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Physical Controls Associated with the Distribution of Sulfides in the Voisey's Bay Ni-Cu-Co Deposit, Labrador

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Abstract

The Voisey's Bay Ni-Cu-Co sulfide deposits occur within troctolites and olivine gabbros of the 1.34 Ga Voisey's Bay intrusion, formerly known as the Reid Brook Intrusive Complex. The Voisey's Bay intrusion is the oldest known member of the predominantly anorthositic Nain Plutonic Suite, which straddles the ca. 1.85 Ga suture between Archean gneisses of the Nain province to the east and Paleoproterozoic rocks of the Churchill province to the west.

The Reid Brook, Discovery Hill, Mini-Ovoid, and Ovoid zones are mineralized domains within a subvertical conduit dike system that appears to span between two large troctolite intrusions, the Eastern Deeps chamber and the lower Western Deeps chamber. The conduit trends east-west and extends from near the top of the Western Deeps chamber, at a depth of 700 m, toward the north margin of the Eastern Deeps chamber close to surface.

All the mineralized zones in the Voisey's Bay deposits occur as magmatic-textured sulfides associated with fragment-bearing troctolites and olivine gabbros related to the conduit dikes, rather than simply as basal accumulations at the floor of the chambers. Sulfides within the system are preferentially concentrated in traps where physical irregularities and changes in conduit morphology favor the precipitation, capture, and preservation of sulfides as a result of changes in the velocity and viscosity of a magma. There is a consistent relationship between different sulfide textures and the physical environment existing in the conduits where each of the mineralized zones occurs. This suggests that sulfides were deposited in their present sites by consistent magmatic processes within the conduits but were locally influenced by the physical parameters existing at these sites. Later remobilization or mass movement of sulfides would not generate the consistent textural relationships observed. Therefore, sulfide deposition is ultimately related to a complex interplay of dike geometry (i.e., changes in dike orientation and thickness) and the fluid dynamics in the fragment-bearing magma within a conduit system, i.e., the Ovoid mineralization appears to fill a bulge in the conduit, and the Reid Brook zone is located close to the axis of inflection along its strike. The Eastern Deeps zone, although it does occur at the base of the Eastern Deeps chamber, is more specifically associated with the line of entry for the feeder conduit close to a structural low at the base of the Eastern Deeps chamber.

The Voisey's Bay deposit does not conform to the traditional model for magmatic sulfide generation such as Sudbury, in which sulfides accumulate largely by gravitational settling within a magmatic chamber, following attainment of sulfur saturation as a result of local assimilation. In fact current evidence suggests, in the Eastern Deeps mineralized zone, that little gravitational settling took place because a large proportion of sulfides occur as high Ni tenor minerals trapped interstitially in sulfides in coarse phases of the variable-textured troctolite. Furthermore, sulfide saturation and generation of magmas with varying sulfide contents clearly appear to have occurred in chambers at a depth of several kilometers, rather than at the levels currently exposed. In contrast to gravitational settling, sulfide distribution within the Voisey's Bay deposit is controlled by magma emplacement through multiple braids of a dynamic, channel-like conduit dike system.