

## Origin of Cu-Ni-PGE Sulfide Mineralization in the Partridge River Intrusion, Duluth Complex, Minnesota

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### Abstract

Four subeconomic Cu-Ni-PGE sulfide deposits occur near the base of the Partridge River intrusion, a mafic layered intrusion emplaced along the northwestern margin of the Duluth Complex. The host troctolitic rocks are in contact with sulfide-bearing metasedimentary rocks of the Virginia Formation. The origin of the sulfide mineralization has generally been linked to contamination of the mafic magma through partial assimilation of the argillaceous country rocks.

Three main types of sulfide mineralization have been recognized within the four deposits. These are (1) PGE-poor disseminated sulfides; (2) PGE-rich disseminated sulfides; and (3) semimassive to massive sulfides. The PGE-poor disseminated sulfides typically occur within the lower 250 m of the intrusion and are hosted mainly by heterogeneous norite and olivine gabbro, both of which contain abundant country-rock xenoliths. This type of mineralization shows numerous features, such as high proportions of pyrrhotite and arsenide minerals and high Cu/Pd, Ni/Pd, and Cu/Pt ratios, which suggest that the magma had undergone substantial contamination. These sulfides appear to have formed at low to moderate ratios of silicate magma to sulfide melt (mean  $R$  factor = 600–2,400), as deduced from their metal-poor nature. The PGE-rich disseminated sulfides occur well within the intrusion directly beneath ultramafic layers and show little signs of contamination. They are composed mainly of chalcopyrite and pentlandite, with lesser amounts of pyrrhotite and cubanite. They appear to have formed at high  $R$  factors (mean = 6,000–7,700), which explains their relatively high PGE and base metal contents. The semimassive to massive sulfides occur mainly as veins and lenses both along the basal contact and within the underlying sedimentary country rocks. They are typically zoned, being composed of both pyrrhotite-rich (Fe-rich) and chalcopyrite-cubanite-rich (Cu-rich) portions, the latter often forming along the base or top of massive sulfide bodies. The zonation in the massive sulfides is interpreted to be the product of fractional crystallization of a sulfide melt, the pyrrhotite-rich sulfides representing the cumulate of this crystallization and the Cu-rich sulfides the fractionated liquid.

Based on the above evidence, we interpret the compositional variations observed between the different types of sulfide mineralization to originate from the combined action of three different processes that operated in sequence from magma emplacement until complete crystallization of the sulfides. These processes are (1) country-rock assimilation; (2) interaction between the sulfide melt and the silicate magma ( $R$  factor); and (3) fractional crystallization of the sulfide melt.