THE LAC DES ILES PALLADIUM DEPOSIT: MINERALIZATION DURING REPEATED INJECTIONS OF VOLATILE-RICH MAFIC MAGMAS. J.G. Hinchey¹, K.H. Hattori², and M.J. Lavigne³, ¹,² Department of Earth Science, University of Ottawa, Ottawa, Ontario, Canada, K1N 6N5. Corresponding author e-mail: jhinc333@science.uottawa.ca, ³ Independent Consultant.

The Lac des Iles Palladium mine in northwestern Ontario represents the only primarily Pd-based mining operation in Canada with the geological reserves of 163.8 Mt ore with an average grade of 1.55 ppm Pd[1] (production plus reserves with cut-off grade of 1.1 g/t Pd for open pit operation and 3.5 g/t Pd for underground operation). The deposit is hosted by the 2.69 Ga Lac des Iles mafic-ultramafic intrusive complex in the Wabigoon Subprovince of the Canadian Superior province (Fig. 1).

Fig. 1: Simplified map of the Superior province illustrating location of the Lac des Iles deposit.

The intrusive complex is divided into three bodies consisting of the ultramafic North Lac des Iles Intrusion, the gabbroic Mine Block Intrusion, and the Camp Lake hornblende gabbro [2]. All economic mineralization discovered to date, including the Roby, Twilight, and Baker zones, is hosted by the Mine Block Intrusion (Fig. 2).

Fig. 2: Simplified geology of the Mine Block intrusion illustrating the location of ore zones.

The mineralization is characterized by high Pd compared to other PGE (Pd/Pt ≈ 8.5, Pd/Ir ≈ 7720 for samples from the southern Roby and Twilight zones) and low sulphide contents, 3 to 5 vol. %. Host gabbroic rocks range from early leucocratic to late melanocratic-clinopyroxenitic rocks and show complicated textures, such as the occurrence of pods of pegmatite, breccias and magma mingling. Detailed mapping of the southern Roby (1:20) and Twilight zones (1: 60) revealed that the early leucocratic rocks are essentially barren and that the bulk of the PGE was introduced by a series of late, melanocratic rocks. The contents of PGE and Au show positive correlations with base metals and S, suggesting primary magmatic mineralization where PGE were concentrated in immiscible sulphide melt in the parental magmas. This is supported by the exsolution texture of sulphides (Fig. 3). Based upon low, flat normalized REE, and high Se/S ratios, 690 ± 209 x 10⁻⁶, of sulphides in the ore compared to the mantle values (230-350 x 10⁻⁶), the magmas are interpreted to have formed through high-degrees of partial melting in a depleted mantle.

Fig. 3: Primary magmatic sulphide bleb illustrating exsolution textures from the southern Roby zone.

The mine contains the volumetrically minor (< 7 % of the deposit), yet economically important High Grade zone, which is on the eastern margin of the main Roby zone abutting an earlier solidified, barren East Gabbro. The High Grade zone is characterized by abundant pyrite and intense alteration of silicate minerals, forming talc, actinolite, chlorite, anthophyllite, hornblende, and sericite. Pods and veins of pegmatite commonly contain blue quartz. The mineralized samples plot outside the well defined correlation lines formed from the Roby and Twilight Zones on the diagrams of S versus PGE, S versus base metals, and
S versus Se. The scatters from the High Grade zone are attributed to hydrothermal enrichment of Pd and the gain and loss of S. The proposed interpretation is supported by the occurrence of sulphides along cleavage of secondary amphiboles in the ore and moderate enrichment of Pd and alteration in adjacent East Gabbro. The presence of quartz-bearing pegmatite, its localization along a competent earlier gabbro, and the lack of any apparent fluid pathways suggest that the High Grade zone formed from percolating aqueous fluids exsolved from the mafic magmas of the Roby zone.

An important aspect of the Lac des Iles deposit is high concentrations of Pt-group PGE compared to Ir-group PGE (Fig. 4).

![Graph](attachment:image.png)

Fig. 4: Primitive mantle normalized plot of Ni, Cu, Au, and PGE for the southern Roby, Twilight, and High Grade zones. Data has been recalculated to 100 % sulphide.

Low concentrations of Ir-group PGE may be explained by removal of Ir-group PGE by fractional crystallization of olivine, chromite, and other high-temperature platinum group metals during the magma evolution. However, this does not explain the extreme enrichment of Pd (~ 4 ppm) in the late melanocratic rocks. On a plot of Cu/Pd versus Pd, early leucocratic units show high Cu/Pd values compared to primitive mantle value, suggesting earlier removal of sulphide melt in the evolved parental magmas. On the other hand, the late melanocratic units show low Cu/Pd compared to the primitive mantle, suggesting that they had not undergone any removal of sulphide melt. Considering the two lines of evidence, we suggest that the late melanocratic magmas became fertile by incorporating the earlier formed sulphide melt along the conduit.

The mineralization in the Lac des Iles deposit has been compared to contact-type mineralization because of the common occurrence of breccias and pods of pegmatites. However, contact-type mineralization is localized in the margins of intrusions near boundaries with country rocks, and sulphide formation is in response to assimilation of country rocks. By contrast, there is no evidence of country rock assimilation at Lac des Iles and fragments in Roby and Twilight zones are all contemporaneous gabbroic rocks. We suggest that the mineralization at the southern Roby zone and Twilight zone of the Lac des Iles deposit is akin to stratigraphically controlled deposits in layered intrusions where pulses of primitive magmas introduce PGE. Unlike quiescent environments for the solidification of most layered intrusions, the intrusions at Lac des Iles were energetic, forming breccias and magma mingling textures. Furthermore, the exsolution of aqueous fluids at Lac des Iles led the formation of abundant pegmatites, hydrothermal alteration and metal enrichment at the High Grade zone.