Genesis of Fe-Mn nodules in various Geo-chemical zones of Central Indian Ocean Basin

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Abstract

Oceanic Fe-Mn deposits occur mainly in 2-forms, as nodules and as encrustations. Nodules form a carpet on the deep-sea abyssal plains while encrustations occur as caps on seamounts. The samples are mainly obtained from the latitude 9.5ºS to 12º S and longitude 87º E to 89.5º E and water depth varying from 4,500 – 5,500 m. In the present study about 30 samples have been studied out of which 18 are in size class less than 4 cm and 12 are in more than 4 cm. The sample show considerable higher values for metals like Mn, Ni, Cu, Co and Zn and lower values for Fe, SiO_2, Al_2O_3, TiO_2, P_2O_5.The alkalise viz. Na_2O, K_2O, MgO also do not have very significant values. The study indicates that smaller nodules have higher metal concentrations and also that within the smaller nodules, those with rough surfaces are showing the higher metal values. The polished section of the nodules clearly indicates the presence of polynucleus and also very prominent fractures along with the distinct accretionary rings. The Diagenetic nodules have Mn/Fe ratio more than 5 while the hydrogenetic nodules have this ratio less than 2.5. The study area can be divided in to six Geo-chemical zones as follows

Zone 1: Carbonate dominant sediment with low Mn- Fe
Zone 2: Carbonate free siliceous sediment with high Al and Ba
Zone 3: Carbonate free siliceous sediment with high abundance of Mn nodule and low Al & Fe
Zone 4: Carbonate ooze with very low Fe, Al & Ti
Zone 5: Carbonate dominant red clays with high Mn
Zone 6: Terrigenous dominant sediments with very high Al, Ti & Fe

The bulk geochemical analysis for nodules for Mn/Fe (2.38 to 3.66) and Cu + Ni (1.99 to 2.46) suggest the uniformity of regional geochemical conditions. This ratio of Mn/Fe indicates that the nodules are of mixed origin i.e. authigenitic as well as diagenetic. The inter element association distinctly forms two groups i.e. Mn-Cu-Ni-Zn and Fe-Co-Pb. The correlations of Ni, Cu and Zn with Mn indicate that these elements are concentrated in Mn minerals. XRD pattern reveals that most of the Ni rich nodules contained todorokite (10Aº manganite) rather than ẟ MnO_2 (7Aº manganite) as their principal mineral phase, and in these nodules the association Ni, Zn and Cu with Mn probably results from the ability of Ni^{2+}, Cu^{2+} and Zn^{2+} ions to replace Mn^{2+}in todorokite. The Mn poor variety i.e. ẟ MnO_2 (7Aº manganite) is also recognised in larger nodules. It is identical with birnessite. Fe occurs mainly as goethite. The mineralogy of Mn phase in nodules is an important determinant of their minor element composition; nodules containing todorokite contain more Cu, Ni and Zn. The mineralogy of the nodules is governed by the environment of formation together with chemistry rather than the water depth only.

The influence of diagenesis or biogenic components has an important role in the genesis of these nodules. Mn, Ni and Cu are derived from the sediment pore water which contains higher concentrations of these dissolved metals caused by early diagenetic remobilization. The inter element relationship between Mn, Ni and Cu reflects a balance between the release of Ni Cu from biogenic phase and reduction remobilization of Mn oxides. The Co correlation with Fe is a result of adsorption and oxidation of Co^{2+} to Co^{3+} on the ferric hydroxide silicate particles.

The Mn/Fe ratio and the various ternary diagrams (Cu + Ni + Co) ×10 – Mn – Fe ; Cu – Zn – Ni ; Al – Mn – Fe and Si – Mn – Fe suggest that these nodules belongs to typical nodules oxide – hydroxide field and is hydrogenetic. The association of Cu, Ni and Zn with Mn is primarily controlled by their strong correlation with the latter, i.e. 0.92, 0.90 and 0.72 respectively, whereas that for Co and Pb with Fe is controlled by their strong correlation with Fe, i.e. 0.92 and 0.78 respectively.

Chemical partitioning technique accurately discriminates Mn rich mineral and the minor elements associated with it; from Fe rich minerals and the minor elements associated with it. This experiment envisages two coexisting phase viz. Mn – Ni – Cu and Fe – Co – Zn. The occurrence of phillipsite indicates slow sedimentation and indicates its origin to both as final alteration product of sea floor basalt and also as authigenic precipitation. The decreasing Mn/Fe ratio and intensity of todorokite towards larger nodules suggest that the smaller nodules are prone to increasing influence of early diagensis than the larger ones.

Keywords: Central Indian Ocean Basin, Fe-Mn Nodules, Geo-Chemical zone, Genesis