MARINE SEDIMENTATION AND MANGANESE NODULE FORMATION

IN THE SOUTHWESTERN PACIFIC OCEAN

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ABSTRACT

An extensive field of iron-rich, nickel- and copper-poor manganese nodules covers the deep sea-floor of the northeastern quadrant of the Southwestern Pacific Basin, and the eastern side of the Samoan Basin. The nodule field has a relatively well-defined western boundary, the location of which is determined by differences in sedimentation regimes. Immediately east of the Tonga-Kermadec volcanic arc and New Zealand, as well as around Rarotonga (Cook Islands) and the Samoan chain, rapid accumulation of volcanic ash and microfossils has buried potential nodule nuclei before significant ferromanganese oxide encrustation could occur. Further east, where sedimentation rates are lower, the nodule field has developed. The nodules occur almost exclusively on medium to dark brown silty clays which contain a significant proportion (5-15%) of red-brown semi-opaque oxides (RSO's). The brown silty clays consist principally of phyllosilicates (illite, montmorillonite, chlorite and kaolinite) plus subsidiary quartz and feldspar. Microfossils are generally rare, but all of the brown silty clays contain trace quantities of calcareous nannofossils.

On the basis of nodule morphology, internal structure and composition, two nodule facies can be recognized in the area--the Cook Island Facies and the Southwestern Pacific Basin Facies. Nodules of the Cook Island Facies are characterized by (a) spheroidal and faceted spheroidal nodule shapes; (b) rough microbotryoidal surface textures; (c) an internal structure consisting of a thin (1-2 mm) Fe-Mn oxide accretion crust overlying a massive, burrowed Fe-Mn oxide subcrust and a volcanic nucleus

in some state of alteration and replacement; (d) Mn/Fe ratios near or below one; (e) low Ni and Cu contents; and (f) δ-MnO_2 as the principal manganese phase. The Southwestern Pacific Basin Facies (from the southeastern corner of the study area) is characterized by (a) polynucleate nodule shapes; (b) botryoidal to rough microbotryoidal surface textures; (c) an internal structure consisting of Fe-Mn oxide layers interspersed with silicate microlaminae, and no discrete nucleus; (d) Mn/Fe ratios above one; (e) high Ni and Cu (and low Co) contents; and (f) todorokite and δ-MnO_2 together making up the manganese phase.

The nodules have formed by both ferromanganese accretion and replacement processes at available nucleus sites. The existence of a megascopic nucleating object which remains at or just beneath the sediment-water interface is essential for nodule initiation. The emplacement of prospective nodule nuclei in the study area has probably involved the deposition, partial consolidation, and breakup of hyaloclastite layers. Burrowing of the hyaloclastite by tiny benthic organisms facilitated later chemical replacement and infilling processes. Accretion of Fe-Mn oxides from seawater and interstitial water onto hyaloclastite fragments was accompanied by alteration of the hyaloclastite to montmorillonite and phillipsite, along with chemical replacement of some of the hyaloclastic material by Fe-Mn oxides, and the filling of nucleus interstices by authigenic silicates and Fe-Mn oxides. Volumetrically, these replacement processes occurring within the nucleus have been more significant than accretion in accumulation of ferromanganese oxides in southwestern Pacific nodules. The replacement zone is more Mn-, Ni-, and Cu-rich than the Fe-rich outer accretion layer.