The Sakatti Ni-Cu-PGE deposit in northern Finland

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GEOLOGICAL BACKGROUND
The Sakatti Cu-Ni-PGE deposit is located in Lapland, northern Finland, 150 km north of the Arctic Circle and 25 km north of the county town of Sodankylä, in an area of excellent infrastructure (Fig. 3). The topography of the region is generally flat, with extensive bog coverage and mixed pine-birch forest. Outcrops in the region are sparse, generally less than 2%. The climate is typical northern European Arctic with long cold winters, with temperatures as low as −40 °C, and short, light (land of the midnight sun) summers, during which temperatures can rise to more than 30 °C.

Sakatti is a grassroots discovery in the eastern Finnish portion of the Central Lapland greenstone belt (CLGB). The 2.44–1.98 Ga, northwest-trending Proterozoic CLGB (Hanski & Huhma 2005) hosts many deposits, including Agnico-Eagle’s significant Kittilä (Suurikuusikko) mine with approximately 7 million ounces (Moz) Au (Agnico-Eagle Mines Limited website), First Quantum’s (large, low grade, disseminated) Kevitsa Cu-Ni deposit and the small Lapland Goldminers Pahtavaara Au mine.

The CLGB is a parallel greenstone belt, of strikingly similar age and lithology, to the Pechenga (Petsamo)-Imandra–Varzuga greenstone belt (P-IVGB) in the Kola Peninsula, north-western Russia (Melzhik 1996, Hanski & Huhma 2005, Fig. 4). The P-IVGB is the site of Norilsk Nickel’s world-class Kola Area Operations (Pilgjärvi, Kaula, Kotsevaara and Monchegorsk mines).

Mineralisation at Sakatti is magmatic, predominantly ultramafic-hosted and consists of disseminated, vein (at least three generations) and semi-massive and massive sulphides (Fig. 5). The mineralised body sub-crops below a thin glacial till cover and plunges as a coherent body at an angle of 45° towards the north-west. Mineralisation has been traced for over 1 500 m but remains open to the west, north, south and at depth. Exploration has delineated three distinct zones at

Figure 3. Location of the Sakatti Deposit.
Sakatti: a large Main Zone, which encompasses the main portion of the deposit, a shallow North-East Zone and a South-West Zone.

Mineralisation in the Main Zone is distinctly zoned, with an eastern, (peridotite-dominated), disseminated and minor vein-related chalcopyrite zone. This copper-dominant zone contains platinum (Pt) > palladium (Pd), and is typified by diamond drill hole DDH08MOS8007, which cuts 62.70 m grading 0.51% Cu, 0.23% Ni, 0.44 g/t Pt, 0.22 g/t Pd and 0.13 g/t Au. The central portion of the Main Zone (also peridotite dominant) contains massive and semi-massive chalcopyrite veins, which were injected into the disseminated mineralised body. An overprint of Au is noticeable in a number of these injected vein sets. It is in this central portion of the Main Zone that the first evidence of pyrrhotite (Po) and associated pentlandite (Pn) mineralisation is observed, typified by DDH09MOS8017, which returned 270.15 m grading 0.78% Cu, 0.25% Ni, 0.45 g/t Pt, 0.27 g/t Pd and 0.33 g/t Au. This intercept includes a narrower, higher-grade interval of 39.15 m averaging 1.35% Cu, 0.47% Ni, 0.38 g/t Pt, 0.30 g/t Pd and 0.17 g/t Au.

In the western mineralised portion at depth, the host rocks are a mixture of peridotite and aphanitic ultramafic rocks, which appear to be coeval as intermixing is evident. These host rocks contain a mixture of disseminated chalcopyrite and very minor pyrrhotite-pentlandite mineralisation, which is associated with massive pyrrhotite, pentlandite and chalcopyrite intervals up to 26.50 m thick, as observed in DDH11MOS8049. There, from 766.80 m down hole, the massive ore averages 3.69% Cu, 4.16% Ni, 0.18% Co, 1.10 g/t Pt, 1.27 g/t Pd and 0.24 g/t Au, within a wider intercept of 237.40 m grading 0.60% Cu, 0.71% Ni, 0.21 g/t Pt, 0.21 g/t Pd and 0.06 g/t Au. The massive sulphide forms a coherent body of varied thickness, splitting into three closely spaced stacked lenses, which have been intersected in all the drill holes situated in the western portion of the Sakatti Main Zone. The massive sulphide was subjected to varying degrees of hydrothermal alteration and, in places, the pyrrhotite has been altered to cobaltiferous pyrite.

The drill core shows clear evidence that several mineralisation pulses derived from a deeper feeder chamber contributed to the Sakatti deposit. The ultramafic body at Sakatti was intruded into a mafic volcanic host rock. A thick hanging-wall breccia, commonly hematite stained and of disputed origin, is found to the north and west of the Main Zone.

Initial sulphur isotope studies conducted by Will Browncombe as part of a PhD project at Imperial College (London) reveal δ34S values between 3 and 4%o CDT, indicating a magmatic origin for the sulphides, thereby confirming field observations. This conclusion is contrary to the long-established view that sulphur saturation occurred through admixture with the Matarakoski sedimentary rocks (Hanski 2005, Mutanen
Figure 4. Comparison of CLGB (see text for explanation of acronyms) and Pechenga IVGB (after Hanski & Huhma 2005, Melezhik 1996).

1997). Bench-scale metallurgical and ore characterisation studies on four different mineralisation styles are presently underway by Outotec Oy of Espoo, Finland. Preliminary results from the metallurgical testing show positive recoveries, with the potential to produce high-grade Cu and Ni concentrates from the three massive sulphide ore types. The disseminated sulphide style returned lower recoveries, as expected.

EXPLORATION AND DISCOVERY

Sakatti was discovered utilising conventional exploration methods and by not being overly influenced by generally accepted geological models for nickel sulphide deposit formation (Naldrett 1999). Initial target generation by Jim Coppard and consultant geophysicist Brian Williams highlighted a number of prioritised targets, of which Sakatti was picked as number eight. A detailed infill GTK Aeromagnetic and Frequency Electrical Magnetic (AEM-FEM) survey was flown at an offset 200 m line spacing from the first data set to obtain a 100 m line spacing product in order to better define targets. The targets were followed up by ground geophysical methods, initially Max-Min and soil geochemistry.

Base-of-till geochemistry proved to be the most effective geochemical tool and is the primary method used today. A coherent combined Ni-Cu-PGE geochemical anomaly, with values of up to 20 times that of host peridotite background levels, was detected on a three-line profile over the eastern portion of the Sakatti target and coincident with the aeromagnetic anomaly.

Initial drill testing started in 2006 when three diamond holes were drilled at the eastern edge of the magnetic anomaly. DDH06MO08003 returned short intervals of Cu-PGE-Au, including 7.90 m grading 0.45% Cu, 0.04% Ni, 0.12 g/t Pt, 0.42 g/t Pd and 0.27 g/t Au. A year-end review of the 2006 field programme by both internal and external nickel commodity experts concluded that Sakatti was a low-priority target and, as a consequence, all worked ceased. An exploration review at the Finnish office in 2007 highlighted once again the potential of Sakatti, and finance was redirected within the country from other projects to continue work on the target. This initially led to the completion of
a detailed base-of-till geochemical survey. The survey results defined coherent Ni, Cu and PGE anomalies, with values up to 6 957 ppm Cu, 5 575 ppm Ni and 739 ppb Pt. A second drill phase commenced in winter 2008, during which the first important disseminated and minor vein-related mineralisation was intersected by DDH08MOS08007.

The official discovery hole at Sakatti, proving it to be a significant system, was DDH 09MOS08013, which returned 150.80 m averaging 1.01% Cu, 0.23% Ni, 0.43 g/t Pt, 0.24 g/t Pd and 0.29 g/t Au. In 2010, the Sakatti project became an Anglo American Category II project.

Additional GTK AEM/FEM and VTEM airborne geophysical surveys were subsequently flown over the area, but none of them directly detected the main Sakatti mineralised body. These surveys only detected the smaller, structurally offset mineralised zones, which are situated beyond the Sakatti Main Zone (e.g. the North-East and South-West Zones). The North-East Zone consists of a similar style of mineralisation to the western portion of the Main Zone, and drilling has defined two massive sulphide lenses and a disseminated zone. The South-West Zone consists of sub-cropping, weathered massive sulphide.

The potential for discovery of more deposits in the region is clear. Anglo American Exploration and now through the local Finnish entity, AA Sakatti Mining OY, have valid tenure and applications covering approximately 830 km² of the most prospective CLGB. Anglo American Exploration has already discovered nine additional mineralised intrusions.

Sakatti is one of only a handful of major nickel-copper sulphide deposits discovered in the past half century by means of a programme designed specifically to explore for them, a true example of a concept to discovery exploration programme (cf. Sillitoe & Thompson 2006).