



Workshop on the Results of a Project to Develop a Geological Model of Polymetallic Nodule Deposits in the Clarion-Clipperton Zone

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Relationship between nodule coverage, morphology and distribution in the eastern part of the CCZ

Ryszard Kotlinski and Valcana Stoyanova

Abstract

The distribution pattern, coverage and abundance variations, type and morphology of polymetallic nodules in area covers more than 810 000 km² laid out in the eastern CCZ between 8^o38.77' - 16^o52.76'N and 118^o52.5' – 125^o 19.75'W is presented. Our observations are based on data from about 900 stations sampled with a box corer and grabs during the prospecting and exploration activity of the IOM. With purpose to evaluate the relationship between seafloor coverage and abundance of polymetallic nodules and their unconformity due to sediment-blanketing processes total of 262 km photo profiling data and thousand of bottom photograph were analyzed. Nodule abundance varies from 0 to 43.6 kg/m², averaging 43.6 kg/m², thus the highest percentage of both coverage and abundance are found in water depths between 4,300-4,500 m. Stations that yielded high nodule abundance were found to be situated virtually on all types of seafloor morphology, and the highest abundance values are found between 12^o and 16^o N. Nodule blanketing by the sediment is a characteristic feature of the entire studied area. The blanketing intensity is prevailed in the northern part and decrease in the north-south direction, which in turn evidences a parallel reduction in the intensity of recent sediment accumulation. Thus, the maximum intensity of blanketing is typical of those stations located on undulating plains and horst slopes within the depth interval of 4100 – 4300 m.

Throughout the studied area, the discoidal and ellipsoidal shaped nodule types and their regenerated fragments are dominant and their size distribution is bimodal, the picks involving 2-4 cm and larger than 8cm size intervals. It is confirm that small (up to 4 cm in diameter), usually spheroidal, with smooth surface nodules compose mostly by amorphous Mn minerals (δ -MnO₂), whereas larger ones (6-12 cm in diameter), predominantly discoidal and ellipsoidal in shape and with rough surface consist 10Å manganate as a major Mn mineral; the intermediated in size nodules, with smooth upper and rough lower surface, predominantly ellipsoidal, flatted, and plate-shaped nodules essentially consist of 7Å manganate minerals.

Diagenetically grown nodules (**D**) and its **D_I**-subtype are dominant within the entire area (35.7 and 21.9%, respectively) with emphasis distinct in their size distribution; 4-6 cm and larger than 8 cm are dominant for **D**-type, while the size distribution of **D_I** nodules is virtually homogenous, peaking slightly at the 2-4 cm size fraction. Hydrogenetically grown (**H**) and intermediate (**HD**) nodules showed unimodal distribution with 2-4 cm dominant size. Distribution pattern of nodule types and seafloor depth suggested that **H** and **HD** are particularly abundant in the northern part of the area and they found frequently within the shallower depth range of 3750 – 4000 m, while its **D** and **D_I** variety were correlated with more than 3995 m isobath. The complexity of bottom morphology reflects on delineation of nodule deposits as streaked (2-10 km wide) and extensive coating-shaped (up to 70 km wide and up to 120 km long) deposits bordered by nodule-free areas, volcanic massifs, and more seldom by less prominent tectonic structure (horsts and troughs). Investigated in this study spatial patterns in nodule coverage and abundance, variability of nodule types in relation to morphological characteristics of seafloor will enable a better understanding and prediction of circumstances responsible for formation of nodule deposits in the entire CCZ.

Effects of the structural-tectonic and volcanic processes on formation of polymetallic nodules in the CCZ

Ryszard Kotlinski, Valery Yubko, Valcana Stoyanova

Abstract

In order to understand the effects of geological processes in time and scale establishing the Clarion-Clipperton Fractures Zone (CCZ) itself on of the formation of polymetallic nodules, the relationship between seafloor tectonics, volcanic and hydrothermal activity, sediment composition and occurrence of polymetallic nodules is discussed. The general structure of the CCZ (between 115⁰W and 160⁰W) was formed in Oligocene-Miocene and in Late Miocene-Pliocene however the isochronous of the basement successively decreasing eastward from 90 millions year at 153⁰W to 20 millions year at 118⁰W and their trend is nearly parallel to the East Pacific Rise.

The seafloor lowering westward producing systematic increase of water depth from 3,800-4,200 m at 115⁰W to 4,800-5,200 m at 130⁰W, and to 5,400-5,600 m at 145⁰W; the complexity of the bottom relief consequence by the system of rises (Paleo East Pacific Rise, the Central and the Cooper Rise), depressions and fractures which mainly formed two orthogonal directions: Hawaiian Archipelago (with azimuth ~ 300°-315°) and “Ortho-Hawaiian” (azimuth ~ 30°-45°).

Volcanic activity, predominately associated with sub-latitudinal oriented fractures seems to be the most important sources for ore supply in nodule growth processes according to the results of the young (late Quaternary) basalt lava analysis from samples of the Shimada Seamount (16⁰50'N; 117⁰30'W). The prominent role in the processes of relatively young volcanogenic and hydrothermal activities in the area is pertaining to the Mahi-Mahi Fracture Zone (MMFZ), which is the most extended parallel to the CCZ structure. As an evidence of that suggestion are metalliferous sediments and flints detected within the MMFZ path with high contents of Fe, Cu, S, Ag, Ni, Co, Mn, Pb, and Zn.

The sediments cover in the CCZ has a thickness of 100-300 m and their facies exhibit a unidirectional gradient trending from predominant carbonate ooze in the southern part to predominant siliceous ooze and red clay in the west-northwest. This particularity of sedimentation process effects on prevailing distribution of hydrogenetically growth nodules in the north part of CCZ, whereas the diagenetically and diagenetic-hydrogenetically types mostly occur in their central and southern part. There are also unconfirmed latitudinal zonations of a variety of young (Pleistocene-Holocene) sediment facies and a pronounced surface unconformity of Middle Miocene age, denoting an interruption of the sediment accumulation, dislocation and erosion of the earlier cumulated sediments.

It is assumed that within a period of 15-10 MY the new geologic and morphostructural setting of the entire CCZ is established as results of the Middle Miocene unconformity and supported by filling in the sedimentary accumulation the post-erosion siliceous-argillaceous sediments. Those, in combination with the intra-plate volcano-tectonic and hydrothermal activity concentrated along the MMFZ seems to form the most favorable conditions for nodule formation within the entire CCZ area during the last 5 MY period.

BIOGEOCHEMICAL MODEL OF MN, NI, and CU CONTENT

Charles Morgan

This study evaluates the geographical distributions of nodule Mn, Ni, and Cu concentrations as functions of three proxy variables, chlorophyll concentration in surface waters (itself a proxy for primary productivity), the distance from the East Pacific Rise and the North American Continental slope, and the carbonate compensation depth (CCD). The hypothesis is that these metals in the Clarion-Clipperton deposits come primarily from terrigenous or volcanic sources to the east and are delivered to the deposit sites through incorporation into organic detritus that settles onto the seafloor.

To identify empirical relationships between metal content and these proxy variables we used non-linear regression methods. The statistic used to estimate the success, or fit, of the regression is the “corrected” R^2 . This statistic is the square of the Pearson correlation coefficient. It ranges between zero and one and approximately represents the fraction of variance of the dependent variable (in this case metal content) that can be accounted for by the regression equation. The results indicate that the best single predictive variable of the three is chlorophyll, which results in R^2 values for Mn, Ni, and Cu, respectively, of 0.49, 0.44, and 0.39. Slightly improved regression fits can be obtained using regression equations with various combinations of these three proxy variables. These results support the hypothesis that the Mn, Ni, and Cu concentrations in these deposits are related to the present-day primary productivity in the overlying surface waters.

REGIONAL EXAMINATION OF SEDIMENTS

Charles Morgan

The purpose of this study was to integrate the available information on surface sediments in the study area to examine the relationships between sediment type and nodule metal content and abundance. Data sets were provided to the study by three Contractors in the Area, including the French consortium Afernod, the Chinese consortium COMRA, and the multi-national consortium IOM. In addition, publicly available sediment data within the CCZ study area were downloaded from the U.S. National Geophysical Data Center (NGDC).

In order to investigate the relationships between the sediment type and nodule abundance and metal content, we interpolated a sediment type for each of the 0.1° grid points where nodule data are available. We then calculated the average metal content and abundance for each sediment type represented in the data set. The results generally confirm the qualitative conclusions noted by scientists for many years, i.e. that the highest abundances of nodules occur in the siliceous sediments and not in the calcareous sediments. However, somewhat surprisingly, siliceous, calcareous muds host the highest abundances, and the pure siliceous oozes host surprisingly low abundances.

Abstract
Review Report of the
“Development of Geological Models and Prospector’s Guide for the Clarion-Clipperton
Zone Polymetallic Nodule Deposits”

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December, 2009

The area between the Clarion and Clipperton Fracture Zones (called CCZ) has been the focus of much international attention for many years since it is there where obviously the largest and richest manganese nodule occurrences exist. The main task of the presented ISA reports is therefore to improve the ISA’s resource data bank and assessment for this CCZ region as well as to present the state of the art about the formation of these deposits.

The idea is that if assumed relationships between certain environmental and oceanographic data and nodule grade as well as abundance could be statistically tested, the results could be used as proxies for further high-grade nodule deposits in areas not yet studied in detail. However, this work hypothesis demands that there is a good and provable understanding of how economically interesting nodule deposits form.

With great mathematical effort approaches were made to establish the Geological Model for nodule growth and distribution in the CCZ. The respective algorithms are presented and described, the respective softwares are generally accessible and can be considered as well established tools. Several data sets (abundance and metal content) of polymetallic nodule deposits from different institutions or sources were used to carry out the modeling work. In order to be able to share the huge amount of data among the scientists working on the project, it was required to convert these data into a merged data bank which accommodates the proprietary aspects of the owners. The methods used to raise and process the merged data sets are described. Descriptive statistical variables were calculated to present the spread of the data.

Both volumes represent a very important undertaking since they summarize for the first time all knowledge about the CCZ area with regard to the abundance and grade of the manganese nodule deposits. Many features are well described and some highly interesting results are presented. The volumes can be distinctly improved by the mentioned changes and additions.