Significances of 12 Ma manganese ores in the Hokuroku district, Akita: unique Mn accumulation and interaction with organic matter during submarine hydrothermal activities

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Various Mn ores are found in the Hokuroku district in Akita through the course of the present study. Stratified and veined Mn ores, which lengths are up to 10 cm, are formed during volcanic recession periods (less than 1 Ma) with associated with carbonaceous sediments and local hydrothermal systems. Such short-term precipitation of “pure” Mn ores is unusual, compared to normal Fe-Mn nodules or crusts. In order to understand detailed mechanisms, in particular, role of organic matter, of Mn ore formations, we performed standard mineralogical characterization, magnetic field analyses and oxygen isotope analyses on Mn ores. The first type of Mn ores appear on mudstone and veins in hydrothermally altered hyaloclastite of rhyolite lavas. Detailed geological and geochemical studies revealed that local submarine hydrothermal processes mobilized Mn and Fe in host rocks, Fe-oxides were precipitated first and then discharged Mn were precipitated as oxides (rhodonite and todorokite) on mudstone. $\delta^{18}O_{SMOW}$ value of Mn oxide is + 7.7‰ showing the precipitation temperature less than 112 C. Mn carbonate (rhodochlosite and kutnohorite) also appears in the same region. $\delta^{13}C_{PDB}$values of Mn carbonate were -21‰ (PDB), suggesting interaction with organic matters during intrusive activities of later rhyolite. The second type of Mn ores appear as veins in rhyolitic tuff or stratified lenticular forms with mud/tuffs. Ca. 30 μm colloform structures consisted of organic matter and Mn oxides can be observed. Major Mn mineral in these second type is todorokite. $\delta^{18}O_{SMOW}$value of second types of Mn ores is + 8.5‰ indicating low temperature precipitation of Mn oxides less than 101 C. Magnetic field was detected on Mn oxides in colloform structure by magnetic field microscopy (MFM). Such magnetic fields indicate high cation vacancies and abundance of Mn^{4+}, which are common in biogenic Mn oxides. Formational processes of both Mn ores provide new insight of the unique formational process of Mn ores, especially geological separation from $Fe^{2+}$and interaction with organic matter, in hydrothermal systems at the subseafloor on felsic volcanic setting. Further, this study indicates that low temperature (<100 C) hydrothermal activities can form the Mn ores with high precipitation rates.

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