

Controls on PGE Mineralization in the Lac des Iles Intrusive Suite: Insights from Trace Element Geochemistry and $\delta^{34}\text{S}$ in Sulfides

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The Lac des Iles Intrusive Suite (LDI-IS) comprises a ~30 km ring-shaped array of Neoproterozoic mafic-ultramafic intrusions in northwestern Ontario, Canada. These intrusions host variable palladium-bearing sulfide mineralization, including the mine block intrusion of the world-class LDI mine. While the LDI intrusions have been extensively studied, the coeval mafic intrusions of the LDI-IS have received comparatively little attention. This study integrates mineralogical characterization, with in situ trace element chemistry (LA-ICP-MS) and sulfur isotope analysis (SIMS) of base metal sulfides to: (1) characterize ore mineral assemblages; and (2) understand the petrogenesis of individual intrusions and their context within the LDI-IS.

Sulfide assemblages of the LDI-IS show a continuum from primary magmatic ores of pyrrhotite-pentlandite-chalcopyrite-pyrite to weakly altered pyrite-chalcopyrite \pm millerite. Palladium concentrations are typically <2 ppm, except for pentlandite from the Wakino Lake intrusion, which averages 726 ppm Pd. These values are comparable to mineralized LDI orebodies (e.g., the B2 zone, where pentlandite averages ~1000 ppm Pd). Sulfide S/Se ratios across the LDI-IS range from ~2000–4500, are within, or slightly lower than, mantle range (~2850–4350). The Dog River and Legris Lake intrusion sulfides display elevated S/Se ratios (22000 and 30500, respectively), suggesting an additional sulfur input. However, all $\delta^{34}\text{S}$ values from the LDI-IS lie predominantly within the mantle range ($\delta^{34}\text{S} = 0 \pm 1\text{‰}$).

Sulfides in the LDI-IS are magmatic with monosulfide generation playing a key role in Pd enrichment. The sulfide mineralization across the LDI-IS records a range of processes that collectively influence PGE mineralization. These processes include early sulfur saturation, high but variable R factors from fluctuating volumes of magma fluxing through local structures, and localized hydrothermal upgrading. This study of genetically related, yet variably mineralized intrusions provides important insight into the petrogenesis of the LDI-IS and the processes responsible for the exceptional Pd-PGE endowment at LDI.