

THE ROLE OF MINERALOGICAL STUDIES IN OPTIMISING MINERAL PROCESSING AT NORTH AMERICAN PALLADIUM'S LAC DES ILES MILL

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INTRODUCTION

In mid-2001, North American Palladium (NAP) commissioned a new 15,000 tonnes per day milling and flotation circuit at their Lac des Iles Mine (LDI), located near Thunder Bay, Ontario, Canada. The open-pit mine and milling operation is one of only two primary platinum group element (PGE) producers in North America. The mill treats an ore containing 2 g/t palladium (and 0.3 g/t total platinum, gold and rhodium) producing a concentrate assaying 250 g/t palladium, at a recovery of roughly 75%.

Since start-up, the mineralogical services, primarily QemSCAN (Pignolet-Brandom et al, 1988 and Latti et al, 2001) at SGS have been used to gain an understanding of the mineralogical factors affecting plant performance, and this has helped in the post-commissioning optimisation of the mill. The objectives of the mineralogical study were multi-faceted, and focused on:

- 1) Understanding feed PGM mineralogy and establishing relationships between PGM floatability and mineralogy, and
- 2) Bulk sample mineralogy, including sulphide assemblage, and liberation, and establishment of the mineralogy of the culprit silicate minerals floating to the final concentrate.

MINERALOGICAL TECHNIQUES

A suite of mill feeds, concentrate and tailing samples were received periodically from November 2001 to December 2002. In the PGM study, the samples were classified into two or more size fractions by cyclosizer. Semi-automated and automated systematic trace mineral searches on numerous polished grain mounts were performed for each size fraction using the LEO440 QemSCAN. PGM data was correlated with PGE-distribution reported by fire assay. In the bulk sample mineralogy study, the samples were examined either as-received or by size fraction. Mineral assemblage and liberation (where desired) was determined using fully automated QemSCAN bulk modal analysis and particle mapping analysis. Again, mineralogical results were tied to chemical analyses.

MINERAL PROCESSING AT LDI

The circuit consists of top-size control crushing ahead of semi-autogenous milling, which also incorporates pebble crushing. A portion of the SAG mill feed is crushed to ~25mm to increase throughput through the mill. Product from the SAG mill circuit is further ground in ball mills, before being delivered to the flotation circuit. Flotation consists of roughing and scavenging, with the rougher and scavenger concentrates each being reground using vertimills. Cleaner flotation uses two stages of cleaning using mechanical cells, and a third stage using flotation columns, the column tails being scavenged using a bank of mechanical cells. The flotation reagent system consists of amyl xanthate collector, dithiophosphate promoter, MIBC frother and a polymeric talc depressant, usually a form of carboxy methyl cellulose.

PLATINUM GROUP MINERALOGY AND EFFECT ON FLOTATION AT LDI – FEEDS

Mineralogical studies were performed on five mill feed samples taken at different times during the period. Sample assays ranged from 1.56 g/t Pd+Pt to 3.00 g/t combined Pd+Pt. While the mineralogy of the five samples varied widely, broad trends were evident. A total of 444 individual PGM grains comprising twelve distinct PGM species were identified in the feed samples from LDI. These were dominated by tellurides, with lesser amounts of arsenides/antimonides, sulphides and alloys. Kotulskite-telluro-palladinite ($Pd(Te,Bi)$ – Pd_9Te_4) comprised roughly two-thirds of the PGM grain population. Palladoarsenide (Pd_2As) was the next most abundant PGM species, comprising 20% of the PGE. Ten other PGM species were observed. PGM particle size ranged from <1 µm to 15.7 µm (recalculated circular diameter). The frequency, area and volume % distribution of these grains showed an interesting trend, with a large clustering of grains in the <8 µm size category (Fig. 1), and smaller population in the 8 to 16 µm size category. Some 45% of the PGM occurred as liberated grains, or inclusions within and attachments to sulphides. The remainder occurred as fine inclusions within, and attachments to silicate minerals. Another key textural feature of PGM in the LDI ore is the presence of fine clusters (10s to 100s of grains) of kotulskite in epidote-plagioclase, with typical PGM grain size <1 µm in diameter.



FAST- AND SLOW-FLOATING PGM

A total of 180 fast-floating PGM grains (from the rougher concentrate), and 87 slow-floating grains (from the scavenger concentrate) were studied. In general, the PGM speciation observed in the fast-floating concentrate reflected that observed in the feed, indicating no clear selectivity in PGM flotation kinetics. For example, kotulskite-telluropalladinite comprised approximately 65% distribution of the PGM, similar to that observed in the feed.

The difference in floatability is driven by grain size and liberation. PGM grains in both concentrates exhibited a bimodal size distribution, with a high frequency population less than 14 µm in diameter and a second smaller population (approximately 39 area %) ranging from 16 to 22 µm in diameter. The fast floaters were characterized by an overall coarser particle size distribution and a high quantity of liberated grains or simple middlings with silicates (85 area %). The 'slow' floaters exhibited an overall finer particle size distribution and low PGM liberation (17 area %), a high proportion occurring as 'disease-like' fine-grained inclusions in silicates (67 area %), typically amphibole and to a lesser extent, epidote.

TAILINGS

Collection of PGM grain data was more difficult in mill tailing samples as a result of their low grades (as low as 0.5 g/t). A total of 43 PGM grains, comprising 7 distinct PGM species, largely the same as those observed in the feed were identified in three tailing samples from the LDI mill circuit. PGM grains identified ranged from 0.6 µm to 5.8 µm diameter, clearly finer than the feed or concentrate PGM grains. This population overlapped with the fine end of the 'slow' floater population identified in the concentrate samples, indicating a group of 'very slow' floaters. All PGM occurred as simple, low-grade middlings, and locked and exposed inclusions in silicates (epidote, plagioclase and amphibole). Fine clusters of PGM 'disease' were noted in all samples.

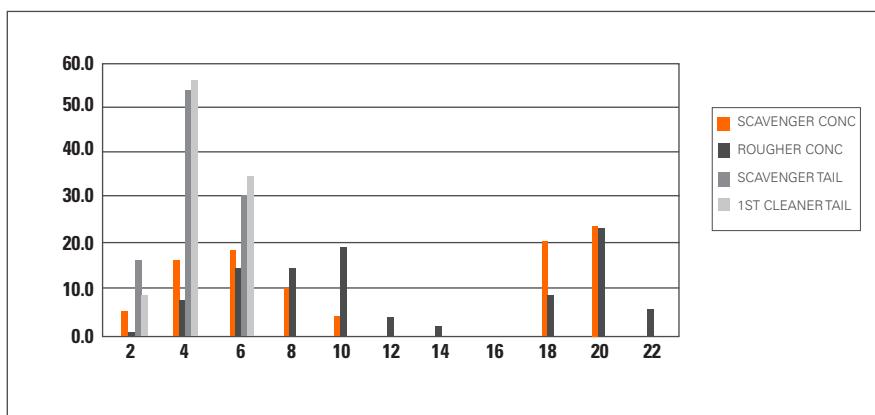


Figure 1: PGM Grain Size Distribution in the Fast-floating and Slow-floating Concentrates, and the Tails

Rougher/scavenger flotation kinetics at LDI are bi-modal in nature, flotation clearly being driven by the bimodality in PGM grain size. Rather than being of any particular species, the faster-floating PGM are coarser and better-liberated or present as simple middlings. The finer PGM grains, even those occurring as dense clusters in host silicates, float much slower and the fact that the grain size distribution of the un floated PGM overlap the slow-floating PGM, indicates that flotation has not reached a natural end-point at LDI. Improved recoveries can be achieved by either regrinding and floating ultra-fine liberated PGM or floating more of the low-grade PGM middlings, both of which will require long residence times and/or well tuned cell hydrodynamics. This is a common feature of PGM circuits, which often incorporate in excess of an hour of residence time, and oversized agitator systems. Laboratory and pilot plant studies at

LDI have shown that a fine primary grind (80% passing 40µm) can yield substantially improved recoveries. However, while benchtop and pilot plant machines are capable of recovering the ultra-fine PGM, the performance of LDI's 130m³ tank cells in the recovery of ultra-fine PGM is less satisfactory. The differences in cell dynamics between the two are currently being investigated.

SILICATE AND SULPHIDE MINERALOGY AND EFFECT ON FLOTATION AT LDI

The LDI ore is comprised primarily of silicate minerals including feldspar, amphibole, chlorite, quartz, micas, epidote, talc and accessories. Sulphide minerals are only a trace to minor component (~1 wt.%) of the ore and are dominated by pyrite, pentlandite and chalcopyrite.

Unlike other primary PGE producers, LDI ships its concentrate to the Sudbury area nickel smelters. These smelters have a relatively low tolerance for MgO, so the rejection of magnesium silicates is a crucial function of the LDI cleaner circuit. After start-up, early concentrates shipped to the Sudbury smelters, contained unsustainable levels of MgO and the first role of the QemSCAN effort was to identify the cause of the high MgO levels. Results indicated that sulphide liberation was highly acceptable. For example, 94% of the sulphides in the rougher concentrate were liberated. Clearly, finer regrinding was not needed. The silicate minerals in the concentrate were found to be predominantly talc and amphibole/talc intergrowths. The key to MgO rejection lay, therefore in talc depression, which is best achieved by multi-stage cleaning, with repeated contact with threshold doses of polymeric depressant. Supported by this mineralogical evidence, the decision was made to modify the circuit to ensure all concentrates were subjected to multi-stage cleaning with CMC depressants. This immediately yielded a marked and sustainable drop in MgO levels in the final concentrates to acceptable levels. At 5-6% MgO, the LDI concentrates are amongst the most silicate-free in the PGE industry.

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