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Enrichment of mobilizable manganese in deep sea sediments in relation to Mn nodules abundance

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The Clarion-Clipperton-Fracture Zone located in the northern Central Pacific is a promising area for future Manganese nodules mining. Yet, nodule abundance varies within tens of meters within a prospective field. However, economic nodule mining requires a detailed knowledge of nodule distribution and its controlling factors. In order to examine factors controlling occurrence, size, composition, and formation of ferromanganese nodules, selective leaching experiments of sediments from 37 box cores were carried out. Data was compared to XRF analysis of the bulk composition of the sediments, grain size distribution, scanning electron microscope (SEM) analysis of sedimentary components and total organic carbon measurements. To interpret local variations of the sediment geochemistry other influencing factors have been taken into account such as hydrodynamic conditions, seafloor topography and sedimentation rates of the sampling sites.

Due to recent oxic conditions at the seafloor manganese is accumulated in its insoluble oxidized form (Mn^{4+}) and nodules grow slowly and predominant by hydrogenetic precipitation. However, suboxic diagenesis prevailed periodically in the past during which Mn^{4+} got mobilized, leading to enhanced nodule growth and depletion of Mn within the sediment. First results of our leaching approach indicate that more than 80% of the total manganese is bound as Mn^{4+}-oxide in the near surface sediments decreasing with depth to $\sim$50 % in average. Base metals such as Ni and Co are strongly associated with Mn therefore following the same leaching pattern. However, under the conditions of suboxic diagenesis Fe is not mobilized. Different types of Mn^{4+} / Mn_{total} and C_{org} profiles can be distinguished and correlated to nodule abundance, even if concentration-depth profiles of C_{org}, Mn^{4+} and Mn_{total} are highly variable. However, some prominent features are common varying with depth, probably indicating variable hydrodynamic conditions.

In general, cores without or with very low nodule abundance show low Mn_{total} concentrations, a constant decrease of the total and mobilizable Mn_{4+} with depth and no or only slight degradation of C_{org}, indicating oxic conditions. In contrast, cores with a high coverage are in general characterized by large nodules, high Mn_{total} concentration and a strong depletion of mobilizable and Mn_{total} within the upper cm, primarily followed by an increase or steady concentration.

Cores from the south-eastern part of the research area show a pronounced carbonate peak at 19-28 cm bsf. which may correlate to the last glacial maximum (LGM). SEM analysis indicates a high content of well preserved foraminifers. Within this layer no Mn micro nodules are found. However, micro nodules are found above this layer associated with a strong increase of leachable Mn_{4+} and siliceous microfossils. Therefore, it is assumed that the last major mobilization event took place at the LGM. Increasing abundance of micro nodules towards the top indicate oxidized top layers and fixation of mobilized Mn_{2+} migrating upwards.

Our data indicate that nodule abundance depends on the combination of mobilizable Mn_{4+} concentration, Mn_{total}, C_{org} concentration and degradation as well as mobilization intensity. However, local variations may be caused by hydrodynamic conditions, sediment properties and the intensity of sediment accumulation or erosion.