DEEP-SEA POLYMETALLIC NODULES: RENEWED INTEREST AS RESOURCES FOR ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT

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ABSTRACT

Deep-sea polymetallic nodules have been traditionally considered as a potential resource for Ni, Cu, Mn and Co, however the recent research showed that they contain a large variety of metals, including molybdenum, zinc, zirconium, lithium, platinum, titanium, germanium, yttrium, and REEs, which increased their combined value as an alternative supplies for expanding economies and emerging green energy technologies.

The highest nodule abundance (more than 10 kg/m^2) with the high average percentage of metals (at least 2.5 % combined content for Ni+Cu, 0.2% Co, 30% Mn, 0.15% Zn, 0.07% Mo, etc.) were found at seafloor in the eastern equatorial Pacific (Clarion-Clipperton Fracture Zone, CCZ) and in the central equatorial Indian Ocean.

Within the recent decade, the International Seabed Authority (ISA) granted to ten national and multinational entities (Japan, China, Korea, India, Russian Federation, France, Germany, Tonga, Nauru, and Interoceanmetal Joint Organization) exclusive 15-years contracts for polymetallic nodules exploration in ten claim areas, each covering 75000 km^2 in the international seabed area. The commercial viability of nodule mining has yet to be established, but the size of deposits, the grade of several metals contained in nodules as well as the promising trends in metal market continue to motivate contractors to carry out their exploration activity.

This paper discusses the renewed importance of polymetallic nodule in the context of forecasted increasing demands for metals coupled with their environmentally advantages as alternative sources to land-based mining.

Keywords: polymetallic nodules, exploration activity, Clarion-Clipperton Zone.

INTRODUCTION

The deep seabed is one of the most potentially rewarding frontiers that challenge mankind in its exploration activity for marine minerals to ensure sustainable development and material achievement.

Polymetallic nodules as the primary mineral resource found in the deep seabed area promise to make an enormous contribution to the world's resource base. In particular, resources of polymetallic nodules in the eastern equatorial Pacific (within the Clarion-Clipperton Zone, CCZ) have 1.1 times more Mn, 1.4 times more Te, 1.85 times more

Ni, 3.2 times more Co, and 4 times more Y than the entire global land-based reserves for those metals. Thus, metals in CCZ nodules as a percent of the total global land-based reserves are Cu 22%, Mo 63%, W 21%, Li 19%, Nb 13%, and REEs 11% [1, 2, 3]. As a potential resources, polymetallic nodules containing 7.5 thousand million tonnes of Mn, 340 million tonnes of Ni, 285 million tonnes of Cu and 75 million tonnes of Co with at least 2.5 % combined content for Ni+Cu, 0.2% Co, 30% Mn, 0.15% Zn, 0.07% Mo, etc.[3].

Because those large seabed regions laid beyond any national jurisdictions (termed the "Area") such regions fall under the administration of the International Seabed Authority (ISA) in accord with the 1982 UN Convention on the Law of the Sea (UNCLOS) and the Agreement relating to the implementation of Part XI of the Convention. Thus far, the ISA is the main international institution, which is responsible for regulating, and controlling activities associated with the exploration for, and the exploitation of the mineral resources in the Area. In 2000, the ISA has adopted Regulations to govern prospecting and exploration for polymetallic nodules in the Area (Mining Code) [4] what cleared the legal way for ISA to enter into the first ten contracts for explorations with national and multinational entities from Japan, China, Korea, India, Russian Federation, France, Germany, Tonga, Nauru, and Interoceanmetal Joint Organization. The contacts, following the standard clauses and valid 15 years, require contractors to carry out exploration activity in its claim areas, covering 75000 km^2 and to report annually to the Authority on implementation of exploration plan of work, environmental studies, the development of mining technology, and other legal and financial issues.

The commercial viability of seabed mining of polymetallic nodules has not yet a reality but the size of deposits, the grade of several metals contained in nodules as well as the promising trends in metal market continue to motivate contractors to carry out their exploration activity. Moreover, regarding the most recent economic models available, mining of these deposits could generate an internal rate of return of between 15% - 38% [5, 6]. As key components in their commercialization are recognized the mineral extraction at great depth (4000 - 5000 m) what involves never before attempted technological, environmental and legal issues, which have together delayed mineral exploitation to date.

BASIC ADVANTAGE OF POLYMETALLIC NODULE DEVELOPMENTS

Current trends in metal demands

The renewed interest to develop deep-sea polymetallic nodules is result both from growing demands for metals by the rapidly developing countries such as India, China, Brazil and continuous depletion of known land deposits of minerals. Furthermore, decreasing ore grade of terrestrial ore deposits with the resulting increase in energy requirements and quantities of waste that must be disposed of, also affect the future availability of the deep-sea mineral resources that may be economically feasible for mining in the next decade.

It was published in June 2010 that the EU countries are in the face of shortages in the supply of rare earth elements (REE) and other metals considered critical "technology metals" e.g. Ni, Co, Mn, Pt, Ge, Ti etc., which are essential for the development of many branches of industry, including electronics and emerging technologies. These metals are among the most common found in deep-sea polymetallic nodules, which will be needed to meet the growing demands.

Economic feasibility

The abundance of nodules on the seabed and the grade of the ore are the critical terms in determining the economic feasibility of mining nodule deposits. Preliminary assessment showed that at least 34 thousand million tonnes polymetallic nodule deposits cover an interpolated area of 9 million km^2 in the CCZ (5° - 20° N; 110° - 160° W) with the highest nodule abundance (more than 10 kg/m^2), and with combined Cu and Ni concentrations >2%. These deposits appear to be the best in the world in terms of commercial value, with good to very good metal assays. It is suggest that those recourses could be potentially enough to sustain the estimated 6000 metric tonnes per day minimum mining requirement [4, 6].

World metal prices today are affected by factors external to the metals industry and they continued to be variable and unsteady. The metals industry is a part of the world and national economies, so changes in those economies can affect metals' prices. Higher metal prices between 2005 and early 2008 encouraged the exploration, planning, and development of many new Cu-Co and Ni-Co projects, including deep-sea minerals. The global economic recession that began in late 2008, however, caused much of this development activity to be suspended, postponed, or cancelled.

According to most experts, Ni will be the mainstay of the nodule industry. Cu, Co and Ni will be produced jointly, with Mn and several trace metals probably being produced as by-products from the tailings. The preliminary examination indicate that REE's and other trace metals may significantly increase the potential return on investment, compared to the existing economic models for the major metals of interest, such as Ni, Co, Cu and Mn [3, 8, 9]. For example, the added value from trace metals in terms of the total metal content is in the order of 60 to 70 per cent of the combined value of the major target metals. It has, however, to be stressed that these values represent potential maximum figures, not considering highly complex metallurgical factors and other parameters to be considered in economic feasibility models of seabed mining [6, 7].

Environmental sustainability

In the context of this paper environmental sustainability' refers to the maintenance of the ecosystem and the natural resource base. Because, the polymetallic nodule developments will occur in the international seabed area, the deposits will be developed sustainably for the benefits of all mankind under an international safety regime accepted by the overall 157 States members of the ISA.

Polymetallic nodules as source of supply the Green Economy

Polymetallic nodules have the potential to become a major source of metals, which requires by electronics and emerging technologies such as battery systems, hybrid cars, wind turbines and other renewable green energy technologies, which require increasing amounts of Ni, Co, Cu, Mn. Research of alternative energy shows that Green Energy technology is far more Ni and Cu intensive than traditional form of energy [10]. For example, a single wind turbine requires 12 times more Cu to produce 1 kW than conventional power generation; an electric car requires twice as much Cu than a conventional car. Estimates for the amount of Ni contained in NiMH batteries used in the hybrid electric vehicle was counted to increase by a factor of 10 between 2003 and 2010, what represent about 1.5 percent of total Ni apparent consumption in the United States in 2010 [11].

Nodule mining versus onland-based ore mining

A basic advantage of marine mineral developments is that nobody lives there and deep-sea mining of polymetallic nodules does not require the social dislocation, loss of livelihoods and will eliminate a large class of legal restrictions related to environmental protection or social disruption.

Deep-sea resource production will involve vessels and surface platforms constructed in efficient shipyard locations as opposed to land based mines ‘on site’. Deep-sea infrastructure such as ships and pipes could be re-used and re-located from one mine site to other. In contrast, much terrestrial mining infrastructure is fixed.

Polymetallic nodule deposits occur directly on the seafloor and therefore, unlike terrestrial deposits, do no demand large pre-strips or overburden removal to access the ore deposits.

Disposal of tailings produced from the flotation process of laterites (terrestrial Ni-Co ore) are often recognized as the biggest environmental threat posed by the onland based mining. The tailings produced from the flotation process in generally represents more than 98 percent of the original Cu ore. In contrast, processing polymetallic nodules can leave zero waste or residue and thus not require additional tailing storage facilities.

IOM EXPLORATION AND ENGINEERING ACTIVITIES

The Interoceanmetal Joint Organization (IOM), an intergovernmental consortium certified by the governments of Bulgaria, Cuba, Czech Republic, Poland, Russian Federation, and Slovakia, was signed on 29 March 2001 a contract with the ISA for exploration of polymetallic nodule deposits in the area (75000 km^2) situated in the eastern part of the CCZ, NE Pacific. In implementation of the 15-yrs plan of work for exploration, IOM carrying out comprehensive research and development studies in geology, marine environment as well as in the mining technology and processing of polymetallic nodules.

The main objective of the IOM current activity is delineation of nodule fields and identification of nodule deposits and reserves within prime areas that could be mined in the future. IOM has made considerable progress in geological exploration using multi-beam echo-sounder system, deep-tow photography survey, bottom sampling and performed a huge amount of analysis of physical, mechanical and chemical properties of sediments and nodules.

Environmental study was focused on the collection of environmental baselines data on physical, chemical, geological and biological components of marine environment in the exploration area.

Research on development of mining technology included analysis and assessment of the existing nodule technology and development of a conceptual design for a future mining system.

The work on nodule processing involved the optimization of the existing technological schemes for extraction valuable components from polymetallic nodules, and development of the basic technological schemes for polymetallic nodules processing.

There are several proposals of technical approach for achieving satisfactory results in picking up polymetallic nodules, transporting them vertically to the mining ship or platform and finally processing them into the metals or metal condensates. Usually, mining and processing stages are considered as separate operations but there are many common issues with mutual interactions.

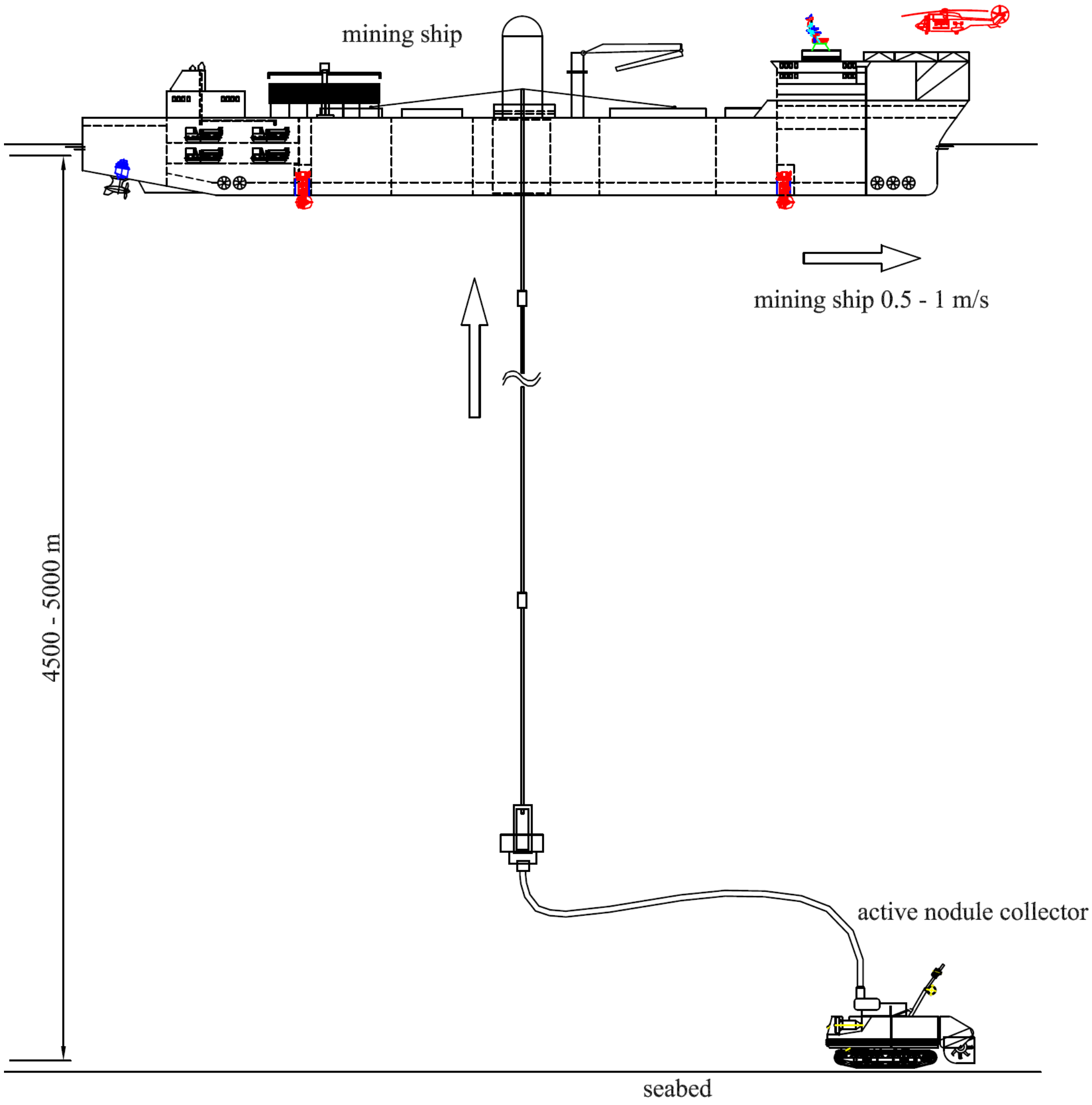
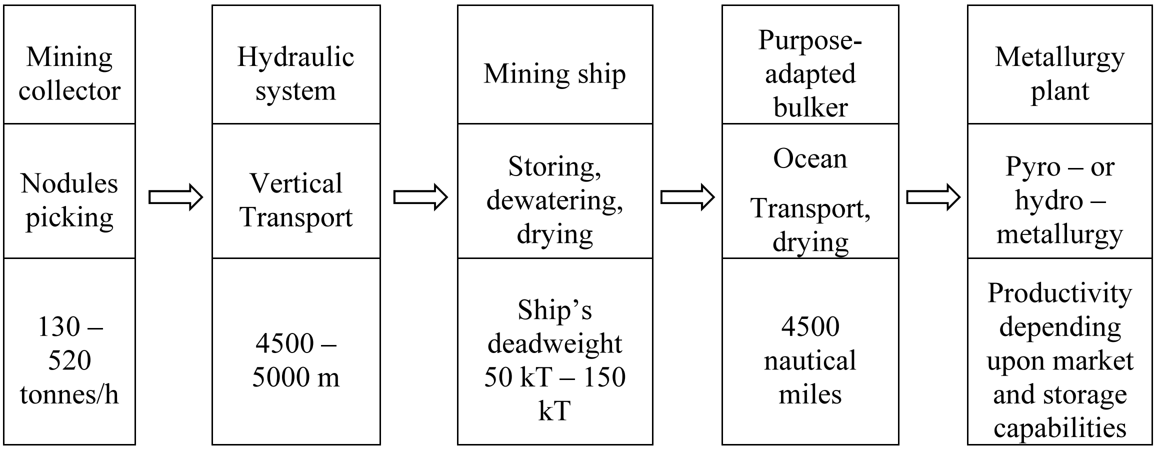


Fig.1. Mining system.

An input parameter for both operations is the year productivity of the enterprise. Values of between 1 up to 4 million tonnes per year of nodules are considered. Assuming of the 320 working days in a year, results in the range from 130 – 520 tonnes/h. While for the processing plant located on land these values could be easily attained they cause several design problems for mining underwater equipment which need to be precisely considered. At present the IOM carries out the research and design works focused on so-called hydraulic mining method. The layout of the system is given in fig. 1. The system consists of nodule miner (collector), buffer with slurry pumps, vertical transport pipe (riser), and the mining ship. The track of mining ship is dynamically positioned and it follows the collector moving along designed mining tracks. The collector picks up the nodules, rinses them off the clays and sediments. They are then crushed and as the slurry, pumped to the buffer and to the mining ship. The function of the mining ship is storing, dewatering and drying until they are trans-shipped on the specialized bulk cargo carrier. The transhipment operation undergoes each few days and nodules are transported to the metallurgy plant. The process flow in general outline is given in fig.2.



Mining collector	Hydraulic system	Mining ship	Purpose-adapted bulker	Metallurgy plant
Nodules picking	Vertical Transport	Storing, dewatering, drying	Ocean Transport, drying	Pyro – or hydro – metallurgy
130 – 520 tonnes/h	4500 – 5000 m	Ship's deadweight 50 kT – 150 kT	4500 nautical miles	Productivity depending upon market and storage capabilities

Fig. 2. An outline of the enterprise project flow.

As an organization interested in future nodule development, IOM carried out comprehensive geological research with purpose to assess nodule resources within exploration area. Based on both the kriging and geological blocks methods of interpolation the amount of nodule resources as well as the resources of base metals (Ni, Cu, Co, Zn, Mo, and Fe) were estimated. A total of 33 940 km^2 ore-bearing fields were delineated within the IOM exploration area with 446.53 million tonnes of wet nodules (mean nodule abundance of 13.15 kg/m^2) or 304.26 million tonnes (mean nodule abundance of 9.0 kg/m^2) of dry nodules were counted. The resources of Ni, Cu, Co, Mn, Mo, and Zn were estimated at 3988.8 thousand tonnes (mean contents1.31%), 3583.2 thousand tonnes (mean contents 1.18%), 548.3 thousand tonnes (mean contents 0.180%), 94361.6 thousand tonnes (mean contents 0.141%), respectively.

The monetary value of products of mining and processing the commercial ore within the contoured prognostic nodule resources of the IOM exploration area was calculated for different indices of ore-bearing (1.0, 0.7, 0.6, 0.5),dilution (5, 10, and 15%), and losses during mining and transportation (20, 30, and 40%). As shown by the calculations, the supply of commercial ore for a future mining enterprise processing 3 million tonnes dry nodules, at the worst-case scenario of geological and mining conditions should be sufficient to meet required terms of an exploitation license.

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