The seabed - an important mineral resource of Slovakia in the future

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In 1987, Slovakia bought part of the ocean bottom with the occurrence of mineral resources future - polymetallic nodules. The polymetallic nodule is a geological term for naming natural features consisting of more than 40 metals and other chemical elements. These special services originated in the ocean for two to three million years and nowadays, they are of main interest for countries whose mineral wealth is little or no available. Nodules contain about 30 % manganese, 1.2 % copper, 1.2 % nickel, 0.2 % cobalt, rare earth elements, etc. The existence of submarine nodules was found by the British ship HMS "Challenger" by oceanographic research in 1872 - 1876. Research and the subsequent mining of nodules were particularly points of interest for Western countries as well as the USSR. Rules for the use of mineral resources of the seabed beyond the limits of national jurisdiction were codified in the Convention on the Law of 1982, which came into force on 16.11.1994, and in the Slovakia on 21.7.1996. The seabed is one of the international space next to the high seas, Antarctica, outer space and celestial bodies, which are not subject to the sovereignty of any state authority.

Key words: *Deep Seabed Mineral Resources, Polymetallic Nodules, Interoceanmetal IOM, Clarion-Clipperton Zone, Slovakia.*

Introduction

Growth demands on energy and mineral resources in the industry and increasing demands on people's quality of life increases dependence on raw materials. Safety is not just concerned with military threats, but increasingly also with non-military threats. The military threats are also threats related to deficiencies and subsequent security of mineral resources and energy resources (Ivančík a Kelemen, 2013). Finding new sources is one way to reduce the risk of exhaustion of mineral resources. For these reasons, it is very important to survey and research in the field of mining and the possibilities of using the non-traditional mineral resources. Sea polymetallic nodules can be regarded as such an alternative and interesting source of raw materials.

Deep sea polymetallic nodules are formed at the bottom of the world's oceans in addition to flora and fauna and are also significant mineral reserves. Nodules are tubers and clods lying in sediments and differing from surrounding by its composition. Nodules contain a very large stock of mainly non-ferrous metals, especially manganese, cobalt, copper, nickel, titanium, chromium, and zinc. In addition, there was also found an increased content of gold, silver, uranium, and more rare elements in them. They are called the polymetallic nodules mostly because they contain especially manganese, in the amount of about 13-25 %. The average manganese content in the earth's crust is about 0.095 to 0.1 %, and thus, a general interest in them is quite logical. Stocks nodules lying freely on the ocean are estimated at one trillion tons. Polymetallic nodules also contain relatively high amounts of iron, about 10-20 %, so its name tends to be iron - manganese concretions since 1958, but because some traces of many other metals, a total of more than 40, a universal name polymetallic nodules is often used. Polymetallic nodules are interesting also because such a combination of metals (iron, manganese, cobalt, copper and nickel) cannot be found on the mainland.

The discovery of nodules on the seabed is considered one of the most outstanding achievements of geology in the 20th century. Therefore, no wonder that this issue has started to address the United Nations because this mineral wealth was claimed as the property of all humanity. The United Nations convened the third conference on the Law of the Sea as early as 1973. The United Nations Convention on the Law of the Sea signed in 1982 came into force until 1994 (www.1). It was created by the International Seabed Authority based in Kingston, Jamaica and the International Tribunal for the Law of the Sea established in Hamburg (www.2).

1. Legislative background

Polymetallic nodules were discovered during an exploratory voyage of the ship Challenger in the Pacific Ocean in the years 1872-1976. Their systematic research began in the mid- 60s of the 20th century, when methods of analysis, which revealed high levels of the mentioned metals and thus their usefulness to industry,

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were discovered. Mainly western countries, and also the former USSR, showed their interest in the research and subsequent extraction of nodules.

Rules for the use of mineral resources of the seabed beyond the limits of national jurisdiction were codified in the Convention on the Law of 1982, which came into force on 16.11.1994, and in the Slovakia on 21.7.1996. The convention on the Law of the Sea identifies the seabed beyond national jurisdiction as an "area", which is the common heritage of humanity and managed by the International Seabed Authority (International Seabed Authority - ISA) based in Kingston Jamaica. ISA allows the exploration of minerals on the seabed and in the future will allow their extraction (Fig. 1, www.2).

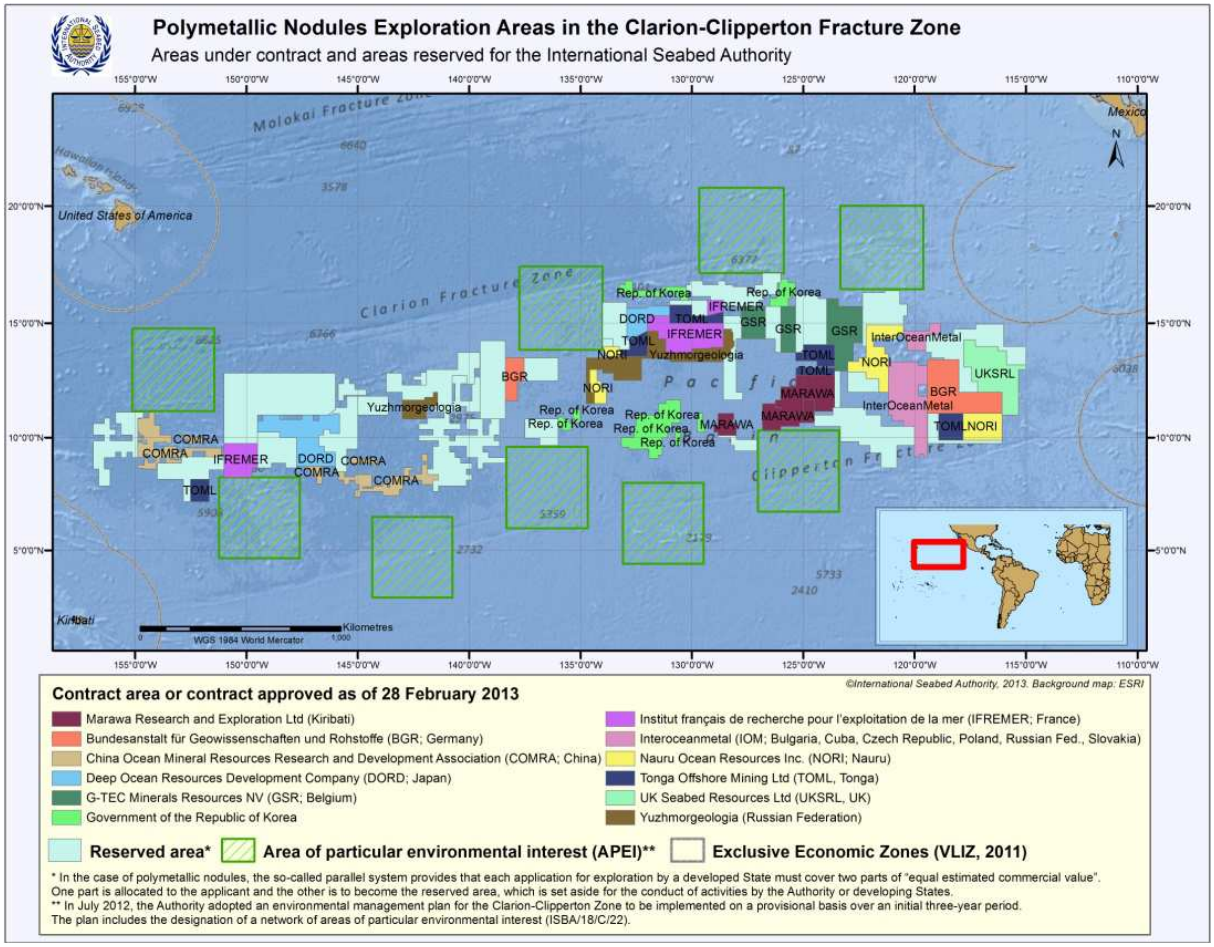

Fig. 1. Map Clarion - Clipperton Island in the Pacific Ocean with the position of polymetallic nodules areas (www.2).

Before the adoption of the Convention on the Law of the late '70s and early '80s, however, consortia of western countries and the Soviet Union divided the most profitable area of Clarion - Clipperton Island in the Pacific Ocean. On conference on the Law of the Sea, the United Nations decided in its Resolution in 1982 that, if these consortia or states meet certain conditions may be preferentially examined and prepared so as mining nodules as a pioneer investor in the restricted area, which registers the Preparatory Commission for the International Seabed Authority and the International Tribunal for the Law of the Sea (International Tribunal for the Law of the Sea). Whereas the western countries (France, Japan and the consortium of Belgium, Netherlands, Germany, Italy, Great Britain, USA, and Canada) registered much more territory in a wealthy area of Clarion - Clipperton in comparison to Eastern Bloc, the International Tribunal for the Law of the Sea (the initiative of the USSR, and discussions in the UN bodies) decided in 1986 on the possibility of countries in Eastern Europe and developing countries, individually or as a consortium, to apply for a pioneering investor status with the allocation of area on the seabed (www.2).

1.1. Slovakia and InterOceanMetal

In 1987, based on the decision made by the International Tribunal for the Law of the Sea, the organization InterOceanMetal was founded (founding members USSR, Czechoslovakia, Poland, Bulgaria, East Germany, Cuba and Vietnam). Since then, the organization's task is to search for Polymetallic nodules, their afterward research and preparation for mining.

The home office of the organization is situated in Szczecin, Poland. In 1989, Vietnam gave up its membership and East Germany (as the successor of GDR) has also left InterOceanMetal in 1991. USSR's membership was taken up by its successor the Russian Federation. In 1993, after the separation of Czechoslovakia Federation, both newly founded countries (Czech Republic and Slovak Republic) had become members of InterOceanMetal. After 12 expeditions, InterOceanMetal has found the most suitable location in the eastern parts of the Clarion-Clipperton area (Pacific Ocean). Afterward, InterOceanMetal requested the International Tribunal for the Law of the Seas for official registration of the areas in 1991. On the 21.8.1991, the General Committee of the International Tribunal for the Law of the Sea has allocated an area of 150 000 km^2 to the member states of InterOceanMetal. Other than technical issues, one of the conditions for obtaining this area was the clarification and approval of territorial borders with China and the Republic of Korea, which have applied for registration of their territory after the request of InterOceanMetal. The signature of the exclusion of overlaps and conflicts in relation to deep – seabed were necessary from the governments of Belgium, Canada, Germany, Italy, Netherland, Great Britain and USA (represented companies and organizations within the international consortium registered in the United States of America). The agreement between the governments of member states and the members of InterOceanMetal was singed on the 20th August 1991 in New York.

Each of the pioneer investors was required to carry out a series of work established in the Resolution II. of the Final Act of the 3rd UN Conference on the Law of Sea from the 10th December 1982 regarding the protection of preparatory investments within pioneer activities regarding poly-metal nodules. These obligations included a variety of tasks such as – transfer of technology, training of specialized staff for ISA and the review of half of the allocated territory for the purpose of submitting it to the ISA reserves, for the future usage by developing countries. Therefore, InterOceanMetal has reviewed and submitted half of the registered area (75 000 km^2) to the ISA reserves in 2000. During 1994 – 1995, 4 assigned trainees from Pakistan, Sudan, Belarus and Republic of Korea was trained. On the 14th March 1995, the president of the International Tribunal for the Law of the Sea JL Jesus has given to the member states of InterOceanMetal the certificate (document LOS/PCN/145) decelerating the accomplishment of the above-mentioned obligation by the joint organization InterOceanMetal.

In 2000, the ISA approved new rules for searching and exploration of polymetallic nodules in the area. On the 29th March 2001, in accordance with the new rules, the agreement about the exploration of the remaining area of 75 000 km^2 for 15 years was signed in the names of the member states by Dr. Kotliński (then General Director of InterOceanMetal) and Satya Nandan (General Secretary of International Seabed Authority). Therefore, InterOceanMetal has become a so-called contractor (other contractors are: China, Japan, India, France, the Russian Federation, the Republic of Korea, Germany; and private companies - Nauru Ocean Resources Inc., Tonga Offshore Mining Limited, Marawi Research and Exploration Ltd. of Kiribati, UK Seabed Resources Ltd., and G - TEC Sea Minerals Resources NV of Belgium). InterOceanMetal has the exclusive right to nodules in the allocated area until 2016. In the future cases, ISA's approval of extracting nodules in the allocated InterOceanMetal will be prioritized over other applicants. The activities of InterOceanMetal are carried out in the approved plan of exploration by the ISA, including measures to protect the ocean environment. In 2016, Interocenametal may request an extension of the license for the exploration for five years, or a license to pilot extraction.

2. The seabed - mineral resources also for Slovakia

2. 1. Metal resources in the area of Slovakia

Geological reserves of ore minerals include an inventory of balanced resources (economically useable) and non-balanced (potentially economically useable), free, and bound stocks with various degrees of exploration. Industrially feasible are only balanced, available ones, from which the real extraction is possible only in the case of 40-90 % of stocks (depending on the mining method, the size of losses, etc.).

The Decrement of ore mining has been ongoing in Slovakia since 1991, because this research and exploration activities of ore resources are gradually reducing. According to the Government Resolution No. 502 from the 29th March 2005, only the exploration of metal, gold and silver ore may be funded by the state budget. The Ministry of Environment already ended the exploration of other types of ore.

Significant development of ore mining is currently not expected. Imports already cover the vast of raw material necessary in the national economy. Given the high level of geological exploration of the Slovak territory, discovering new resources suitable for usage in current market conditions is unlikely probable.

Only the mining of gold is predictable of all ore resources, even if the opening of new mines and extraction sites in a close range of populated areas is truly not appropriate. Despite it, the District Office of Mining in Banská Bystrica has determined the mining site Detva – proposed by the company EMED Slovakia (daughter company of the Cyprus company EMED Mining Public Limited) on 19th November 2005. EMED plans to mine gold by surface methods with the use of cyanide leaching in the area of Detva called Biely vrch.

On 1st January 2012, the geological resources of ore materials achieved 325 million tons on 46 exclusive deposits, of which 74 % represents non-balanced resources (Tab. 1). Only parts of deposits of iron ore Nižná Slaná - Manó – Kobeliarovo; complex iron ore Rožňava – Strieborná; and the golden ore at deposit Banská Hodruša and Kremnica may be considered as balanced. Verified resources of other metal ore – Cu, PB, Zn, Sb, Hg, W are currently non-balanced.

Currently, 12 deposits are registered in the territory of the Slovak Republic, from which only Banská Hondruša is mined. Others are - Kremnica, Banská Štiavnica, Dúbrava, Pezinok, Jasenie - Kyslá, Dolná Lehota, Zlatá Baňa, Klokoč, Brehov, Magurka, Medzibrod.

Tab. 1. Ore mineral resources of Slovakia – status for the year 2010 (www.4).

Mineral	Number of all deposits	Possible to mine	All resources	Balanced (Z1 + Z2)	Balanced Z3	Non-balanced
Fe ore [kt]	9	-	76 505	17 562	4 165	54 778
Copper [kt]	16	-	533	27	7	499
Lead [kt]	4	-	228	-	-	228
Zinc [kt]	4	-	396	-	-	396
Antimony[kt]	9	-	55	-	-	55
Mercury [kt]	5	-	6 917	0	0	6 917
Tungsten [kt]	1	-	7	-	-	7
Silver [t]	8	-	1 518	795	226	497
Gold [kg]	21	1	153 234	28 587	40 296	84 351

Silver, zinc, lead and copper are present in insignificant amounts in the concentrate obtained by adjusting gold ore in gold mining at the Banská Hodruša deposit. Copper and mercury are present in insignificant amounts found in sulfide flotation concentrate obtained by the adjustment of complex ores from the deposit Rudňany (www.4).

2. 2. Polymetric nodules – The future significant resource of raw minerals

The chemical composition of the nodules is different depending on the type of manganese minerals, size and properties of the core (Fig. 2). Nodules with economic importance have the following chemical composition - Tab. 2

Tab. 2. The chemical composition of nodules with economic importance (www.3).

Manganese - 29 %	Copper - 1.3 %	Calcium - 1.5 %
Iron - 6 %	Cobalt - 0.25 %	Magnesium - 0.5 %
Silicon - 5 %	Oxygen - 1.5 %	Potassium - 0.5 %
Aluminium - 3 %	Hydrogen - 1.5 %	Titanium - 0.2 %
Nickel - 1.4 %	Sodium - 1.5 %	Barium - 0.2 %

In relation to the formation of nodules, several theories about their origin were formulated (Kotlinski, 1999; Kotlinski, 2003). The following two are the most popular:

1. Formation from seawater - type H, in which the nodules are formed by slow precipitation of metallic elements dissolved in seawater.
2. Diagenetic process - type D, in which the manganese is remobilized in sediments and transmitted on the interface sediment/water. These nodules are rich in manganese, but poor in iron, nickel, copper and cobalt.

Fig. 2. Polymetric nodules extracted in the Clarion - Clipperton area in the Pacific Ocean (www.5).

The growth of nodules is one of the slowest geological phenomena - average increase for several million years is measurable in centimeters. Therefore, the age of the Pacific nodules is 2 – 3 million years. However, this theory contradicts with the rapid rise of manganese crusts, which was reported at sunken ships during World War II. If nodules are formed slowly, their formation is according to the theories mentioned above caused by the precipitation of metallic elements dissolved in seawater or by diagenetic processes. In the case of fast formation, their formation from sea water of sediments is not probable. In this case, rather hydrothermal and halmyrolitic processes are applicable (Kotliński and Zadornov, 2002).

The distribution and formation of polymetallic nodules indicate that the decisive importance of the concentration of metals has the following factors:

- the amount of metals present in ocean of hydrothermal and other sources,
- the structure and dynamics of waters,
- low rate of sediment accumulation,
- depth,
- relief of the bottom.

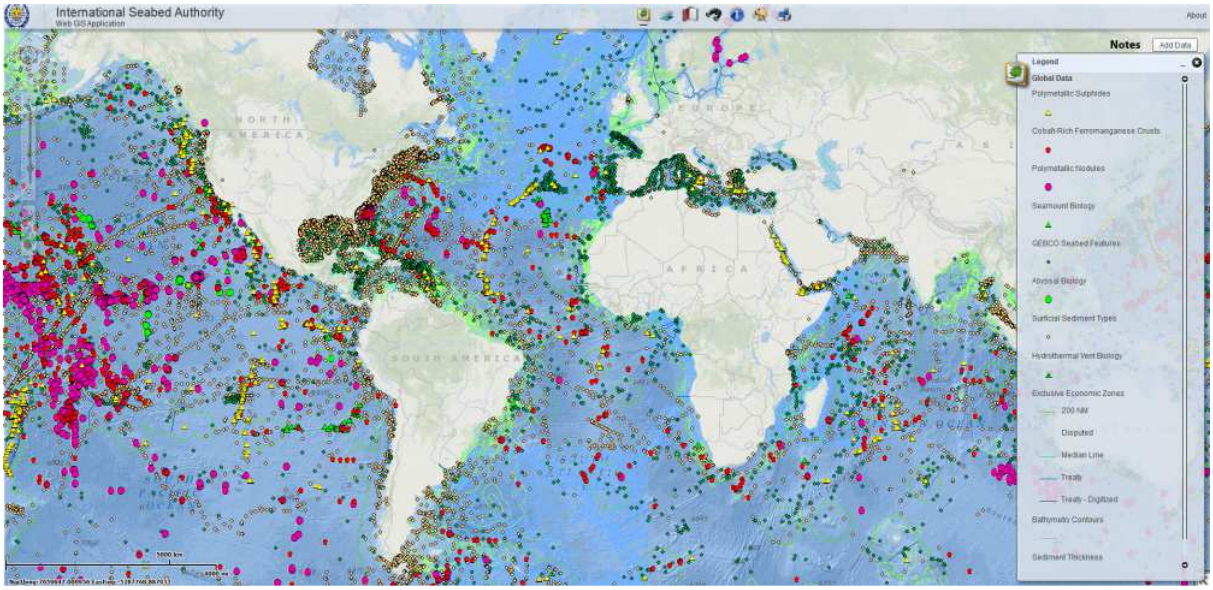

Fig. 3. The position of the deep-sea nodule sites. Taken from GIS (ISA www.2).

Nodules were found in all oceans (Fig. 3), and even in lakes. The accumulation of nodules with economic importance is concentrated in the three following main areas (Fig. 4), which were determined as exploratory areas by the states and the international community:

- Clarion - Clipperton Fracture Zone,
- Mid - Atlantic Ridge,
- Volcanic Ridge in the Indian Ocean.

In addition to these three exploration areas, another area in the Pacific is in the process of contract preparation for the exploitation of the seabed (Fig. 4).

3. The economic benefits for Slovakia from the extraction of polymetallic nodules

The Slovak Republic with the membership in the joint organization InterOceanMetal has received a place in a group of about 15 countries of the world, which have the rights and obligations of a pioneer investor. The rights include mainly the possibility of exploring the allocated area, preparation of extraction and eventually mining. The UN in the Law of the Sea (1982) adopted the principle that materials on the sea bottom (beyond the jurisdiction of coastal states) has to be regarded as the common heritage of humanity.

To avoid the possibility that developed countries explore and extract all the wealth, ISA has adopted two principles:

- Each pioneer investor receives an area of 150 000 km^2 of seabed for exploration.
- After exploration, the pioneer investor retains half of the exploration area (75 000 km^2) for further exploration and mining. All the information about the other half of the exploration area is submitted to ISA,

which in the case of interest in the future submits to one of the today's developing countries or a group of this kind of countries.

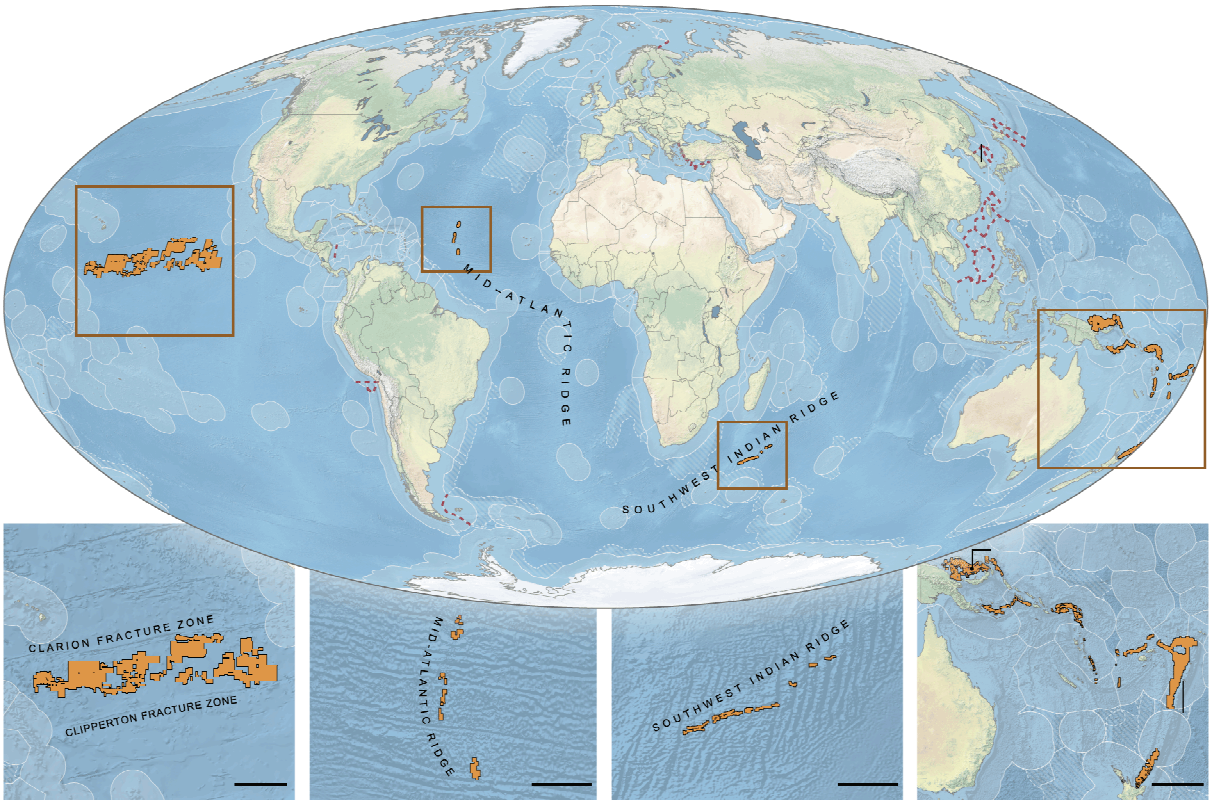

Fig. 4. The position of the allocated mining area by the ISA organization (www.6).

During the previous period, IOM activities in the allocated territory consisted of the following works:

- exploration,
- monitoring of the environment on the seabed,
- the technology of extraction and transport of polymetallic nodules,
- processing technology of polymetallic nodules.

After the resignation of half of the exploration area, IOM remained a territory in the area of 75 000 km^2 divided into two parts. Under B1 stocks, wet nodules represent 69.7 million tons (average density of deposit 12,1 kg/m^2), representing 47,3 million tons of dry nodules at an average density of 8.2 kg/m^2 and supplies:

Ni (1,27 %)	600 000 ton	**Cu** (0,98 %)	461 000 ton
Co (0,195 %)	92 000 ton	**Mn** (28,43 %)	13 400 000 ton
Fe (7,01 %)	3 300 000 ton	**Zn** (0,139 %)	65 700 ton
Mo (0,05 %)	23 600 ton		

Under B2 stocks, wet nodules represent 376 million tons (density of 13.3 kg/m^2), respectively 255 million tons of dry nodules (density 9.1 kg/m^2). This means:

Ni (1,33 %)	3 385 000 ton	**Cu** (1,228 %)	3 129 000 ton
Co (0,177 %)	449 000 ton	**Mn** (31,63 %)	80 600 000 ton
Fe (5,7 %)	14 500 000 ton	**Zn** (0,1452 %)	363 500 ton
Mo (0,0575 %)	146 300 ton		

Concerning the fluctuating world prices of metals, it is meaningless to specify the exact expression of the quantities mentioned above of metals in financial terms. According to previous calculations, the value of these metals should be around $ 150 billion. This does not mean cash. It may be estimated that about 90 % of the value is absorbed by the costs of mining, metallurgical processing and transport of these materials. The remaining 10 % (approx. $ 15 billion) will remain available for the distribution to the members of the IOM. The exploration area in which the Slovak Republic has its share lies in the Pacific Ocean on the 120^0 west longitude (south of California) and between the 10^0 – 15^0 north latitude (west coast of Nicaragua, El Salvador,

and Guatemala). The depth of the sea at this location is between 4-5 km (Hamrák and Domaracká, 2010; Domaracká and Hamrák, 2011).

To illustrate the amount of resources that are situated at the sea bottom is in the following table (Tab. 3).

Tab. 3. Comparison of stocks and mining of selected metals on land and in the oceans (Cehlár et al., 2013; Domaracká et al., 2011).

Element	**World stocks** [t]		**World mining** [t]	
	Land	**Ocean**	**Land**	**Ocean**
Mn	$8.\ 10^9$	$6.\ 10^6$	$15.\ 10^6$	$0{,}75.\ 10^6$
Ni	$100.\ 10^6$	$290.\ 10^6$	$700.\ 10^3$	$36.\ 10^3$
Cu	$600.\ 10^6$	$240.\ 10^6$	$14.\ 10^6$	$30.\ 10^3$
Co	$3.\ 10^6$	$60.\ 10^6$	$50.\ 10^3$	$7{,}2.\ 10^3$
Ni+Co+Cu	**7,0300E+08**	**5,9600E+08**	**2,9750E+07**	**7,3950E+04**
Mn+Fe		**8,4000E+09**		
Ni+Co+Cu+ Mn+Fe		**8,9960E+09**		

It may be concluded that polymetallic nodules are perspective materials of manganese and associated non-ferrous metals. However, their adjustment and metallurgical processing will, regarding investments, represents 50 % of all costs.

Conclusion

One of the largest areas of accumulation of raw materials in the world's oceans (thus the areas of the most concern to many countries from an economic point of view) are represented by polymetallic nodules of a huge range, located in the NE Pacific tectonic Clarion - Clipperton. They are situated in the territory of pioneering investors, and these investors have the exclusive right to perform reconnaissance operations in authorized areas in the region. The status of Pioneer investor was assigned to France, Japan, Russia, India, China, South Korea and Interoceanmetal. Member of this international organization is the Slovak Republic (since 1993), which became a global along CR as the first landlocked country participating in the deep sea bathymetric survey.

The continuation of ongoing works on polymetallic nodules in the Clarion - Clipperton zone is considered as an important role in 2020, having regard to the progress made in establishing effective extraction units, application of modern processing technologies for extracting the main metals - manganese, nickel, cobalt and copper, and the inclusion of movement components of Mo, Zn, Ti and rare earth elements into usable metals. At the beginning of the 21st century, it is clear that the oceans are a vast source of non-traditional materials. A prerequisite for the rational use of ocean resources is to protect the natural ocean environment.

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