

Nanomineralogical Evidence of Microbial Formation of Deep-Sea Ferromanganese Crust

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Since the Late Paleocene, ferromanganese crust (Fe-Mn crust) has been deposited extensively on the surface of seamounts or plateaus at 400 to 6000 meters below sea level (mbsl) with a thickness range of 1 to 20 cm. Although cosmogenic nuclide and paleomagnetic dating unambiguously revealed the exceedingly slow growth rates (1 to 10 mm/Myr), the formation process of Fe-Mn crusts is poorly understood. Mn(II) oxidation to Mn(III) is mediated by superoxide formation by oxygen respiration by microbes, whereas Mn(III) oxidation to a Mn(IV) oxide phase is kinetically hindered by a reverse reaction by peroxide produced aerobically in oxygenated circumneutral seawater. Microbial consumption of peroxide is speculated to be involved in the formation of Fe-Mn crusts, but no direct evidence has been presented to date. In this study, the surface of Fe-Mn crust obtained from a depth of 3000 mbsl at Takuyo Daigo Seamount was characterized by a confocal laser microscope, and the dense colonization of microbial cells stained by SYBR Green I was observed on the crust surface. An ultrathin section fabricated by focus ion beam (FIB) was characterized by a transmission electron microscope (TEM) equipped with energy dispersive spectroscopy (EDS). TEM-EDS analysis revealed that microbial cells were enrobed in Fe- and Mn-bearing precipitates. Selected area electron diffraction (SAED) patterns showed that Fe- and Mn-bearing precipitates were amorphous or poorly crystalline. High-Angle Annular Dark Field Scanning TEM (HAADF-STEM) analysis of Fe- and Mn-bearing precipitates around microbial cells and inside the Fe-Mn crust demonstrated that the compositions and nanomineralogical features were identical. It is therefore suggested that the formation of Fe-Mn crust is mediated by microbial activities on the crust surface.

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