded by the lines joining the following turning points, the co-ordinates of which are:

Certificate for Registration as a Pioneer Investor signed by the General Secretary of the United Nations, Boutros Boutros Ghali, on 30 July 1992

Milestones

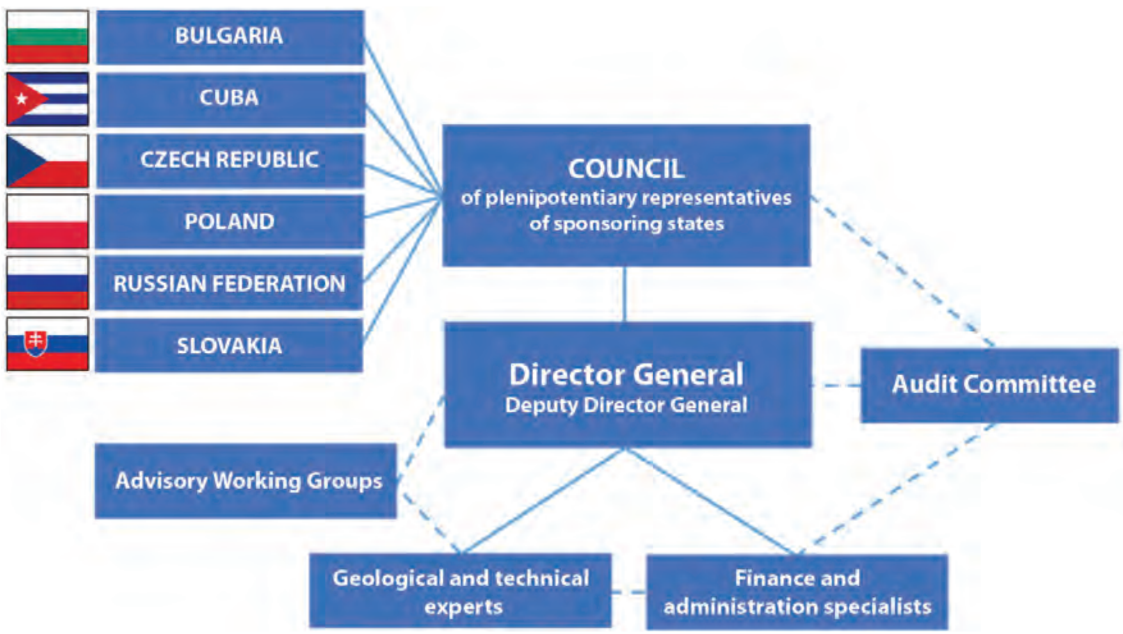
27 April 1987	IOM is formed on the basis of the Intergovernmental Agreement.
30 July 1992	General Secretary of the United Nations awarded IOM the Certificate of Registration, whereby IOM became the Pioneer Investor. The Registered Pioneer Area covered 150,000 km^2.
14 March 1995	IOM received the Certificate of Compliance with obligations as a Pioneer Investor, granted by the PREPCOM.
29 March 2001	IOM and the ISA signed the Contract for exploration of polymetallic nodules referring to the Exploration Area of 75,000 km^2.
25 May 2017	IOM and the ISA signed the Agreement on the extension of the contract for exploration for polymetallic nodules for the period of 5 years.

The contract for exploration of polymetallic nodules within the exploration area of 75,000 km^2 was signed on 29 March 2001

Organization

IOM is governed by the Council of plenipotentiary representatives of the IOM member states. The Council meets twice a year to work out general policies, which conform with the approved plans, relevant provisions of the IOM Statute and the intergovernmental agreement. The Council is supported by Director General as its executive power and by the Audit Committee which maintains control over the IOM's activities. IOM is composed of two departments, one dealing with geological and technical issues concerning exploration and exploitation, and the other is involved in economy, administration and management matters. Advisory groups working Ad Hoc are organised to discuss current problems in the field of geology, mining technology and mineral processing.

Organizational chart



Directors General of the IOM Joint Organization

1987-1992
Ryszard Labus

1992-2011
Ryszard Kotlinski

2011-
Tomasz Abramowski

Organization

The IOM Council members, delegates and the IOM directorate during the meeting in Warsaw, Poland (2016)

The Audit Committee meeting in Szczecin, Poland (2016)

Exploration

IOM's major task is to carry out exploration of polymetallic nodules in the claimed area, with the aim of laying grounds for future exploitation. Works are focused on regional geology and geophysical survey, distribution of polymetallic nodule deposits, determination of chemical composition, geotechnical properties of the nodules and sediments, as well as on environmental studies.

Data and samples are collected during exploration cruises. Until now, 25 cruises were accomplished (independently or in cooperation with other organizations), providing wide range of geological, hydrological, hydro meteorological and environmental data.

Exploration scientific cruises 1987-2014

YEAR	RESEARCH VESSEL (R/V)	EXPLORATION ACTIVITY
1987 – 1988	17 Syezd Profsoyuzov	Regional geological and geophysical reconnaissance preliminary CDC+CTD survey, sediment and polymetallic sampling, geochemical and mineralogical determination, preliminary ecological assessment
1989	Akademik Alexander Sidorenko	
1988 – 1989	Geolog Petr Antropov	
1988 – 1989	Geofyzik	
1988 – 1989	Akademik Alexandr Karpinski	
1989	Akademik Alexandr Sidorenko	
1989	Mikolaj Kopernik	
1989	Morskoy Geolog	
1989	Akademik Alexandr Sidorenko	
1989 – 1990	Geolog Petr Antropov	
1989 – 1990	Profesor Fedinskiy	
1989 – 1990	Akademik Alexandr Sidorenko	
1989 – 1990	Geolog Fersman	
1994	Haiyang IV	IOM/COMRA - baseline investigation
1994	Yuzhmorgeologiya	IOM/MMAJ - participation in BIE/JET test
1994	Yuzhmorgeologiiya	Baseline investigation, selection of IOM/BIE site
1995	Yuzhmorgeologiya	Detailed exploration in IOM/BIE site with the participation of the UN trainees

Exploration

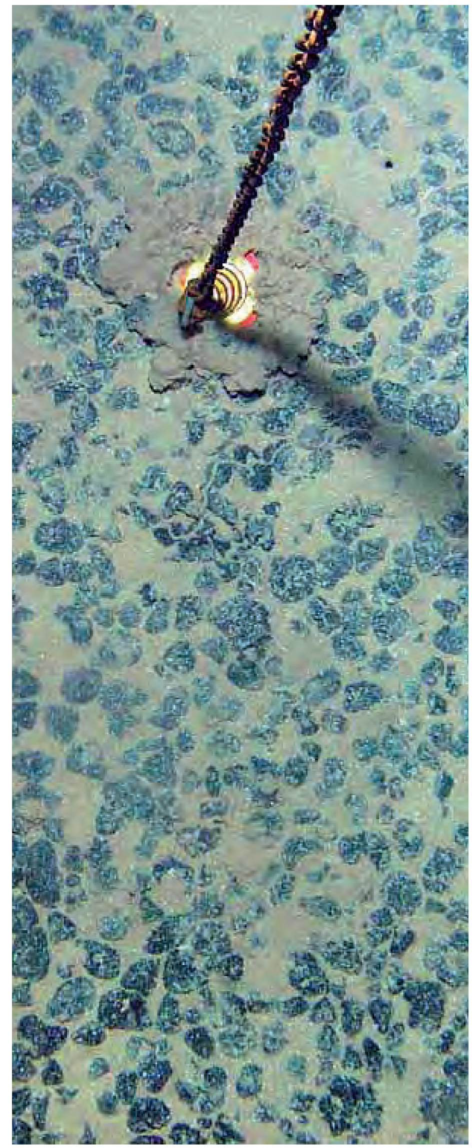
YEAR	RESEARCH VESSEL (R/V)	EXPLORATION ACTIVITY
1995	Yuzhmorgeologiya	IOM/BIE test with the participation of pioneer investors
1996	Sonne	IOM/VWS - participation in geotechnical investigation and ecological monitoring (Peru Basin)
1997	Profesor Logatschev	Meiobiological and ecological monitoring in IOM/BIE site and detailed exploration of site adjoining nodule occurrence - Preservation Reference Area (PRA)
1999	Gelendzhik	Detail bathymetrical survey of the whole IOM claim areas (B1, B2) with multi-beam sonar SIMRAD EM 12- Kongsberg /Norway
2001	Yuzhmorgeologiya	Deep-tow photographic survey, nodule and sediment box-corer sampling, trawling, gravity coring, sediments and pore water investigations, meiobenthos studying in B2 sector. Water column and hydro meteorological observations.
2004	Yuzhmorgeologiya	Nodule and sediment box-corer sampling, trawling, dredging and hydro meteorological observations in B2 sector.
2009	Yuzhmorgeologiya	Side-scan sonar surveys, photo profiling, nodule and sediment box-corer sampling, trawling and hydro meteorological observations in H11 exploration block
2014	Yuzhmorgeologiya	Side-scan sonar surveys, photo and video profiling, nodule and sediment box-corer sampling, biological sampling, trawling and hydro meteorological observations in H22 exploration block

R/V Yuzhmorgeologiya

Exploration

There were 21 exploration expeditions before signing the Contract for exploration between the International Seabed Authority and the Interoceanmetal Joint Organization in 2001. During the contract period (2001-2016) four exploration cruises were carried out (IOM-2001, IOM-2004, IOM-2009 and IOM-2014).

The following sets of data were obtained during the exploration contract period:



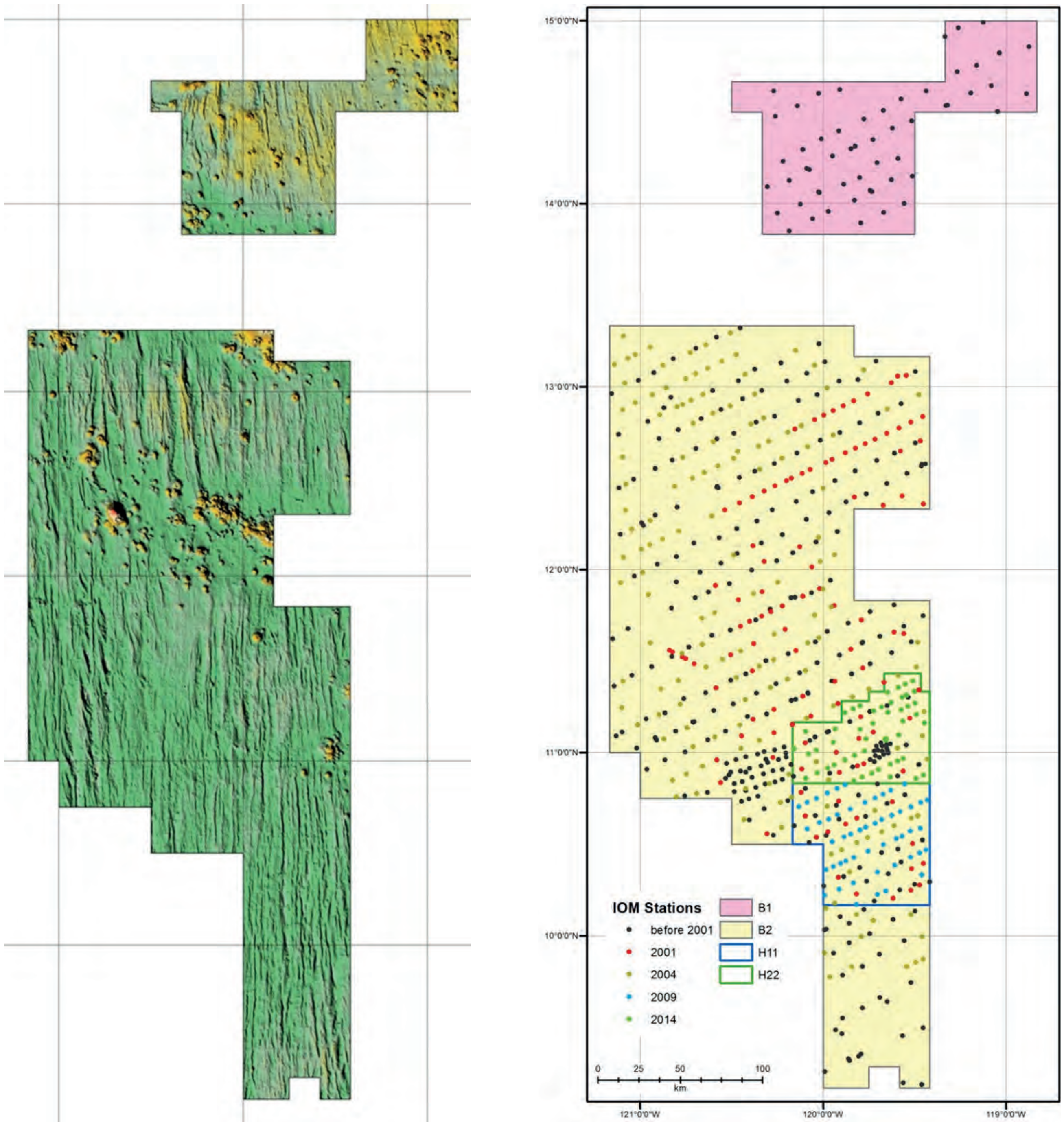
IOM-2001
- 262 km of photo profiling (12,540 photos)
- 103 stations of nodule and sediment box-corer sampling
- 8 stations of gravity corer sampling
- 700 kg of nodules collected by trawling
- 44 stations of sediment and pore water investigations
- 110 biological samples collected (meiobenthos)

IOM-2004
- 158 stations of nodule and sediment box-corer sampling
- 250 kg of nodules collected by trawling
- 2 samples of hard rock seabed (basalt) collected by dredging

IOM-2009
- 296 km of side-scan sonar survey
- 344 km of photo profiling (13,945 photos, 10 profiles)
- 51 stations of nodule and sediment box-corer sampling
- 740 kg of nodules collected by trawling

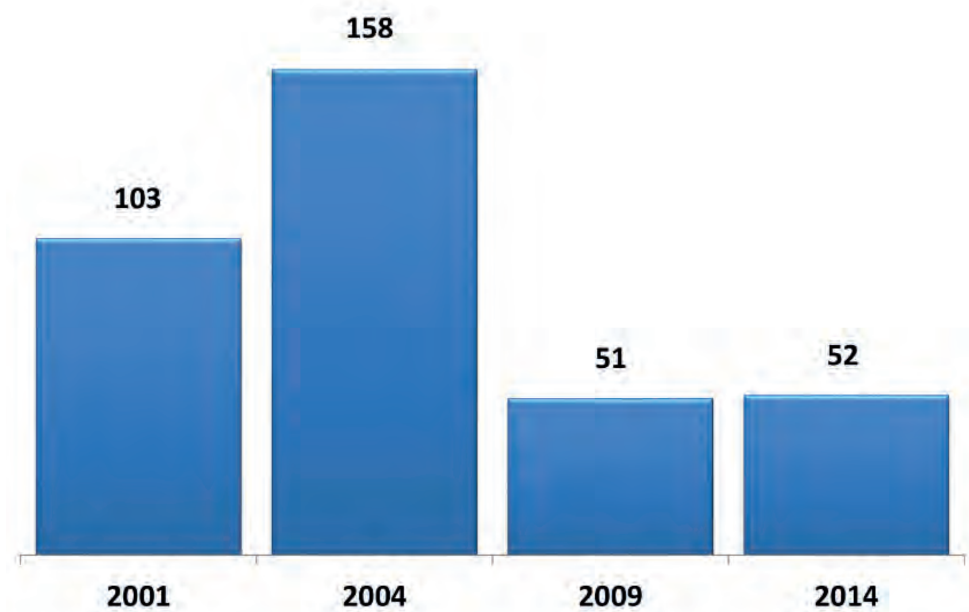
IOM-2014
- 57 km of side-scan sonar survey (1 profile)
- 585 km of photo and video profiling (32,209 photos, 12 profiles)
- 52 stations of nodule and sediment box-corer sampling
- 2,309 kg of nodules collected by trawling
- 94 biological samples collected

Exploration

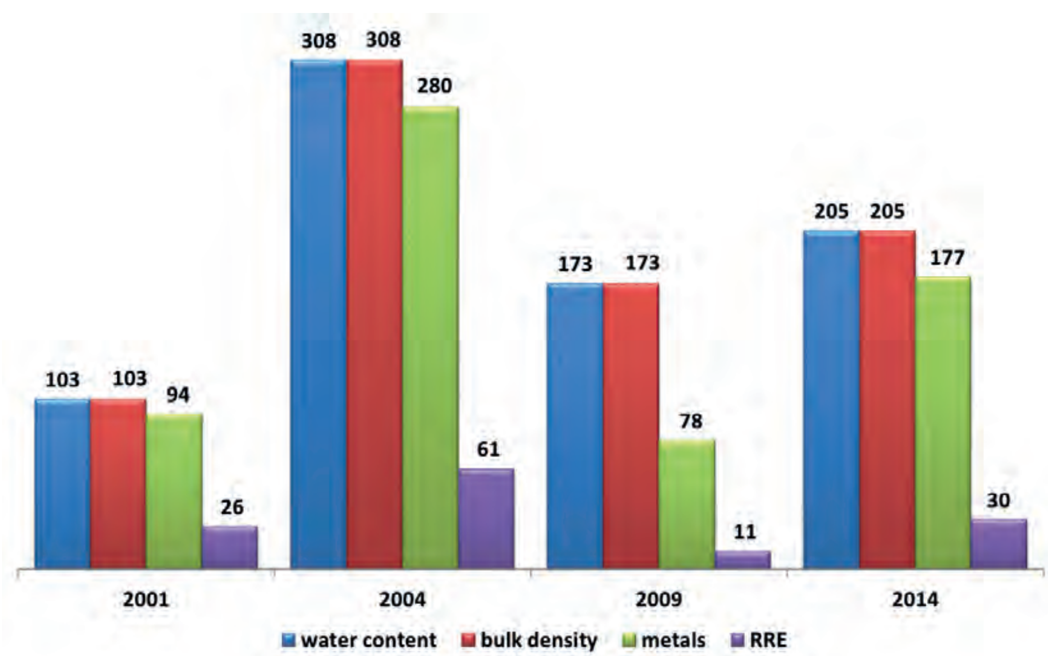


Bottom relief of the IOM exploration area and the localization of stations (sampling points) during research expeditions (1987-2014)

Exploration



Number of stations carried out during expeditions after signing the Contract (2001-2014)



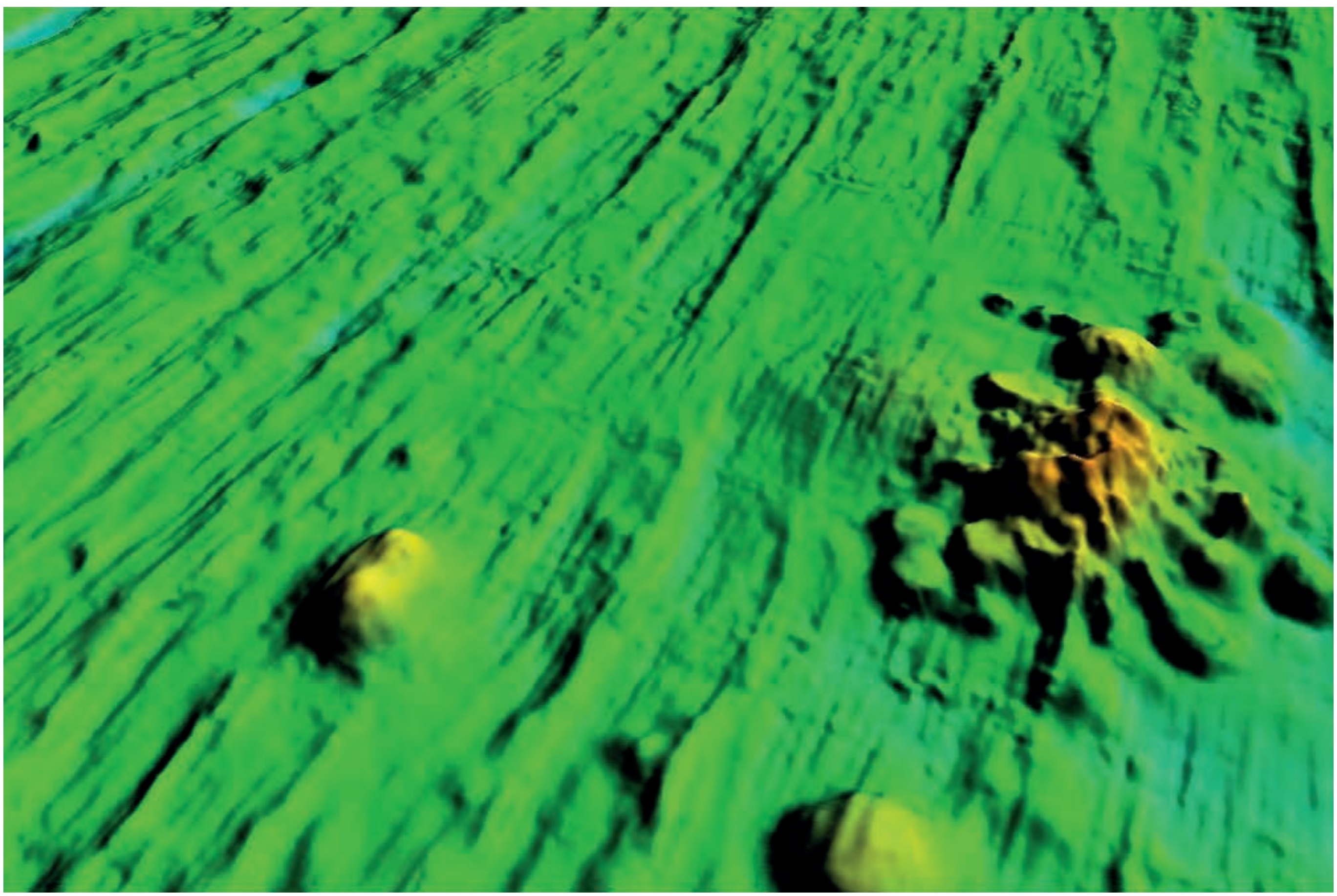
Number of nodule analysis carried out for water content, bulk density, metal content and REE content (2001-2014)

Exploration

Onboard of research vessel

Bathymetry

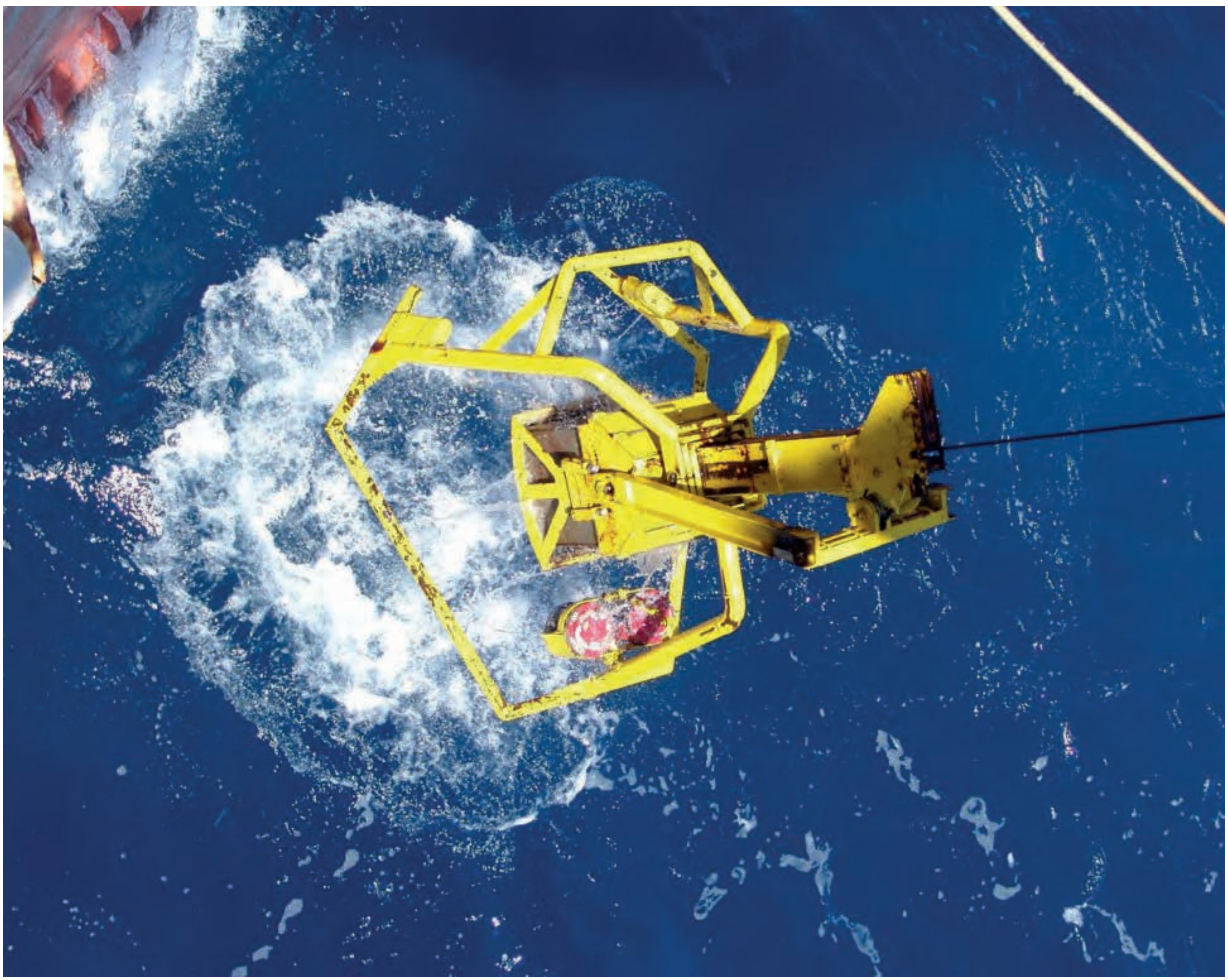
From multibeam echosounding a bathymetric image and a backscattered signal image can be derived. The IOM area is represented by raised and immersed blocks, deep troughs, strictly north-south oriented. Backscattered signal helps to determine basement outcrops, volcanoes, nodule fields and nodule free areas. IOM conducted a bathymetric mapping of the whole exploration area (B1 and B2 sectors). On that basis a relief map of the ocean bottom in 1:200,000 scale was prepared. The bottom surface of the IOM area is located in the depth range 2,450 - 4,750 m below the sea level. The morphological structure of the ocean bottom has been formed by volcanic and tectonic activity during the Oligocene and Miocene periods (34 to 5 million years ago).



3D projection of deep seabed in the IOM exploration area, sector B2, fragment of the H22 exploration block

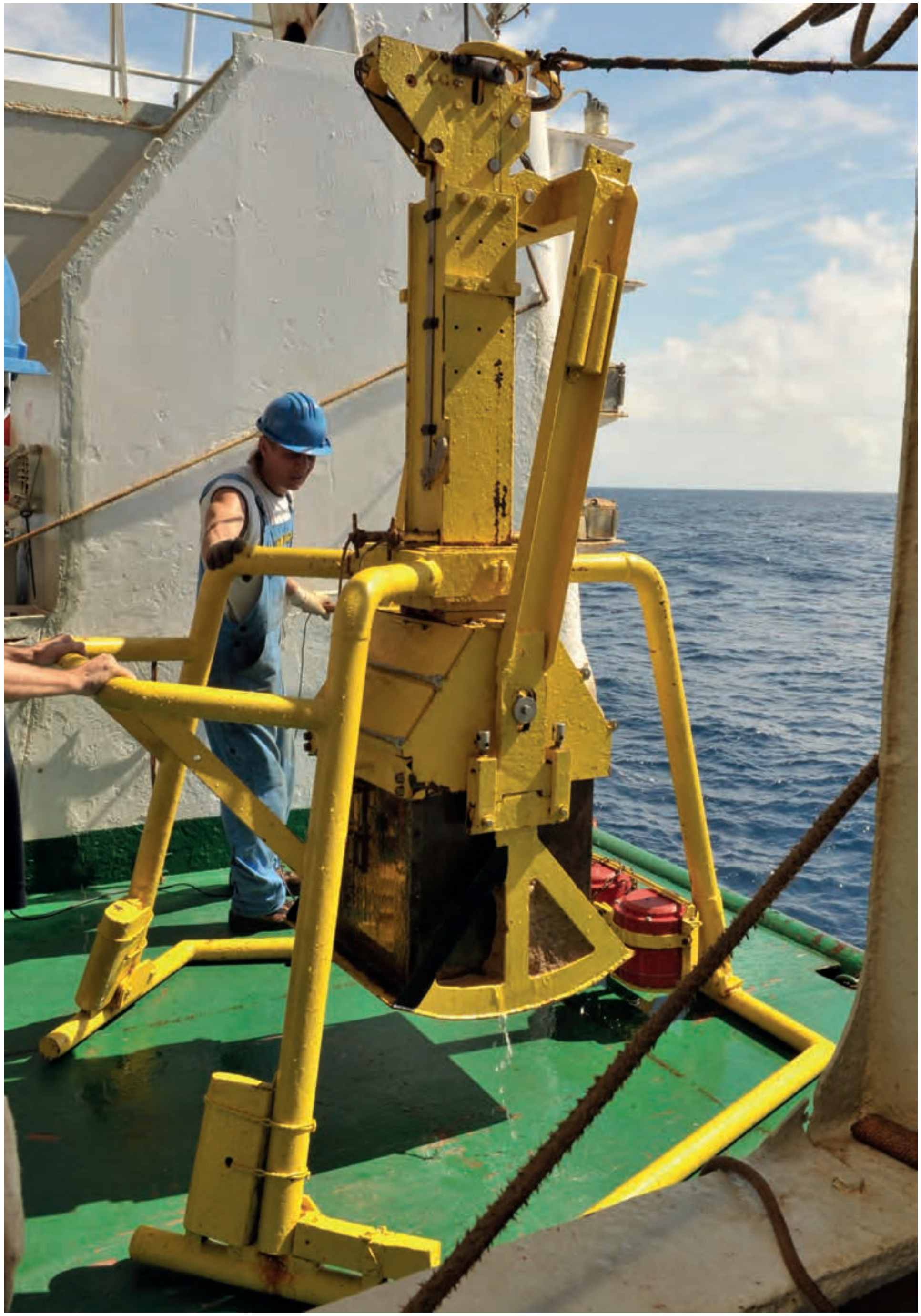
Box corer sampling

Polymetallic nodules, bottom sediments and fauna samples are collected using a box corer. The device has a capture area of 0.25 m^2 (0.5 x 0.5 m) and is equipped with a deep-water photographic system. The lowering and raising operations are carried out with the usage of a winch with a tackle, fitted with a steel three-strand rope of 14 mm diameter, which goes through an aft gantry. The distance between the device and the bottom is determined by an acoustic pinger signal.



Box corer is lifted after sample collection from the depth of about 4,500 m

Exploration



Box corer with seabed sample on board of a research vessel

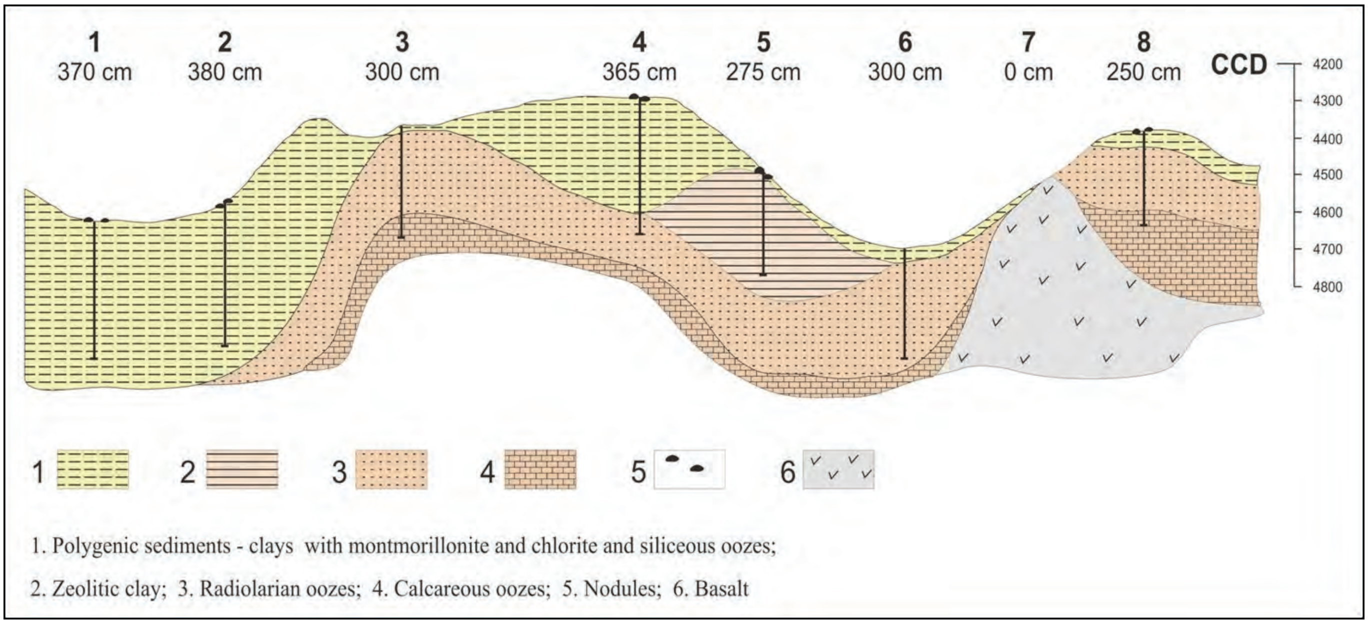
Polymetallic nodules and bottom sediment sample inside the box corer, after pumping out the water

Exploration

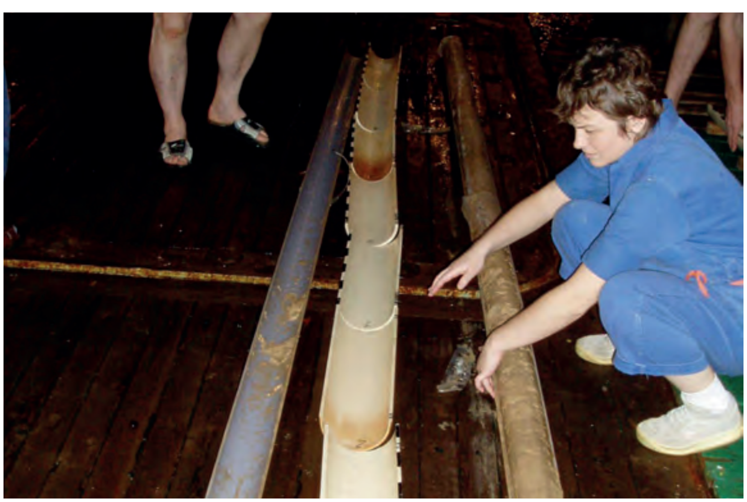
Gravity corer sampling

Gravity corer sampling is carried out using gravitational tube with an internal diameter of 116 mm, a weight of 800 kg and a length of 5 m. The tube is equipped with a plastic liner with an inner diameter of 107 mm. The lowering and raising operations are carried out using a winch.

Geological cross-section of upper layers (up to 4 meters) of sea bottom sediments is based on this kind of sampling, as well as geotechnical parameters measurements.

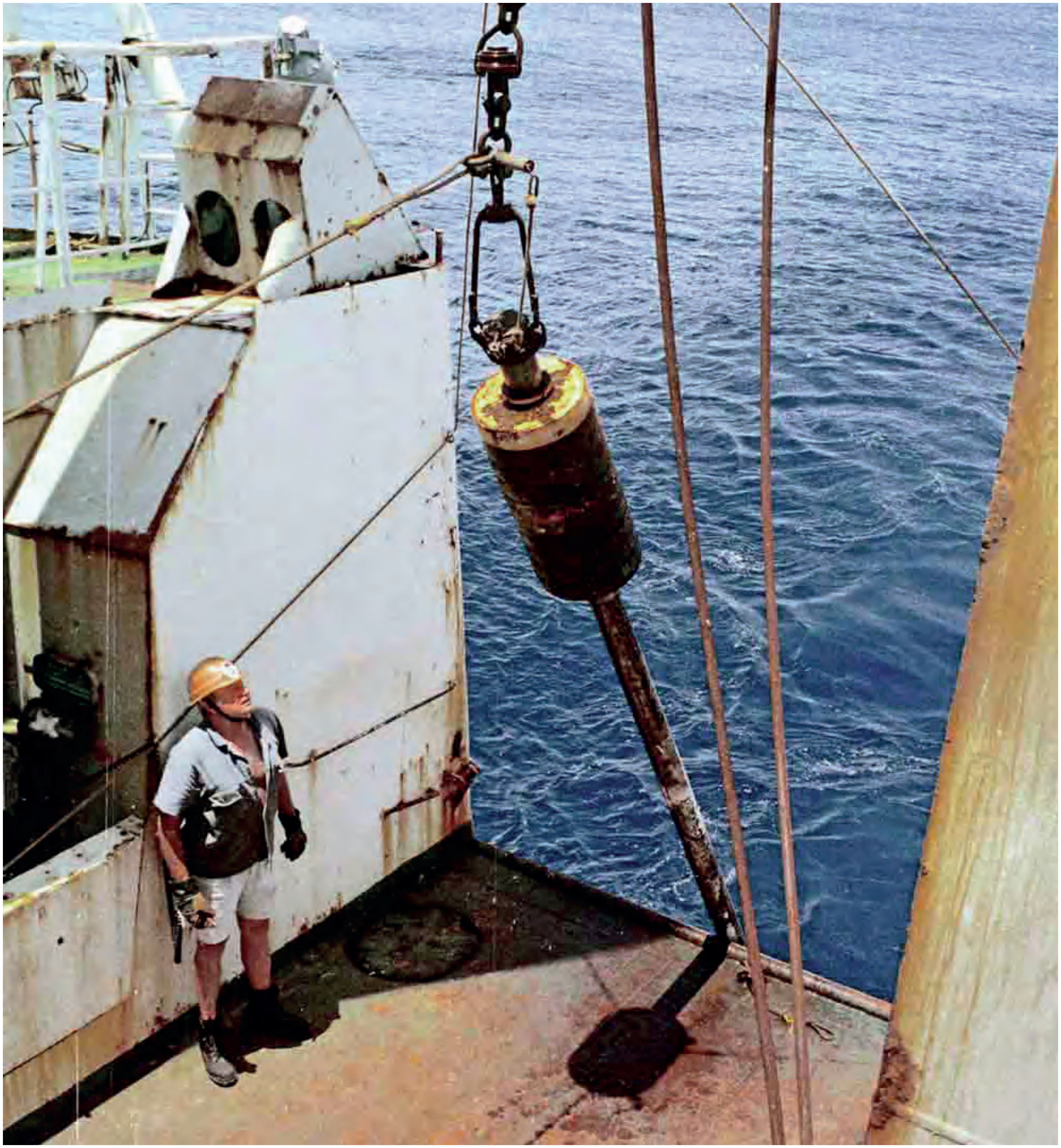


Geological cross-section of upper layers based on gravity corer sampling



Gravity corer sample on board ready for documentation and measurements

Exploration



Gravity corer prepared for sea bottom sampling

Trawling and dredging

Trawling is used for a large-volume nodule sample collection, using a trawl of 40 x 140 cm in dimension. In order to collect nodules, a basket of the general capacity of about 1000 kg and length of 2 m, made of polyamide fabric, is attached to the body of the trawl. Dredging is used to sample hard rock type of seabed (basalts), using a dredge – a 1 m long and 0.8 m in diameter cylinder-like sampler. Devices are towed from a research vessel.

Trawling device for collection of large-scale samples

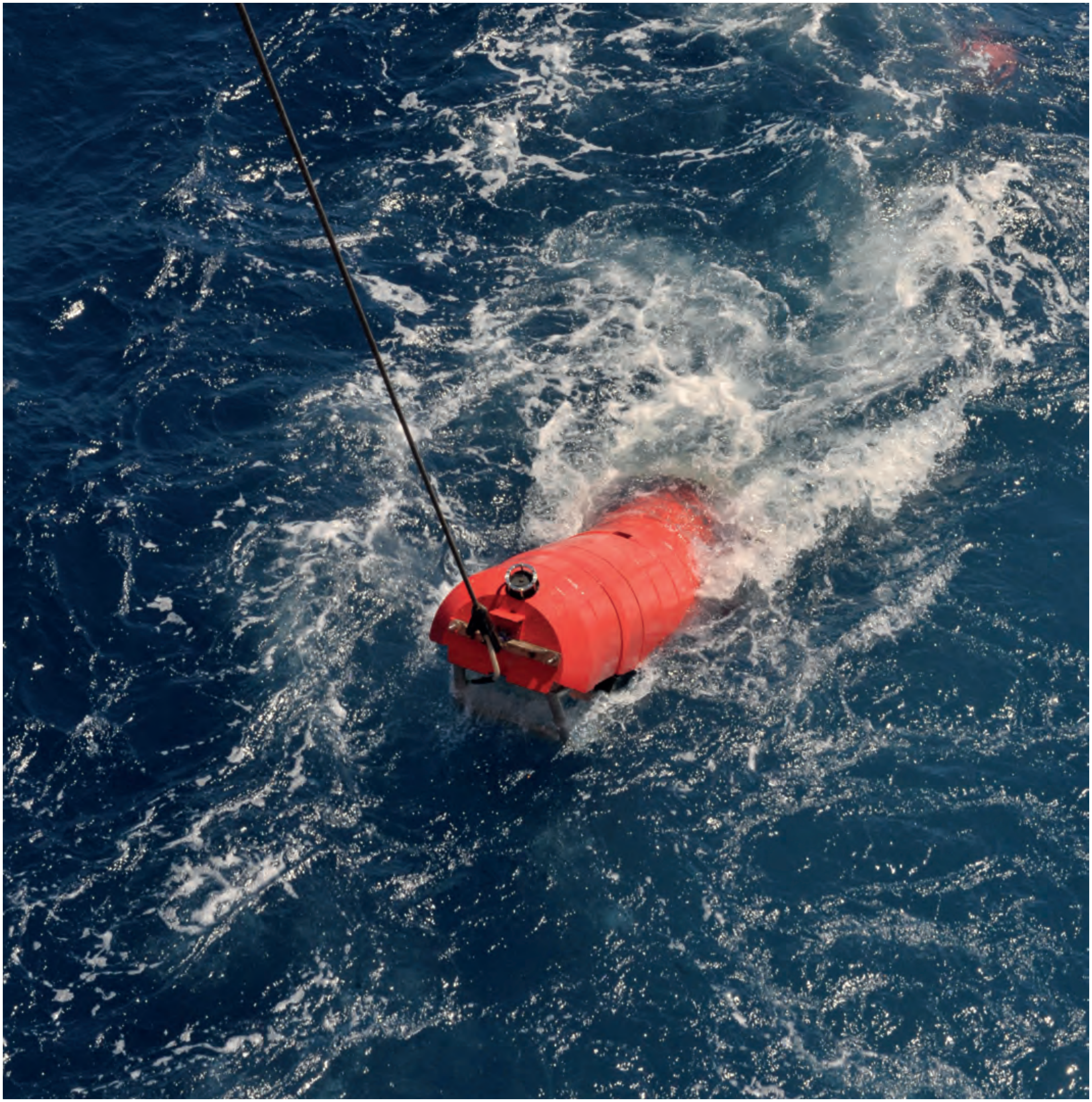
Trawling device capacity is up to 1,000 kg of sea bottom material

Dredger is used to sample hard rock type of the seabed

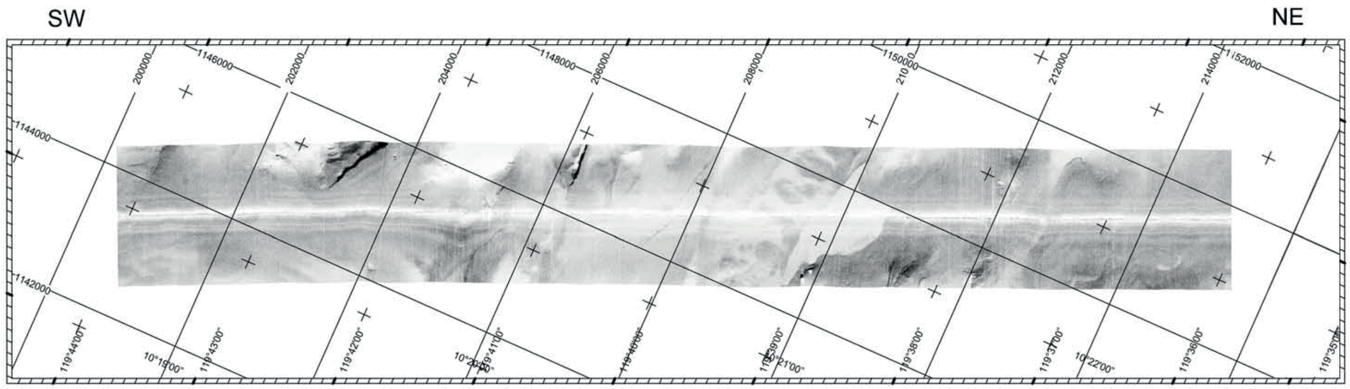
Side-scan and sub-bottom profiling

For creation of an image of large seabed areas, side-scan sonar system is used. It scans an area of 2 km wide (creating 2 strips, each of 1 km width). Side-scan data is received along with sub-bottom profiler data, providing a view of the shallow structure of the seabed. Profiler has a capacity to penetrate the sedimentary cover down to 150 m. Sonar device is towed from a research vessel, 80-120 m above the seabed.

Device for side scan and sub bottom profiling



Device is towed from a research vessel, about 80-120 m above the sea bottom



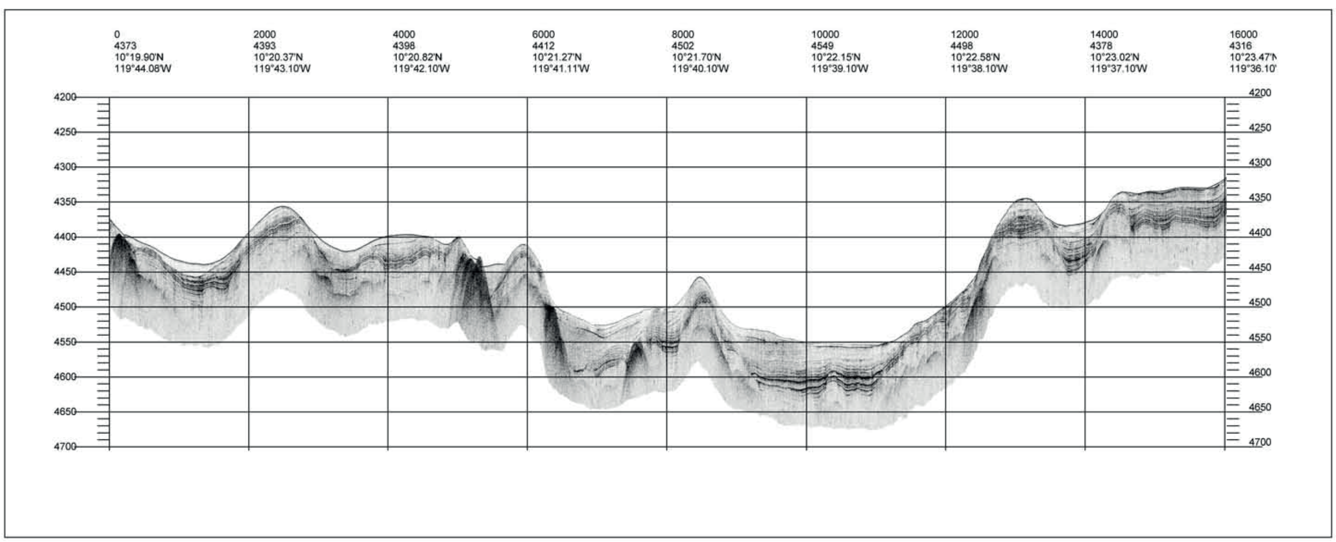
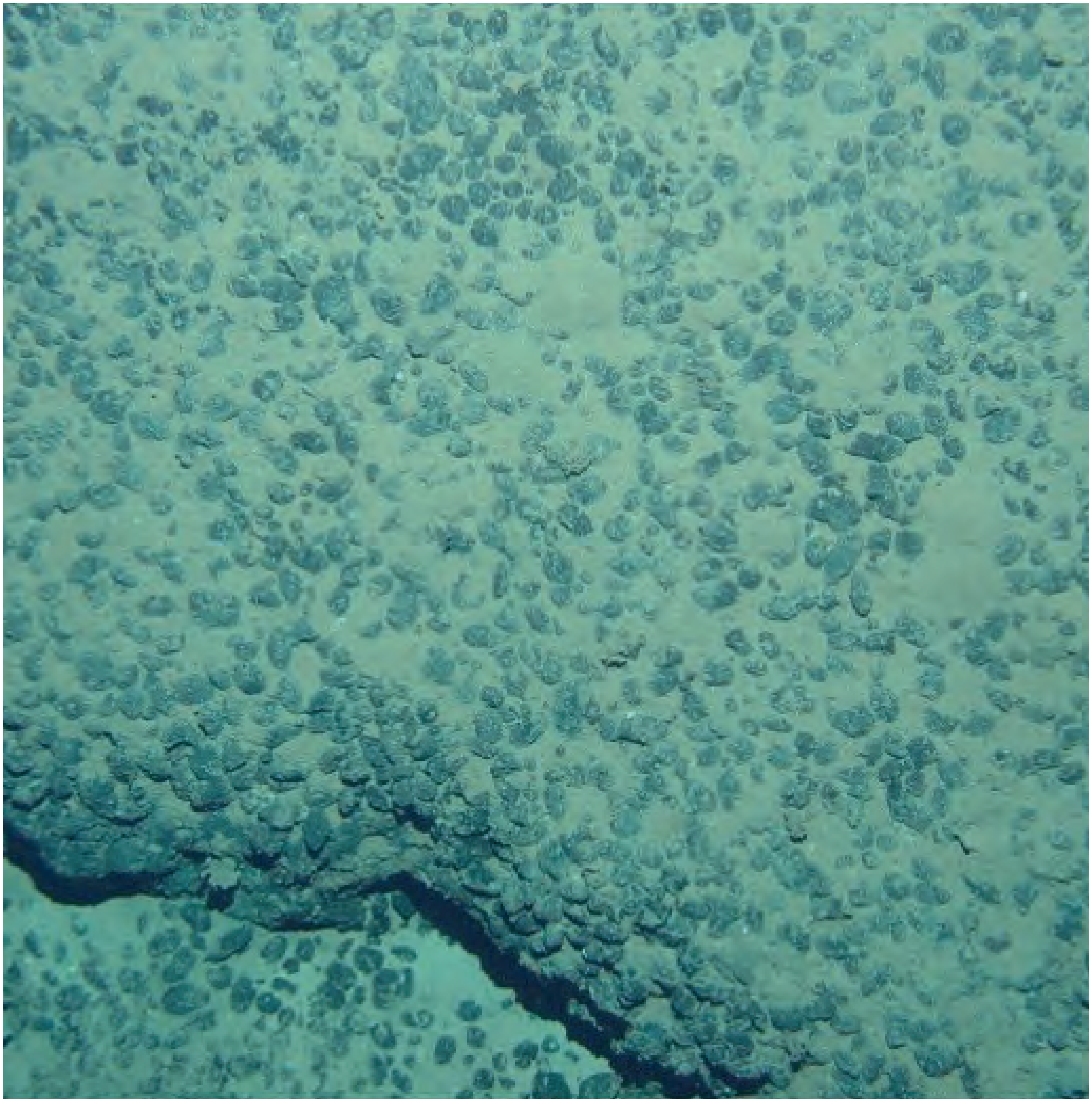


Image of seabed surface (above) and sub-bottom profile (below)

Photo profiling

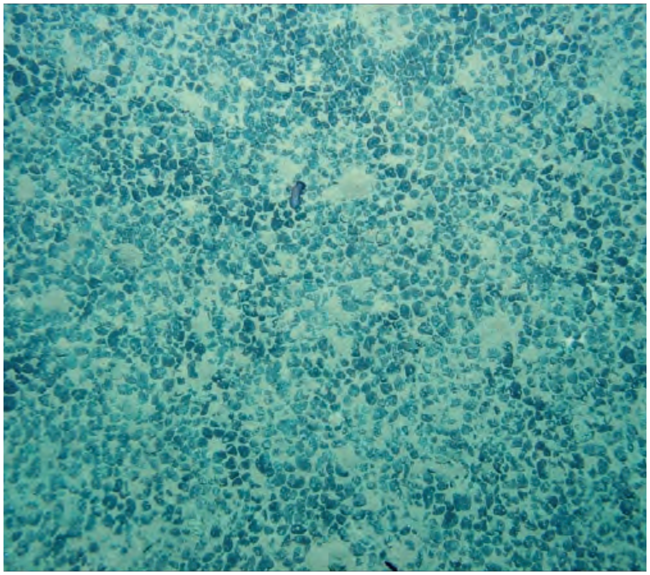
Photo-profiling (photo and video) provides data on sea bottom morphology, nodule abundance, type, continuity of nodule coverage and mega-fauna occurrences. A photo-profiling device is towed from a research vessel, approximately 4 m above the seabed.

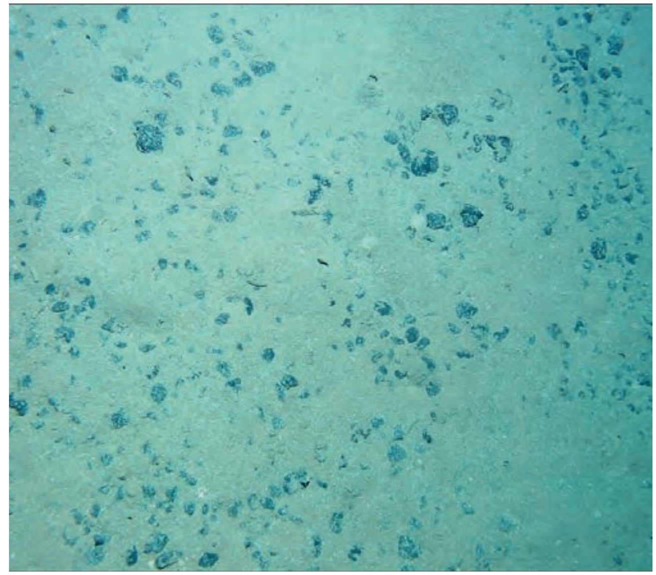
Photo profiling device launched for deep sea research mission



Photographs provide plenty of information on sea bottom chracteristics, including potential obstacles for mining collector

Exploration





Polymetallic nodule abundance is a crucial parameter for resources estimation - nodule coverage 68% (left) compared to nodule coverage 13% (right)

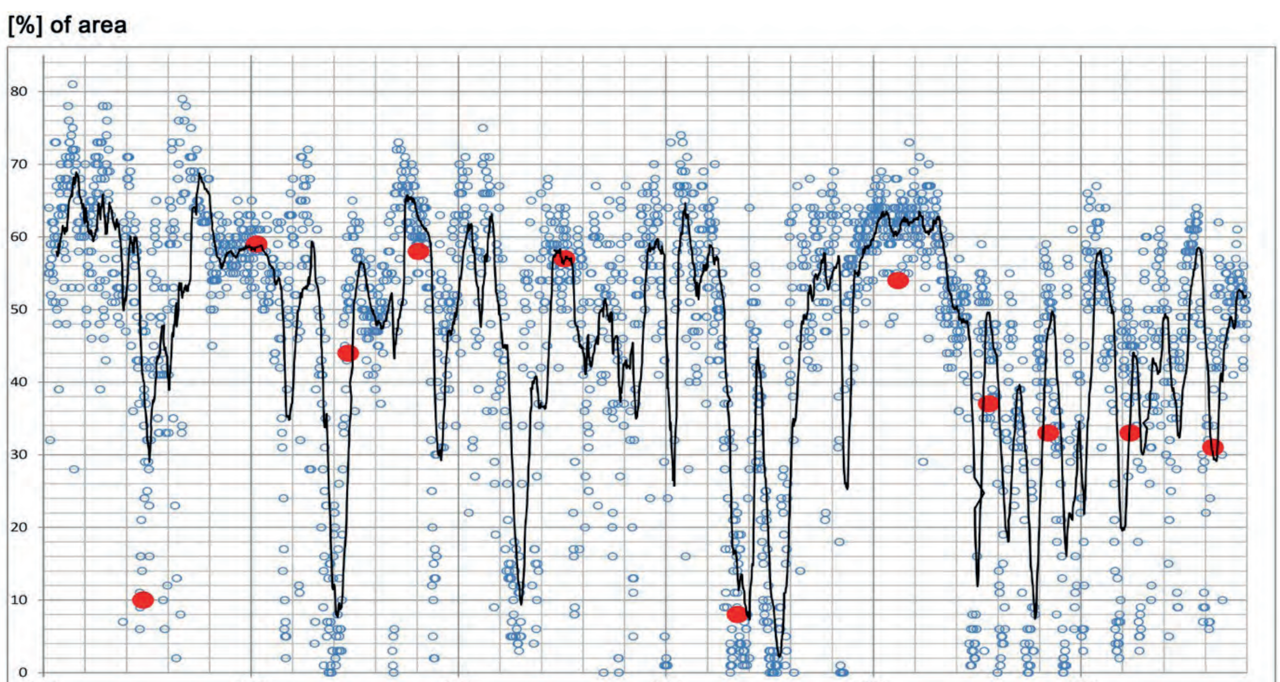
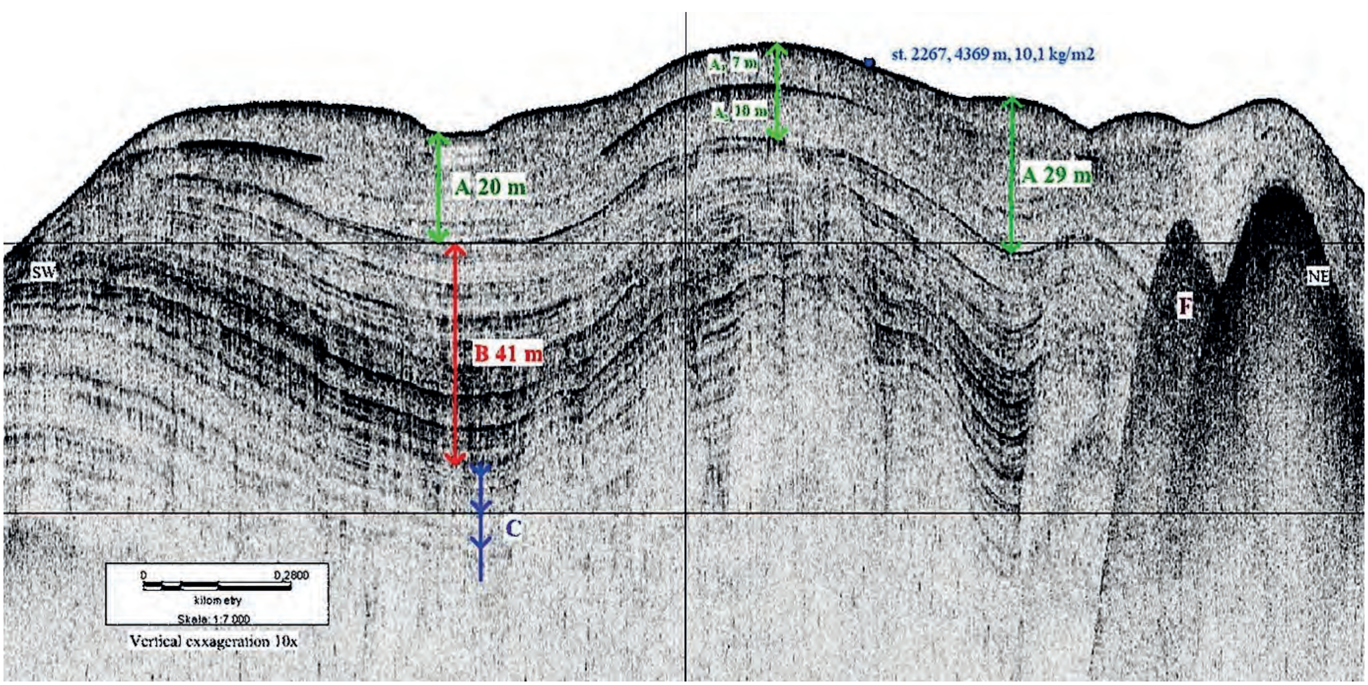


Photo profiles are necessary for delineation of nodule rich areas, photo profiling results of nodule coverage (blue points) are compared to the results from box-corer samples (red points)

Geological and geotechnical research

The sedimentary cover of the eastern part of the CCZ consists of well distinguished facies of nano-fossil carbonates, red pelagic clays and siliceous clays. The bottom sediments within the IOM exploration area are divided into litho-stratigraphic units, based on their origin and composition. The sedimentary cover within the IOM exploration area does not exceed 100 meters. The top 1 to 15 cm layer comprises the geochemically active layer, which is the environment for nodule formation. Based on the results of geo-acoustic profiling including high resolution side-scan sonar, photo and video profiling as well as analysis of sediment samples, several geotechnical strata were identified.

Geotechnical measurements of physical, mechanical and technological properties of the sediment (water content, volumetric density, vane shear strength, penetration resistance) and of polymetallic nodules (water content, volumetric density, compressive strength, rip-off force resistance, nodule apparent density, angle of repose) are carried out on-board on a research vessel and in on-land laboratories.



Interpretation of hydro-acoustic profiles helps to analyse how the topography of the seabed looks like and what is hidden beneath it (hydro-acoustic facies: transparent A and C, stratified B and massive basement F)

On board geotechnical research (nodule rip-off force resistance measurement)

Exploration

Sediment sample preparation for laboratory research and tests

Laboratory tests

On board geotechnical research (bottom sediment penetration resistance measurement)

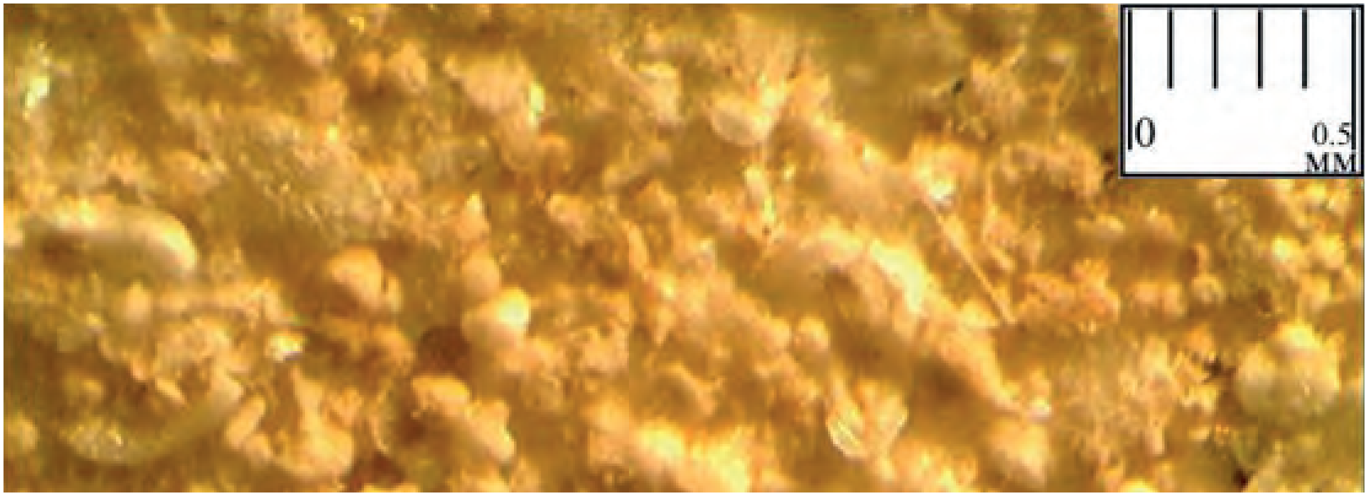
Laboratory tests

Polymetallic nodule sample preparation (grinding and quartering)

Laboratory tests

Primary chemical analysis and determination of metal content is performed on board (atomic absorption spectroscopy)

Laboratory tests



A microscopic study of the sediment fractions (above) and determination of manganese content in nodules by potentiometric titration (below)

Polymetallic nodules

Polymetallic nodules are product of autogenetic crystallization, created around a crystalline nucleus in the zones of the deep ocean floor. They are composed mainly of manganese or iron hydroxides and silicates. Economy models of the future mining are based on exploitation of metals contained in nodules, especially nickel, copper and cobalt.

Nodules consist mostly of nuclei and typically concentric layers of iron and manganese hydroxides and oxides. Nucleus can be composed of volcanoclastic debris, lithified sediment, bioclasts or fragments of older nodules. The following are the main genetic nodule types: hydrogenetic (H), diagenetic (D) and hydrogenetic-diagenetic (HD). The most common colour is brown to black, Mohs hardness 2 to 3. Nodules vary in size, from tiny particles to large pellets of more than 20 centimetres in diameter. Most nodules in the IOM exploration area are between 2 and 8 cm in diameter. Nodules lie down on the unconsolidated sediment-water interface, sometimes are buried in the sediment.

The key manganese mineral components are todorokite, birnessite and vernadite. Major iron component is iron oxyhydroxide. Nodules, in which todorokite prevails, are usually enriched with Mn, Ni, Cu, and Zn, while those where vernadite prevails, are enriched with Fe, Co and Pb.

Main genetic types of nodules: H – hydrogenetic, HD – hydrogenetic-diagenetic and D – diagenetic

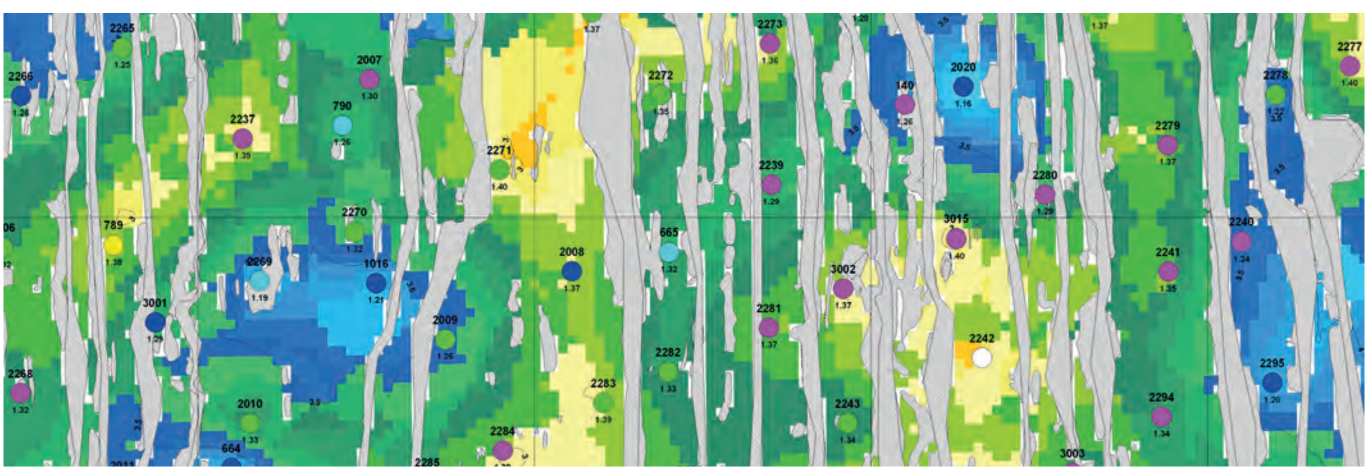
Resources

Resources estimation

The polymetallic nodule resources were estimated in three stages. During the first stage completed in 2007, the overall resources were estimated for both of the exploration sectors B1 and B2, focusing on selected metals (Mn, Ni, Mo, Co, Cu and Zn). During the second stage (2011) resources within the H11 exploration block were estimated, both for the nodules and four major metals: Co, Cu, Mn and Ni. In the third stage (2015) a similar estimation was completed for the H22 exploration block. Ordinary geostatistical kriging method was applied to estimate the distribution and amount of resources. The areas of ocean-floor slope over 7° were not included into the resources estimation.

Mineral Resource Classification	Abundance (wet kg/m²)	Mn (%)	Ni (%)	Cu (%)	Co (%)	Polymetallic Nodules (PN)(million tons)
Measured	-	-	-	-	-	-
Indicated (H11 exploration block)	14.6	31.74	1.31	1.29	0.16	41.4
Indicated (H22 exploration block)	14.1	31.04	1.30	1.29	0.17	31.9
Indicated total						**73.3**
Inferred (B1 exploration sector)	13.4	27.84	1.21	0.90	0.21	62.6
Inferred (B2 exploration sector)	13.1	31.53	1.32	1.24	0.18	242.9
Inferred total						**305.5**

Mineral Resource Estimate for the IOM Exploration Area, calculated for wet PN, abundance cut-off 10 kg/m² of wet PN (2016)



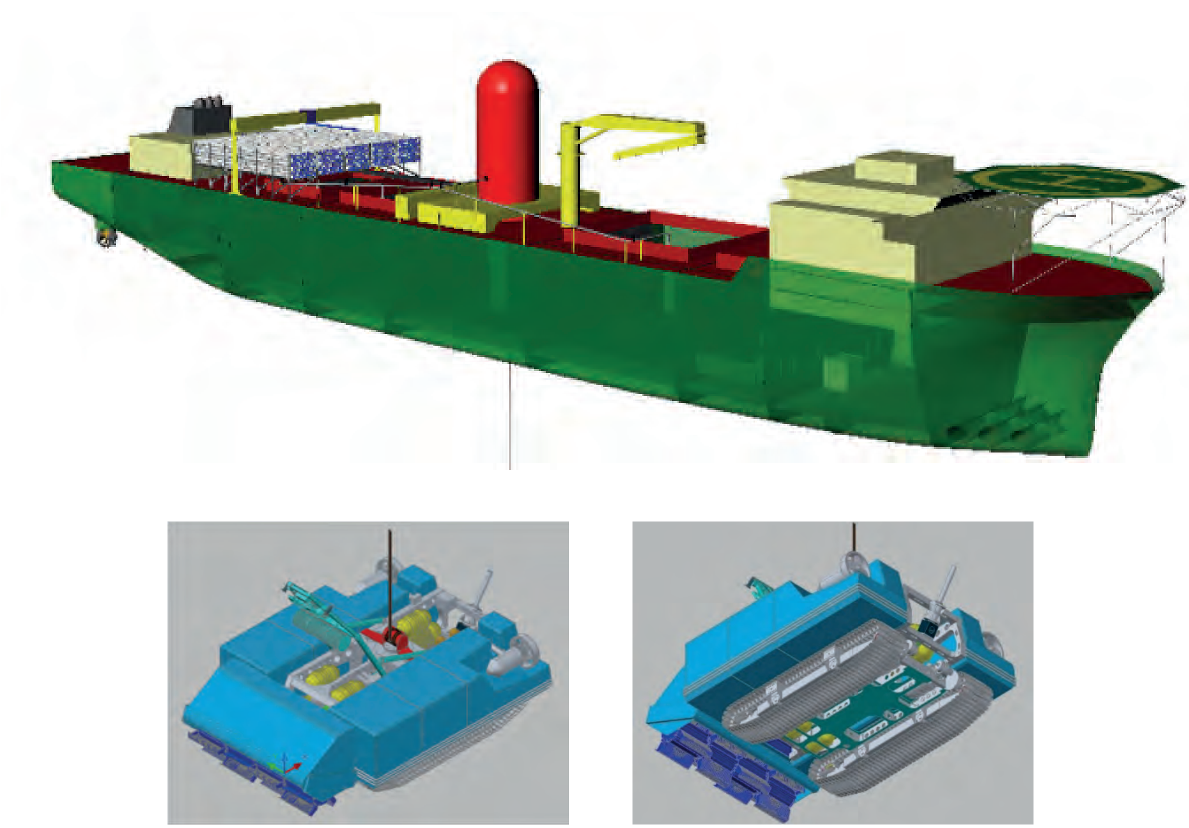
Part of map of Ni metal contents in H11 exploration block (2011)

Mining technology

The aim of the IOM's research in the field of polymetallic nodule mining technology is the development of the conceptual design and functional analysis. Several different configurations of the mining system elements are considered. The experiments were conducted in cooperation with numerous organizations and experts.

The following activities were carried out:

- Conceptual design of the mining ship
- Conceptual design of the nodule collector
- Design and configuration of the hydraulic lift pipe
- Studies and computer simulations of motions and dynamics of the system: mining ship – hydraulic lift pipe – nodule collector
- Computer model of stretching and deformation of the hydraulic lift pipe
- Computer simulations of the water flow around the hydraulic lift pipe

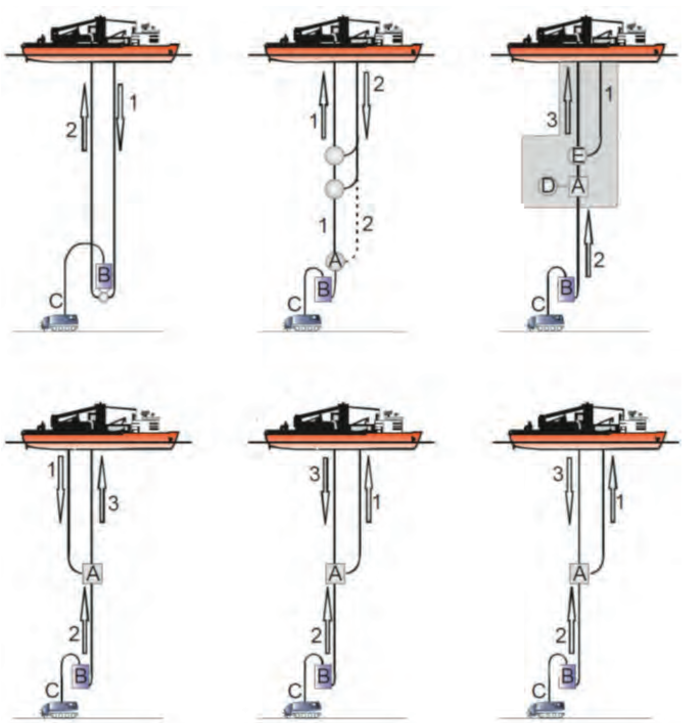


Mining ship and nodule collector concept

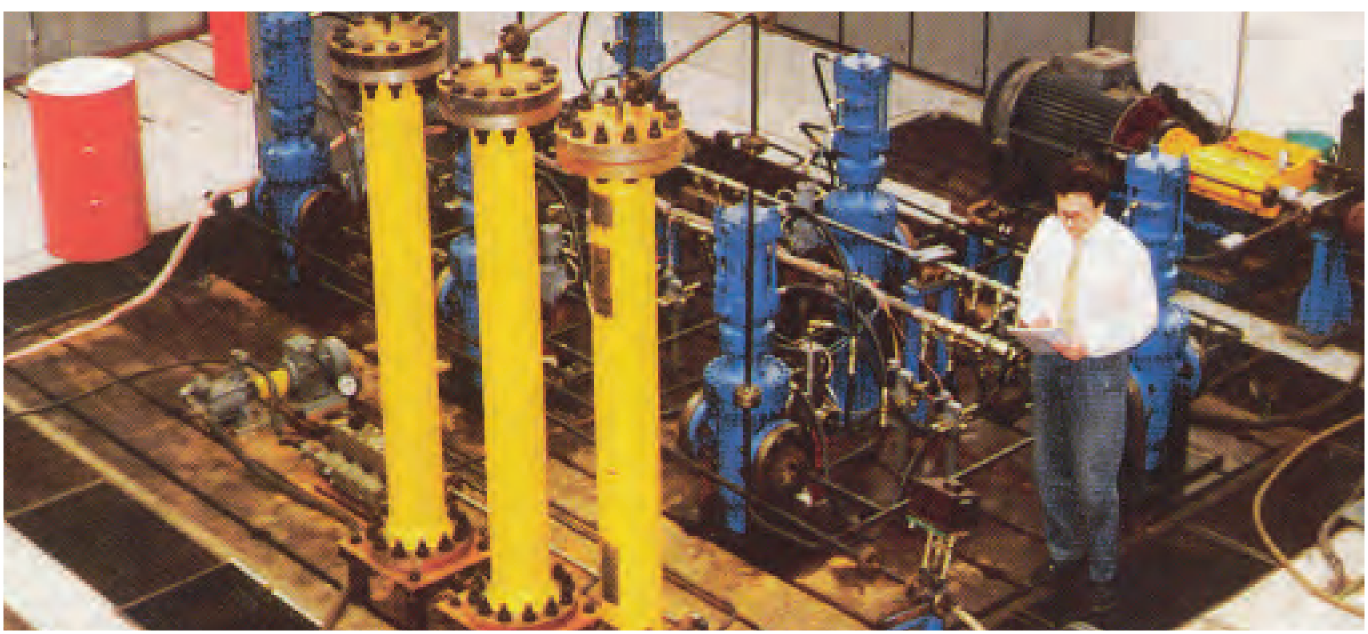
Mining technology

Central Design Bureau "Oceangeotechnika" and IOM prepared project of the Deepwater Research Complex for detailed exploration of ore blocks, studies of the processes of collecting polymetallic nodules and environmental impacts assessment. A device (above) was tested in regions of Anapa and Gelendzhik, the Black Sea, Russia (1999-2001)
Model of self-propelled universal carrier for deep seabed operations (left)

Mining technology



Concept of nodules vertical transport (left) prepared by IOM (A-crusher, B-buffer, C-collector, D-discharge pump, E-lifting pump; 1,2,3-progress mixture direction board pumps)
Model of vertical feeder (below), Laboratory of HYDROSYSTEM project, Olomouc, Czech Republic (2012)



Mining technology

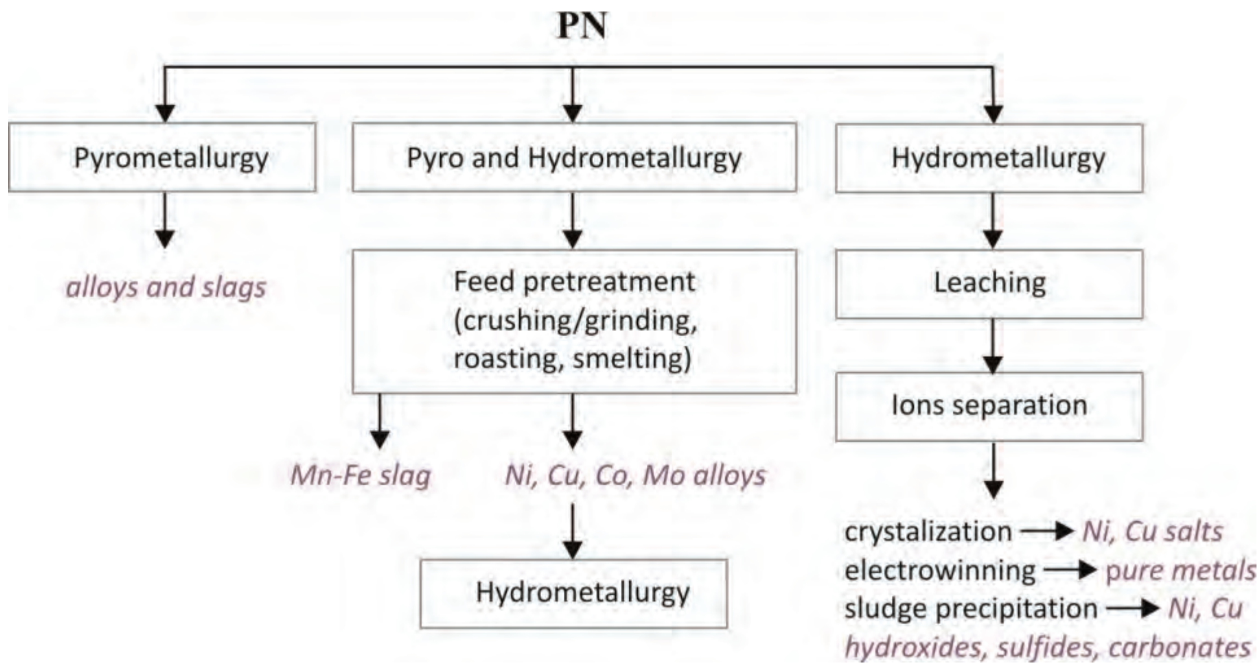
A testing facility (above) for measuring slip velocity of phases in a vertical riser (Wroclaw University of Environmental and Life Sciences, Poland, 2012)

Artificial nodules - solid radiolabeled particles (left) used for the slurry movement study

Mineral processing

Polymetallic nodules reveal the closest similarity with lateritic type land ores, thus most of the processing methods, which have been tested for nodules, are adaptations of the ones originally developed for laterites. The major impediment in the recovery of base metals (Ni, Co, Cu, Zn, Mo) is coexistence with large amounts of iron and manganese, as a basic component of nodules. There are two general types of processing technologies:

- Hydrometallurgical: mainly leaching (acidic – by hydrochloric/sulphuric acid or alkaline – by ammonia reagents) with or without reduction, followed by purification of the obtained solutions and separation of metals in the elemental or compound form
- Pyro-metallurgical: high temperatures pre-treatments (chlorination, sulphonation, reduction roasting, smelting) usually followed by hydrometallurgical metal separation



Technologies of polymetallic nodules processing with the main processes and types of products

Mineral processing

Nodules processing laboratory tests for high pressure acid leaching with reductor carried out in Research Center for the Mining-Metallurgy Industry in Havana, Cuba (2015)

Environment

The legal path leading to the resource exploitation requires evaluation of a possible impact on ecological communities living in the ocean, on the sea floor and beneath it. Several small-scale simulations of nodule sampling using a box-corer, dredging and piston corer have been undertaken within the IOM exploration area. They involved simulation of exploitation (disturbances) and observation of the test area recovery in comparison to undisturbed sites.

The Benthic Impact Experiment carried out in 1995 was the first IOM's contribution to the environmental impact assessment of polymetallic nodules exploitation. The test area covered a total of 3 km^2.

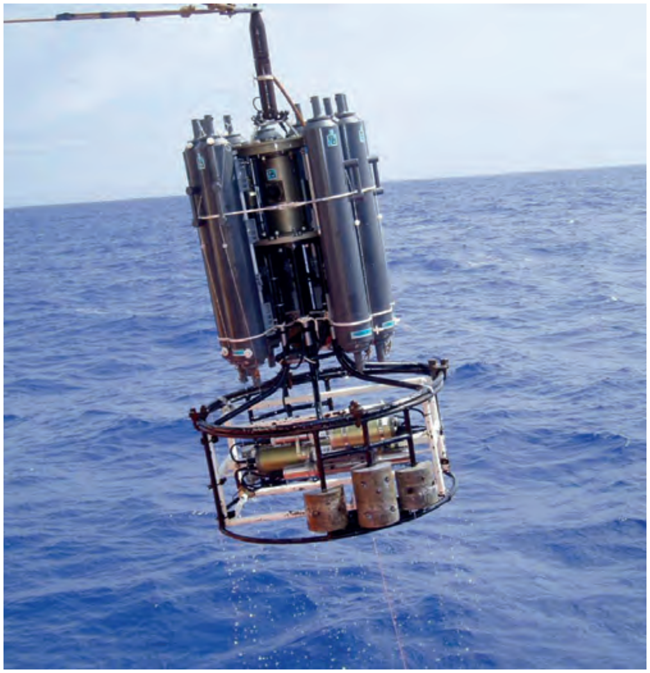
In the past studies, particular attention was paid to the characteristics of the marine environment, especially to the physical and chemical properties of the water column and near-bottom currents, bottom sediments and its pore water, and to biological communities (meiobenthos, macrobenthos and megafauna).

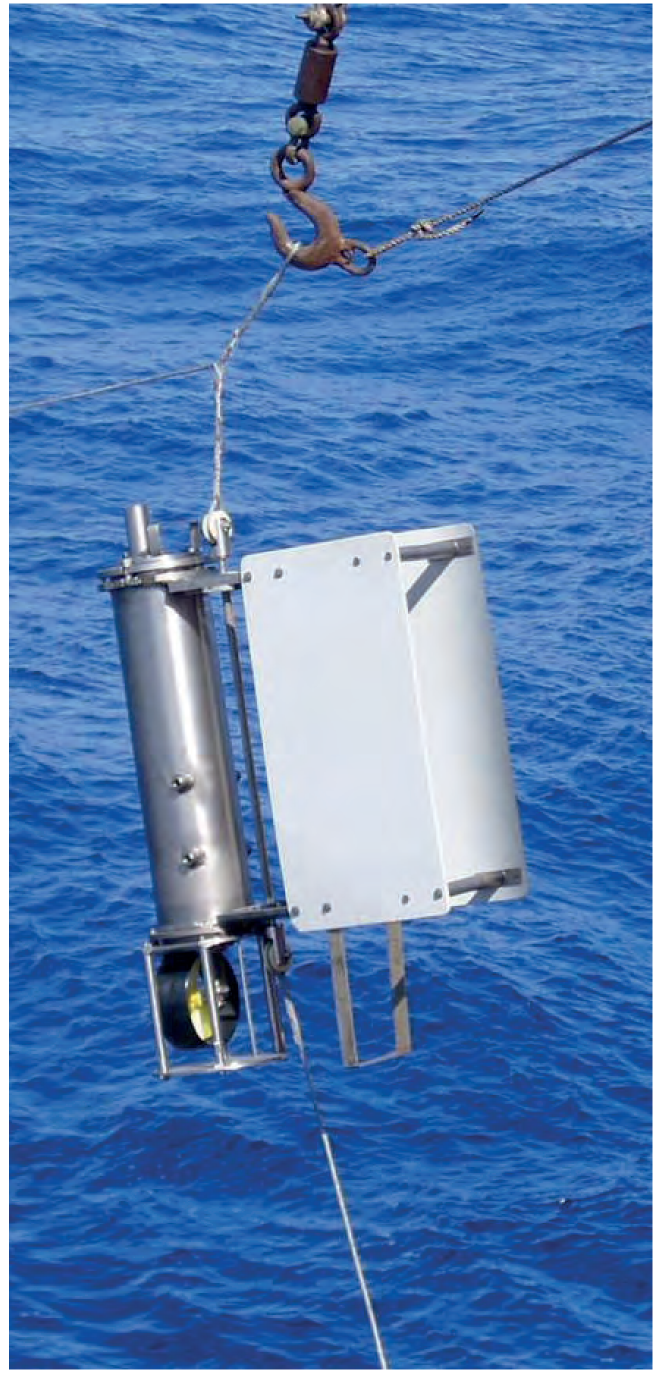
Sample preparation and biological research on board of a research vessel

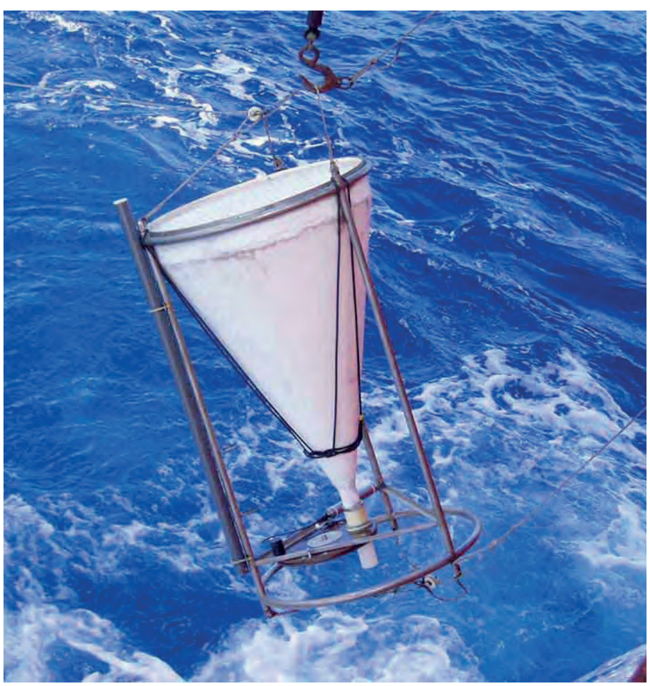
Environment

Disturber device and track of disturber on the sea bottom (1995)

Environment







CTD (conductivity, temperature, depth) device (above), current meter (right) and sedimentation trap device (below) serve to describe water environmental conditions






Species of the sea bottom fauna samples

Outlook

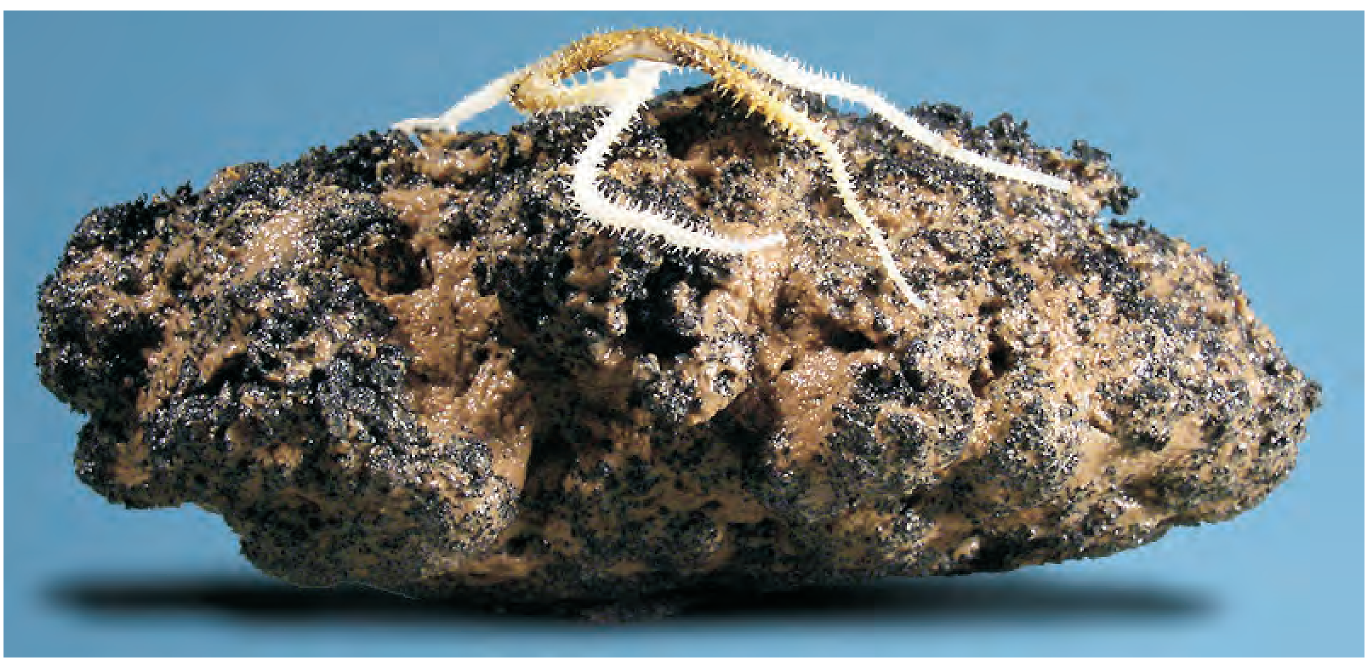
The deep seabed is the frontier that challenges mankind in minerals exploration and exploitation. Today's technology allows to extract gas and oil from water depths of almost 3,000 meters, while the existing offshore mineral mining operations are performed in shallow waters up to 500 meters depth.

All mining project viability depends on many considerations, including geology, technology, economy, legislation and the environment. Commercialization of polymetallic nodule mining will be influenced by the same range of factors.

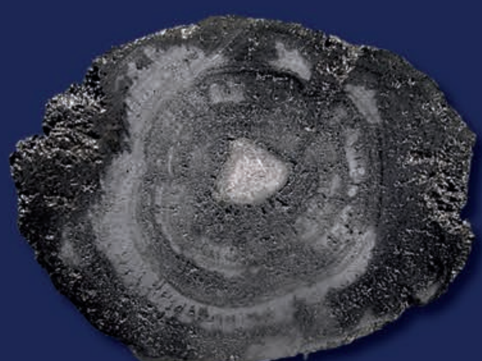
Growing demand for metals (new technologies, industrialization of developing countries), depletion of mineral resources on land (lowering metal grades and increasing mining depth) and problems with access to land will enhance the possibility of deep seabed mining. There has been significantly increased interest in deep seabed exploration in recent years.

The time of deep sea mining is coming closer and IOM is ready to be part of it.

Cross-section of polymetallic nodule (hydrogenetic-diagenetic type)



Polymetallic nodule sample with fauna (Ophiura ophiura)



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