

## Abstracts of Additional Hard Mineral Session Papers

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### Geochemistry of Manganese Deposits of Nicoya Ophiolite Complex in Costa Rica

**Sunit Kumar Addy**  
*Arco Exploration Company*  
*Tulsa, Oklahoma*

**Eric P. Kuypers**  
*Ciudad Universitaria*  
*Costa Rica*

Numerous small manganese deposits have been reported from the Nicoya ophiolite complex in Costa Rica. These deposits are primarily of two types: (1) deposits occurring in radiolarites consisting of laminar units of alternating radiolarite and manganese oxide and overlying manganese crusts which grade into nodular concretions, and (2) deposits occurring as stockworks of veins of manganese oxides within silica lenses (up to 16 × 328 ft [5 × 100 m]) in basalt. The two types occur in different nappe units of Lower and Upper Cretaceous ages.

Geochemical and X-ray analyses of the deposits indicate the following: (a) they show low nickel, cobalt, and copper (total > 0.5%) and low iron/manganese ratio (> 0.1) like the Mid-Atlantic Ridge deposits; (b) iron/manganese in a few basaltic deposits ranges from 0.1 to 0.9; (c) concentrations of rare earth elements (REE) and the shale normalized rare earth elements patterns of the deposits are similar to those found in tholeiitic basalt; (d) absence of cerium enrichment is commonly observed in manganese nodules; (e) higher rare earth elements and copper and lower silica occur in nodular concretions than in other radiolarian deposits; and (f) braunite and pyrolusite as predominant minerals.

These facts, along with other geologic evidence, suggest that the manganese deposits are hydrothermal precipitations and are related to sea-floor spreading processes during Cretaceous time. The laminar units were formed as the fractionated manganese-rich hydrothermal solutions passed through the radiolarian oozes. The crust was formed directly above the main emanation centers and the nodular concretions possibly grew away from the source. Basaltic deposits were formed at various stages of fractionation of the hydrothermal solutions, resulting in deposits of varying chemistry.

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