# CHEMISTRY AND MORPHOLOGY OF DEEP-SEA MANGANESE NODULES AND THE SIGNIFICANCE OF ASSOCIATED ENCRUSTING PROTOZOANS ON NODULE GROWTH

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN OCEANOGRAPHY

AUGUST 1976

By

Brent K. Dugolinsky

Dissertation Committee:

Stanley V. Margolis, Chairman
Keith E. Chave
Peter M. Kroopnick
Johanna Resig
Samuel M. Savin

# ABSTRACT

Scanning electron and light microscopic examination and x-ray spectroscopic analysis of deep-sea manganese nodules from the Northeast Equatorial Pacific have revealed that portions of nodules above the sediment layer display hard, smooth surfaces that are enriched in Fe and depleted in Mn, Ni and Cu relative to buried surfaces which exhibit friable, rough to gritty textures. Nodule surfaces within a few centimeters of the sediment-water interface display very rough protuberances, highly variable chemical compositions, and evidence of relatively rapid growth. Manganese nodules from other areas of the Pacific and from the Southern Ocean display more uniform morphologies and it is usually impossible to distinguish upper and lower surfaces, either physically or chemically.

Bulk x-ray fluorescence analyses of nodules demonstrate relatively consistent chemical compositions over broad regions of the sea floor whereas electron microprobe investigations reveal that individual laminations within single nodules can have widely varying compositions. High Mn, Ni and Cu concentrations within nodules are associated with dense and highly reflective zones lacking biogenic inclusions. Both bulk chemical analyses and microprobe analyses reveal a stronger inverse correlation of Ni and Cu enrichment with Fe than a direct correlation with Mn.

Attached protozoans, including several previously undescribed species of agglutinating foraminifera, contribute to the growth of nodules. Their tests, composed of a wide variety of agglutinated organic

and inorganic sediment particles, become incorporated into the nodule matrix during nodule growth. Nodule surfaces that internally exhibit evidence of most rapid growth are most densely covered with these protozoans. The greatest species diversities and population densities of these animals encountered thus far have been on Cu and Ni enriched nodules from the Northeast Equatorial Pacific. Changes in surface water productivity can alter the flux of particulate nutrients brought to the sea bottom. This may affect the population density of benthic life forms and, indirectly, the growth of deep-sea manganese nodules.