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Element distribution in Pacific polymetallic nodules from the Clarion-Clippertone Fracture Zone, Pacific Ocean

R.A. Kotlinski (1), J. Ciesielczuk (2), and J. Zaba (2)

(1) University of Szczecin, Interoceanmetal Joint Organization, 9 Cyryla i Metodego, 71-541 Szczecin, Poland, (2) University of Silesia, Faculty of Earth Sciences, Poland (justyna.ciesielczuk@us.edu.pl)

Oceanic polymetallic nodules PN show enrichement in Ni, Co, Cu, REE and in Mn and Fe. These elements are used as geochemical indicators of geological processes. The geological evolution of the nodule-bearing oceanic area within the Clarion-Clippertone Fracture Zone (CCZ) is unique with regard to geodynamic activity, age, structure, rate of subsidence, nature of sedimentary cover, depth of nodule formation, configuration of the oceanic floor, Carbonate Critical Depth (CCD) and biological productivity. Detailed geological-geophysical investigations in the CCZ by the Interoceanmetal Co. reveal differences in the distribution, mode of occurrence and in metal concentrations in PN. The aim of our study was to define the distribution of elements within single nodules of hydrogenetic-, hydrodiagenetic- and diagenetic types and to reveal any dependence between the composition of the nodules and their origin and growth. Their internal structure and composition was determined by optical microscopy, scanning SEM+EDS, XRD and electron microprobe EMPA.
The hydrogenetic nodule examined comprises a nucleus ∼5 mm in diameter surrounded by concentric Mn-Fe layers of total thickness ∼8 mm that represent 2 generations. The hydrodiagenetic nodule has a nucleus (∼10 mm) enclosed by 3 generations of layers (∼14 mm). The diagenetic type comprises of nucleus (∼4 mm) with a Mn-Fe envelope ∼24 mm thick. The nuclei are typically cut by 5-30 micrometres thick mineralized veins.
Microprobe chemical analyses were performed on all of the distinct growth generations and on veins in the nuclei. On the basis of bulk chemical analyses, the following elements were confirmed in the nodules: FeO, MnO_2, $Nd2O_3$, $V2O_3$, CoO, NiO, CuO, ZnO, Na2O, MgO, K2O, CaO, TiO_2, Cl, SO_2, MoO_3, P2O5, BaO, $La2O_3$, $Ce2O_3$, $Al2O_3$, SiO_2 and $Y2O_3$.
Manganese is the dominating element in all parts of all of the nodules. Average contents are similar in the hydrogenetic-, hydrodiagenetic- and diagenetic nodules, but there are differences in its distribution between growth generations. The oldest generation and veins cutting the nuclei display the highest MnO_2 concentrations whereas iron and cobalt is mainly concentrated in the youngest generations. Copper and nickel concentrations, decreasing with nodule growth, show positive linear correlations with manganese. Vanadium and zinc contents remain constant. With the growth of the nodules, there is an increasing tendency for CaO, TiO_2, Cl, SO_2 to correlate inversely with Na2O, MgO, K2O. Cerium, the only REE above the detection limit, is concentrated in nodules of hydrogenetic- and hydrodiagenetic origin – mainly in the first generation and in veins cutting nuclei. The content of $Nd2O_3$, MoO_3, $La2O_3$ and $Y2O_3$ is below the EMPA detection limit.