

Threading the Eye of the Needle: Lessons from the Search for Another Voisey's Bay in Labrador, Canada

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Abstract

Magmatic sulfide mineralization is present in three of the four compositional groupings in the Mesoproterozoic Nain Plutonic Suite and in compositionally similar Paleoproterozoic rocks. Anorthosite-hosted mineralization appears to be spatially linked to small gabbro bodies, where sulfide liquids separated from silicate magmas to variable degrees, depending on the wall-rock conditions. Sulfide metal contents are low (0.2–1.0% Ni) and the Ni/Cu ratio is variable, although sulfide Ni values remain fairly consistent within individual occurrences. Pyroxenite-hosted mineralization is essentially restricted to minor intrusions, and locally, has higher sulfide metal contents (up to 2% Ni) and less variable Ni/Cu. There are similarities between pyroxenite- and anorthosite-hosted mineralizations, and they may form part of a broad continuum. Ferrodiorite-hosted disseminated sulfide mineralization is associated with abundant iron oxides, and typically, has low amounts of Ni in the sulfide (<0.5%), and Ni/Cu <<1. Gabbro-troctolite-hosted mineralization contains the most variable and metal-enriched sulfides, containing from 1 to 7 percent Ni, and showing consistent Ni/Cu = 1. The best examples are associated with the Voisey's Bay intrusion (dominantly troctolite) and the Pants Lake intrusion (dominantly olivine gabbro). Significantly, these are the only Nain Plutonic Suite mafic intrusions that were emplaced into or in close proximity to sulfide-bearing paragneisses; exploration of gabbroic and troctolitic rocks within Archean orthogneisses has not yet revealed significant mineralization. The Pants Lake intrusion has intriguing geologic similarities to the Voisey's Bay intrusion and supports some aspects of genetic models for the latter. However, it has lower sulfide Ni contents (around 2%) and relatively elevated Cu and Co, suggesting differences in the source magmas and/or conditions of sulfide segregation.

The different styles of mineralization can be integrated with petrogenetic models for the Nain Plutonic Suite and similar plutonic suites. Anorthosite-hosted sulfide mineralization is interpreted to be derived from residual mafic magma that coalesced and migrated during ascent of semicrystalline anorthositic magmas, and ferrodiorite-hosted mineralization is interpreted to be derived from late Fe-enriched differentiates of deep-seated mafic chambers. In both cases, the source magmas were fractionated, which limits their potential for metals. Crustal sulfur from paragneisses may have played a role in sulfide saturation in both cases but does not appear to be a critical ingredient. Some pyroxenite-hosted mineralization is akin to anorthosite-hosted types, but other examples may be linked to silicic contamination of more mafic magmas. Gabbro-troctolite-hosted mineralization is associated with mafic magmas that rose from deep crustal chambers prior to extensive fractionation; these were richer in Ni, Cu, and Co when they ascended into the upper crust. Sulfide-bearing paragneisses apparently played a critical role in inducing sulfide saturation in the magmas. The lessons from the search for nickel in Labrador are mostly familiar from other areas; the regional metallogeny of the Nain Plutonic Suite underlines the critical roles of a relatively unevolved host magma and crustal contamination processes, possibly involving addition of externally derived sulfur. It emphasizes the importance of identifying and prioritizing these two key factors in the exploration of similar anorthosite-dominated plutonic suites elsewhere in the world.