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Banded Iron Formations: Geochemical and Stratigraphic Markers of Ore-Forming Processes?

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Algoma-type Banded Iron Formation (BIF) is a common lithology in Archean greenstone belts. They are products of slow chemical sedimentation of iron-oxyhydroxide-silica gel during breaks in volcanic activity when contemporaneous volcanogenic massive sulfide deposits (VMS) could form. However, the origin of Algoma-type BIF, its relationship to ore-forming hydrothermal systems, and controls on the timing and stratigraphic position in the depositional basin and the host volcanic sequence are commonly not well constrained. One model favours a biogenic origin and rhythmic changes in physicochemical conditions to account for the characteristic Fe- and Si-rich banding. Another considers the Fe and Si to be direct precipitates from hydrothermal vents (so-called "exhalite"), often along strike from VMS deposits.

A detailed mineralogical and geochemical study of one of the type-localities of Algoma-type BIF, in the 2.73 Ga Temagami Greenstone Belt, provides direct evidence of primary deposition as a water-saturated gel, followed by diagenetic sorting, recrystallization, and replacement to produce the distinctive hematitic chert (jasper) and magnetite bands. The internal layering is a product of an initially homogenous Fe-Si gel that underwent compaction and dewatering, mobilizing Si to the uppermost layers of the sedimentary package and leaving Fe behind. Early-formed nanophase hematite was progressively recrystallized to magnetite, with some layers of primary hematite preserved in quartz and individual crystals of magnetite showing original Si-rich cores. Trace element signatures of the BIF layers were previously interpreted in terms of changing hydrothermal input (e.g., elevated Ge/Si ratios in magnetite layers and smaller La, Eu, and Y anomalies and more abundant REE in magnetite compared to chert layers). We interpret these signals to reflect preferential incorporation of Ge in magnetite during diagenetic growth and the inheritance of REE from early authigenic apatite contained in the original jasper layers, rather than signals of direct hydrothermal input. Metal concentrations in the hematitic and magnetite layers are orders of magnitude lower than in similar BIF associated with VMS mineralization. There are few indicators of undiscovered VMS deposits proximal to the Temagami BIF. Instead, the trace element geochemistry suggests Temagami BIF deposition in an open ocean environment influenced by distal hydrothermal sources and providing a large reservoir of REE and other components with long residence times, as opposed to localized, direct hydrothermal input. We suggest that Algoma-type BIFs represent a continuum of deposit types from VMS-related “exhalites” to “open ocean” deposition, and the distinction (including the different behaviour of Ge, REE, and transition metals) provides a useful tool in exploration.