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Open File Report 5928

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ONTARIO GEOLOGICAL SURVEY

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by

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1995

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Lightfoot, P.C. and Lavigne, Jr., M.J. 1995. Nickel, copper, and platinum group element mineralization in Keweenawan intrusive rocks: new targets in the Keweenawan of the Thunder Bay region, northwestern Ontario; Ontario Geological Survey, Open File Report 5928, 32p.

Ontario Geological Survey

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ABSTRACT

Base or precious metal geochemical data from a sulphide-bearing gabbro intrusion located approximately 10 km north of the Crystal Lake Gabbro are encouraging in the context of the setting. The mineralized gabbros containing less than 2% sulphide carry 0.1 to 2.4 wt % S, 300 to 915 ppm Ni, 200 to 1809 ppm Cu, and although no samples give detectable Pt, mineralized samples typically have 20 to 50 ppb Pd and detectable Au (5 to 21 ppb). These values compare favourably with disseminated sulphides from the hanging wall gabbros at Waterfall Gorge in the Insizwa Complex of Southern Africa and the disseminated sulphide zones in gabbrodolerites of intrusions found in the Noril'sk Region. The presence of blebby to disseminated sulphides in the intrusion north of Crystal Lake Gabbro is consistent with segregation of magmatic sulphide and settling of the sulphide towards the base of the intrusion. The presence of both chalcopyrite and pyrrhotite in the blebby sulphides, and the differentiation of these blebs suggests that the sulphide liquid underwent fractionation after segregation. Local assimilation of sulphur from the Rove Formation sedimentary rocks may explain the presence of small concentrations of sulphides at the margins of dykes and sills, but the presence of anomalously high Ni, Cu, and PGE attests to the equilibration of these sulphides with large volumes of magma.

The significance of the weakly mineralized intrusions in the region southwest of Thunder Bay can not be overstated. This environment may well turn out to be equivalent in many respects to the epicontinental setting of the Noril'sk deposits, and therefore more vigorous exploration efforts are clearly warranted in this region.

Nickel, Copper, and Platinum Group Element Mineralization in Keweenawan Intrusive Rocks: New Targets in the Keweenawan of the Thunder Bay Region, Northwestern Ontario

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INTRODUCTION

Recent studies of the Keweenawan Osler Group Volcanic (OGV) rocks by Lightfoot et al. (1991) indicated that some of the effusive volcanic rocks from the central portion of the volcanic stratigraphy carry geochemical signatures indicating that these tholeiitic lavas underwent extensive interaction with the continental crust. This is indicated by their elevated SiO_2 content (50 to 54 wt %) and elevated La/Sm ratio (3-6). Moreover, these same volcanic rocks also appear to be somewhat depleted in Ni (50 to 100 ppm Ni at Ni/MgO<15) and possibly also Cu (although the variation in Cu reflects zeolite facies metamorphism of the basalts), when compared to more typical flood basalt magmas with 150 to 200 ppm Ni. Naldrett and Lightfoot (1993) pointed out that the composition of these lavas are similar to the heavily contaminated Nadezhdinsky Formation lavas of the Siberian Trap at Noril'sk in Russia (e.g., Naldrett et al. 1992, 1995; Lightfoot et al. 1990, 1993, 1994; Hawkesworth et al. 1995; Wooden et al. 1993). Importantly, small (<250 m thick) intrusions of picrite and gabbronorite at Noril'sk host the giant Noril'sk–Talnakh deposits of Ni, Cu, and PGE, and there is a genetic link between these intrusions and the overlying sequence of flood basalts (Naldrett et al. 1995).

The presence of both heavy contamination signatures and Ni, Cu, and PGE depletion were two of several important factors in the reasoning that Naldrett and Lightfoot (1993) gave for speculating that the northern margin of the Keweenawan Rift in the Thunder Bay Region was a good exploration target for a giant Ni, Cu, PGE-rich magmatic sulphide deposit. Several similarities exist between the northern margin of the Keweenawan Rift in Ontario and the Noril'sk

Region of the Siberian Trap (Table 1).

In 1994, based in part on these findings, Falconbridge Exploration commenced a $1.4 M exploration program on a gravity and aeromagnetic high in the Sibley Formation underlying the Osler Volcanics in Nipigon Bay. In 1995, the Ontario Geological Survey began a renewed investigation of the Keweenawan intrusive and extrusive rocks in Ontario with specific emphasis on rocks of the region southwest of Thunder Bay, in the Nipigon Plate Region, and offshore on the Black Bay Peninsula, St. Ignace Island, and many of the other smaller islands in Lake Superior. The intention of this work was: 1) To provide explorationists with new geochemical data to assist in defining Ni, Cu, and PGE exploration targets. 2) To evaluate the mineral potential of the Keweenawan of the North Shore of Lake Superior in the context of increased alienation of lands from the exploration land inventory. 3) To further refine models which assist in exploration for base and precious metal magmatic sulphide deposits.

This report comes in advance of new mapping and geochemistry, but documents an important new intersection of Ni, Cu, and PGE magmatic sulphide mineralization in a coarse-grained gabbro approximately 10 km north of the Crystal Lake Gabbro (host to the 45.6 million ton Great Lakes Nickel Deposit - Smith and Sutcliffe 1987). This new intersection of disseminated sulphide mineralization made in drill core by Mr. Metro Chaschuck, Prospector, Thunder Bay Region, is of particular importance as it defines the existence of a previously unknown, mineralized intrusion at depth in Blake Township (Figure 1), and this intrusion is located along strike from the mineralized Crystal Lake Gabbro, and is on the trend of an aeromagnetic high which intersects the Crystal Lake Gabbro, the Duluth Complex, and extends along the northern margin of Lake Superior. The report also highlights the significance of targets in dyke rocks of the Pigeon River, Arrow River, and Mount Mollie–Pine River dykes southwest of Thunder Bay.

GEOLOGY OF THE KEWEENAWAN ROCKS, THUNDER BAY REGION

The region of Keweenawan magmatism at issue lies within the Southern Province of the Canadian Shield (Figure 1). The Proterozoic rocks exposed in the area form a relatively unmetamorphosed sulphur-rich epicontinental sequence unconformably resting on Archean rocks of the Canadian Shield.

The Early Proterozoic sedimentary rocks of this region consist of argillites and arenites of the Rove Formation. In detail, the Rove Formation consists of a sequence grading from shales and silts through argillaceous greywackes into quartzite (Smith and Sutcliffe 1987). The Middle Proterozoic igneous rocks intrude into the Rove Formation, and Smith and Sutcliffe (1987) suggest that there were three major intrusive events in the following sequence:

1. Sills and sheets of diabase and granophyre possibly comagmatic with the Logan sills in the Nipigon area.
2. Linear dykes of olivine diabase and quartz diabase termed the Pigeon River and Arrow River Series. These dykes crosscut the earlier sills (Geul 1970, 1973; Smith and Sutcliffe 1987). The Pigeon River dykes crosscut the Arrow River dykes (Smith and Sutcliffe 1987).

3. Crystal Lake Gabbro and Pine River–Mount Mollie intrusion (Smith and Sutcliffe 1987), which appears to crosscut all of the igneous rocks of the region.

A review of the distribution and nature of these rock types is given in Smith and Sutcliffe (1987), and Cogulu (1990, 1993a, 1993b) but for comparative purposes we review and synthesize important features of these three suites of intrusions.

DIABASE SILLS

These sills intrude the Rove Formation and consist of diabase and granophyre buttes and cuestas which dip gently to the southwest. The sills have reversed magnetic polarity and may correlate with the 1108 +4/-2 Ma sills of the Nipigon area (Smith and Sutcliffe 1987). Smith and Sutcliffe (1987) note that the reversed magnetic polarity of these sills correlates with that of sills in the Duluth, Minnesota area (Weiblen 1982).

The sills are fine- to medium-grained equigranular tholeiitic diabases that exhibit chilled contact zones against the sedimentary rocks of the Rove Formation. Typically, the sills grade upwards from an aphanitic to fine-grained chill zone into fine-grained ophitic diabase. A fine- to medium-grained diabase with medium to coarse-grained plagioclase phenocrysts compose the central portion of the sill. The upper part of the sill consists of a medium- to fine-grained iron oxide-rich diabase. Smith and Sutcliffe (1987) document six major sills southwest of Thunder

Bay and suggest that the thickest (44 m) occurs in the northwest of the area.

PIGEON RIVER DYKES

A series of linear olivine diabase and quartz diabase dykes cut the Keweenawan sills and the Rove Formation sedimentary rocks. These dykes range from 50 to 150 m thick, and can be traced for a strike length of 15 km (Smith and Sutcliffe 1987). Some dykes crosscut sills, whereas others merge with the sills. In some cases, it is possible that the sills restricted the upward emplacement of later dykes. Some of the dykes appear to cut the sills, and are therefore not likely to be feeders to the sills. The dykes have either fine-grained chilled diabase at the contact, or they have a marginal phase of granophyre. The dykes vary in grain size and texture from fine- to medium-ophitic diabase and equigranular medium-grain size diabase. Plagioclase phenocrysts and glomeroporphyriths are common to the dykes; other features are marginal heavily disseminated sulphides, pegmatoidal patches, leucocratic segregations, and granitic inclusions (Geul 1970, 1973).

ARROW RIVER DYKES

A small number of dykes trend in a northwesterly direction and appear to be crosscut by the Pigeon River Dykes as shown on the maps of Smith and Sutcliffe (1989).

CRYSTAL LAKE GABBRO

The Crystal lake Gabbro is approximately "Y" shaped and consists of a 5 km long west-northwest-striking north limb, and a 2.75 km long east-northeast-striking south limb (Figure 2). Mapping by Smith and Sutcliffe (1987) suggests that the intrusion has a tilted cone shape open at the western end. The Crystal Lake Gabbro exhibits fresh primary cumulate igneous mineralogy of cumulate plagioclase, olivine, and clinopyroxene and intercumulate oxide minerals, Cu-Ni sulphide minerals, clinopyroxene, and plagioclase (Cogulu 1990, 1993a, 1993b). In the north limb of the intrusion, four major lithologic zones were recognized by Smith and Sutcliffe (1987) in the 135 m-thick intrusion:

1. THE BASAL ZONE: this consists of less than 7 m of chilled gabbro in contact with the Rove Formation. This chilled gabbro locally contains inclusions of Rove Formation sediments and Pigeon River diabase (Smith and Sutcliffe 1987).

2. THE LOWER ZONE: this consists of 60 m of medium- to coarse-grained gabbro with pegmatoidal gabbro patches and inclusions of leucotroctolite and fine-grained gabbro.

The sulphide ores of the Great Lakes Nickel Deposit, which is composed of blebs and disseminations of chalcopyrite, pentlandite, and pyrrhotite occurs in the lower part of the Lower Zone. The upper part of the Lower Zone contains segregations of coarse-grained leucogabbro to anorthosite containing less than 5% disseminated chromite. The chromite is concentrated in elliptical pods oriented parallel to the layering.

3. THE MIDDLE (LAYERED) ZONE: This zone consists of 25 m of anorthosite, anorthosite-chromite-bearing, and gabbro layers. Chromite can constitute 40% (modal) of the narrow anorthosite layers.

4. THE UPPER ZONE: This comprises 80 m of coarse-grained olivine gabbro and overlying medium-grained troctolite.

Cogulu (1990) reports mineral chemical and geochemical date for the Crystal Lake Gabbro Intrusion. He shows the following main points:

1.The Lower unlayered zone contains cumulus olivine with 51 to 70 mole percent forsterite. These values suggest crystallization from a low MgO parental magma. NiO-values of olivine are typically 0.17 wt % which is essentially similar to olivines from rocks which represent magmas which have not interacted significantly with magmatic sulphides (Simkin and Smith 1970).

2. The intrusion is marked by low SiO_2 (<48 wt %), moderate TiO_2 (<2 wt %), and low MgO (<12 wt %). These rocks are also characterized by dominantly moderate Rb (typically <30 ppm), but moderately steep rare earth element (REE) patterns with 20 to 100∗chondrite La. These are typically features of a plagioclase-rich system where elevated TiO_2, Rb, and REE reflect fractional crystallization rather than crustal contamination. The exception appears to be the gabbrodolerite

close to the contact which appears to have interacted with sediments (Cogulu 1990).

PINE RIVER–MOUNT MOLLIE INTRUSION

This intrusion is a major composite dyke of gabbro through diorite to granophyre, extending from the western edge of Crooks Township in the west to McKellar Island to the east. The intrusion is 60 to 350 m wide and extends for 35 km. The medium- to coarse-grained gabbro and olivine gabbro locally exhibits steeply-dipping modal layering. Pegmatitic patches and pods within the gabbro contain sulphide mineralization at the margins of the gabbro. The gabbro grades into diorite at the margin of the intrusion. The diorite varies from fine- to coarse-grained, is often hematized, and contains miarolitic cavities (Smith and Sutcliffe 1987). The diorite exhibits mixing relationships with the gabbro and contains mafic and sedimentary inclusions. The margin of the dyke consists of fine- to medium-grained hematized granophyre with abundant quartz, alkali feldspar, and miarolitic cavities. Smith and Sutcliffe (1987) speculate that the Pine River–Mount Mollie Intrusion, although not spatially associated with the Crystal Lake Gabbro, is probably, in part, contemporaneous with it.

MAGMATIC Ni, Cu, PGE SULPHIDE MINERALIZATION

A number of mineral occurrences in the Crystal Lake area host small amounts of Ni, Cu, and PGE. By far the largest known occurrence at this time is the Great Lakes Nickel Deposit, which contains 45.6 million tons of low-grade Ni, Cu, and PGE mineralization. Postle et al.

(1986) quote grades of 0.334% Cu, 0.183% Ni, 0.027 oz/ton Pd, 0.006 oz/ton Pt, 0.003 oz/ton Au and 0.04 oz/ton Ag. Smith and Sutcliffe (1987) demonstrated anomalous PGE values in the Ni-Cu ores with values of 7810 ppb Pd, 95 ppb Pt, and 210 ppb Au. Smith and Sutcliffe (1987) also obtained anomalous PGE values from the chromite-bearing anorthositic gabbro, stratigraphically above the Cu-Ni ore zone (70 ppb Pt). Anomalous PGE values were also reported by Smith and Sutcliffe (1987) from other parts of the Crystal Lake Gabbro, with samples yielding 55 to 125 ppb Pt and 120 to 340 ppb Pd.

Cogulu (1993b) describes the mineralogy and geochemistry of the sulphides. The main sulphides are pyrrhotite, chalcopyrite, cubanite and pentlandite. Pyrrhotite dominates in the Lower Zone and chalcopyrite and cubanite in the cyclical units. Cogulu (1993b) suggests that the textural and mineralogical evidence are consistent with devolatilization of country rock sulphur, and assimilation of sulphur into the magma which segregated as an immiscible sulphide scavenging Ni, Cu, and PGE from the magma. The significance of immiscible sulphide derived from the country rocks is supported by the association of sulphides with pegmatoidal patches within the gabbro and the presence of blebs of sulphide which show fractionation into pyrrhotite-rich lower portions and chalcopyrite-rich upper portions as described in other magmatic deposits (Lightfoot et al. 1984; Naldrett and Lightfoot 1993).

The Pine River–Mount Mollie Intrusion also carries anomalous sulphide showings with up to 5% chalcopyrite (1665 to 2442 ppm Cu, 715 to 1190 ppm Ni, 245 to 570 ppb Pd, and 70 to 190 ppb Pt - Smith and Sutcliffe 1987). These sulphides occur as lenses of massive and disseminated sulphide.

One other intrusion in the area of the Crystal Lake Gabbro is known to host anomalous PGE: a composite dyke on Naomi Island carries 408 ppm Cu, 390 ppb Pd, and 80 ppb Pt.

Sulphide showings and pits recorded by Geul (1970, 1973) are found at the margins of the Pigeon River Dykes, but no assay data exist for the PGE tenor of these showings.

NEW Ni, Cu, AND PGE TARGETS IN THE CRYSTAL LAKE–PIGEON RIVER REGION

The project which this initial Open File Report is associated with was intended to utilize geochemical methodologies to identify specific domains within the Keweenawan of Ontario which are more likely to host giant Ni, Cu, and PGE mineralization. In the process of the field studies, one major potential new target and a number of minor new targets were identified. These targets are given preliminary documentation in this report; a more comprehensive geochemical study is in progress at the time of publication of this report.

Blake Township Gabbros

Two subhorizontal gabbrodolerite sills crop out in Blake Township as a prominent escarpment, and are essentially similar in petrology to the Logan Sills; one of these sills was mapped as such by Smith and Sutcliffe (1987, 1989). Twelve drill holes bored by Metro Chaschuck, Thunder Bay Region Prospector, collared in the Rove Formation sediments below the lower of these two sills intersected two and possibly three additional sills of gabbro and dolerite which appear not to crop out at surface in Blake Township. The location of this property is shown in Figure 1. Preliminary examination of the gabbrodolerites intersected in drill hole indicates that they belong to two main types. One type is medium grained texturally like the sill exposed at surface which was grouped by Smith and Sutcliffe (1987) as a Logan sill; the other intrusion is a coarse- to medium-grained gabbrodolerite which carries pods of pegmatoidal gabbro and disseminated to blebby sulphide mineralization. The drill core log shown in Table 2 describes an intersection of approximately 430 feet of gabbrodolerite between 1266 and 836 feet and approximately 135 feet of gabbrodolerite between 750 and 575 feet located at 46°12' north, 89° 29' west.

The deeper of the two gabbrodolerites is dominantly a medium-grained rock with large pyroxene poikilocrysts up to 1.5 cm in grain size. The gabbro is vari-textured with medium-grained subophitic diabase and pods/patches of coarse-grained pegmatoidal gabbro with crystals several cm in grain size. The lower contact is an aphanitic diabase and grades into a medium-grained gabbro over about 2 feet. The medium-grained gabbro is succeeded by vari-textured gabbro which is overlain by poikilitic-textured gabbro, and then increasing pegmatoidal gabbros and the development of large numbers of inclusions, granophyric patches, shale fragments, and a breccia with a leucocratic matrix. The upper contact consists of fine-grained diabase with felsic fragments overlain by strongly metamorphosed shale. This gabbrodolerite is unusual in that it contains disseminated to blebby sulphides. The sulphides are pyrrhotite and chalcopyrite in a ratio of approximately 80:20, and constitute 0.5 to 5% of the gabbrodolerite over an intersection between 1266 and 1120 feet (over c. 146 feet). Sulphide mineralization also reappears at the top of the intrusion between 934 and 855 feet and is associated with the granophyric gabbro which hosts the shale fragments. The disseminated sulphides are intercumulate and host phenocrysts of feldspar and pyroxene. There is a tendency for the chalcopyrite to be associated with the coarser grain-size pods of vari-textured gabbro, but much of the more pyrrhotite-rich sulphide is hosted as disseminations in the finer-grained gabbro. The blebby sulphides are fractionated into pyrrhotite-rich lower portions and chalcopyrite-rich upper portions, much like the blebs at Insizwa (Lightfoot et al. 1984) and Noril'sk (Naldrett and Lightfoot 1993).

New assay data for the Blake Township gabbros

Sampling and analysis

The 1.5 inches of drill core was split in half, and one half of the core was bagged in 5 foot intersections between 1135 and 1020 feet and 860 to 835 feet, and 10 foot intersections between 1020 and 860 feet. Samples were crushed in a steel plated jaw crusher and ground in a chromium steel mill to -170 mesh. Samples were analyzed by the Geoscience Laboratories, Ontario GEOServices Centre, Ministry of Northern Development and Mines, for Ni, Cu, Co, Zn, S, Pt, Pd, and Au. Ni, Cu, Co, and Zn were determined by inductively-coupled plasma emission spectroscopy, S by Leco Furnace, and Au, Pt, and Pd by a combined fire assay and inductively coupled plasma emission method (e.g., Geoscience Laboratories, 1990).

Results

Table 3 summarizes assay data for samples taken from the drill hole which carries the sulphide intersection. Although the results do not show startlingly high assay values for the base or precious metals, they are particularly encouraging in the context of the setting and exploration model outlined above. The mineralized gabbros containing less than 2% sulphide carry 0.1 to 2.4 wt % S, 300 to 915 ppm Ni, 200 to 1809 ppm Cu, and although no samples give detectable Pt, mineralized samples typically have 20 to 50 ppb Pd and detectable Au (5 to 21 ppb). These values compare favourably with disseminated sulphides from the hanging wall gabbros at Waterfall Gorge in the Insizwa Complex of Southern Africa (Lightfoot et al. 1984) and the disseminated sulphide zones in gabbrodolerites of intrusions found in the Noril'sk Region (Naldrett et al. 1992, 1995; Hawkesworth et al. 1995).

The presence of blebby to disseminated sulphides in this intrusion are consistent with segregation of magmatic sulphide and settling of the sulphide towards the base of the intrusion. The presence of both chalcopyrite and pyrrhotite in the blebby sulphides, and the differentiation of these blebs suggests that the sulphide liquid underwent fractionation after segregation. At issue is whether any significant body of sulphide mineralization is associated with this disseminated sulphide mineralization. Local assimilation of sulphur from the Rove Formation sedimentary rocks may explain the presence of small concentrations of sulphides at the margins of dykes and sills, but the presence of anomalously high Ni, Cu, and PGE attests to the equilibration of these sulphides with large volumes of magma. The Ni, Cu, and PGE tenors of the disseminated sulphides from the Chaschuck core are consistent with significant enrichment of the sulphide in base and precious metals. At issue is whether there is good geochemical data to suggest that this intrusion was the site of significant sulphide accumulation, and much of this information will come from more detailed mapping, petrology and geochemistry.

The significance of the weakly mineralized intrusions in the region southwest of Thunder Bay can not be overstated. This environment may well turn out to be equivalent in many respects to the epicontinental setting of the Noril'sk deposits (*see* Table 1), and therefore more vigorous exploration efforts are clearly warranted in this region.

ACKNOWLEDGEMENTS

Many of the ideas and concepts developed in this Open File Report have benefited from research carried out with Will Doherty, Tony Naldrett, Valeri Fedorenko, and Chris Hawkesworth. The author is also indebted to Richard Sutcliffe for first suggesting the study of the Osler Volcanic Group rocks. Logistic support for this project was provided by John Scott. Great Lakes Nickel and Metro Chaschuck are thanked for access to their properties. Metro Chaschuck is thanked for access to drill core samples. Analytical work was completed at the Geoscience Laboratories, Ministry of Northern Development and Mines, under tight time constraints.

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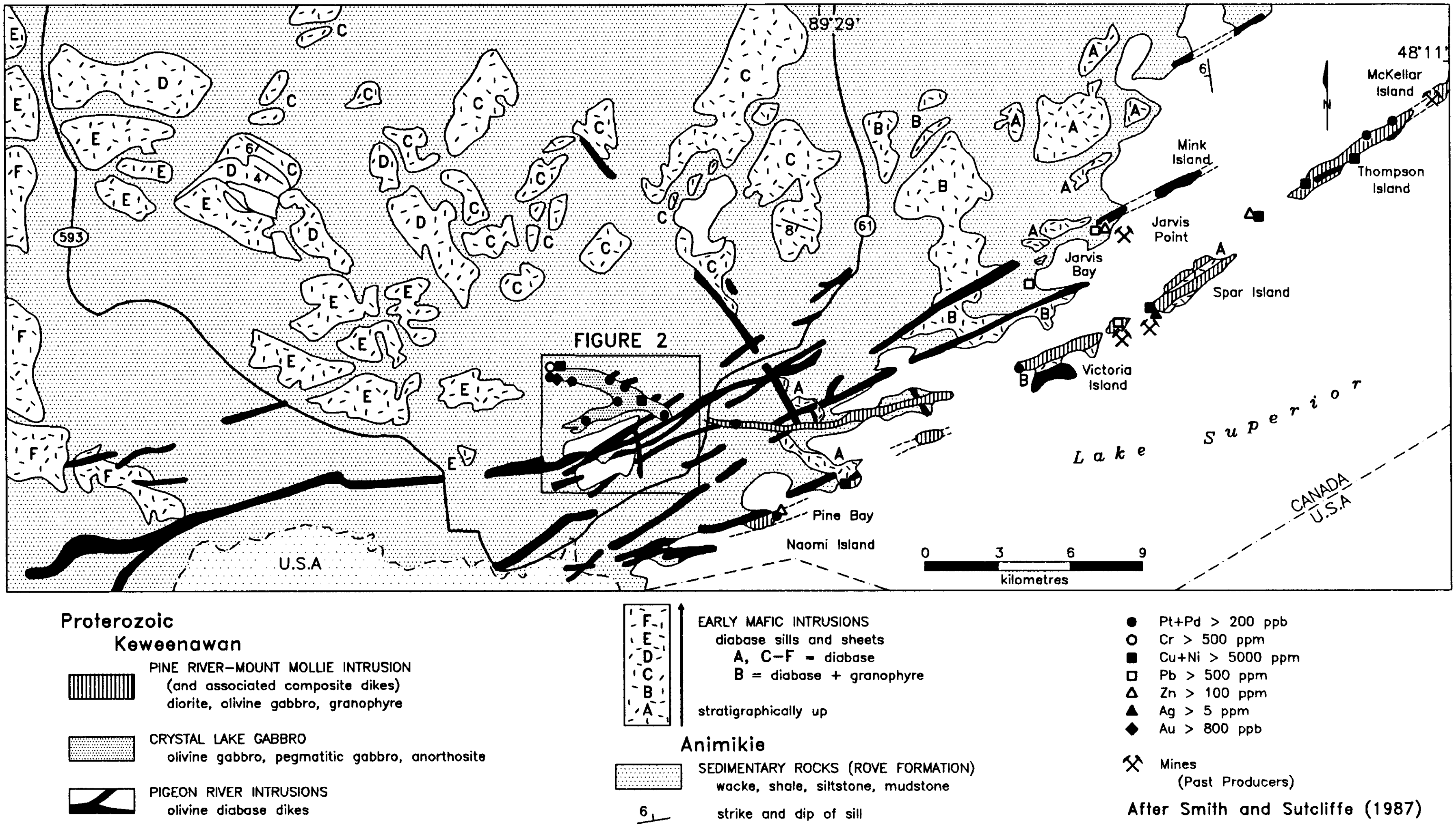

Figure 1. Geology and distribution of intrusive Keweenawan rocks of the Crystal Lake–Pigeon River Region (*after* Smith and Sutcliffe 1987).

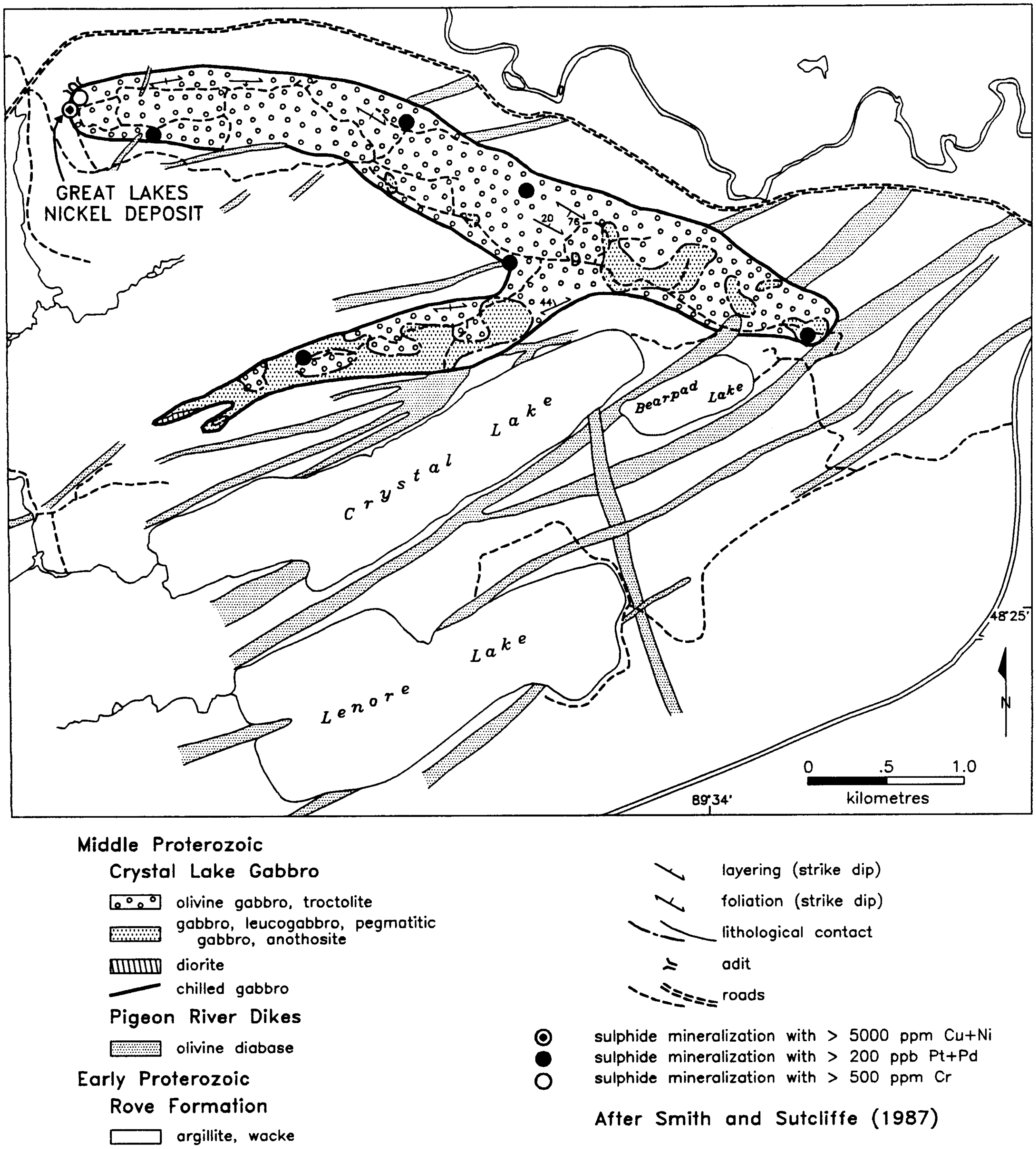

Figure 2. Distribution of rock types in the Crystal Lake Intrusion (*after* Smith and Sutcliffe 1987).

Table 1. Features of the Noril'sk Exploration model and analogues in the Keweenawan Midcontinent Rift.

Feature	***Noril'sk Exploration Model***	***Implications for Keweenawan Exploration in Ontario***
Petrology of the intrusions	- intrusions of the Noril'sk Region are classified into five main groups according to petrology and geochemistry (see Naldrett et al., 1992; 1995); - one of these groups, the Talnakh-Noril'sk Association of intrusions, is associated with the giant Ni-Cu-PGE deposits at Noril'sk and Talnakh; - are gabbrodolerites of low-Mg parentage that are variably enriched in cumulate olivine; - rarely exceed 300 m in width and reside within the Tunguska Series sediments, consisting of a thick sequence of evaporitic deposits; - intrusions have a lower contact gabbrodolerite and taxitic gabbrodolerite; - taxite consists of a complex assemblage of matrix lithologies and inclusions and resembles the Sublayer of the Sudbury Igneous Complex; - petrologically, mineralised intrusions have subtle differences when compared with relatively unmineralised Low Talnakh and Low Noril'sk Intrusions which sit below the mineralised intrusions in the stratigraphy.	- are a number of petrologically different intrusions in the Keweenawan of Ontario; - many are gabbrodolerites which are petrologically similar to gabbrodolerites of the Noril'sk Region, but very few of the intrusions have picritic portions (Sutcliffe, 1987, 1991); - recognised mineralisation in Keweenawan rocks is either disseminated and associated with troctolites of the Duluth Complex, or associated with coarse-grained pegmatoidal gabbros or pegmatoidal patches in gabbros of the Crystal Lake Gabbro and the Port Coldwell Complex; - these associations are very different to those found at Noril'sk; - the intersection of sulphide mineralisation made by Metro Chaschuck southwest of Thunder Bay is different to mineralisation in the Crystal Lake Gabbro: i) much of the mineralisation is associated with gabbrodolerites; ii) only a minor part of the mineralisation is linked to pegmatoidal segregations; - presence of blebby sulphides and disseminations in the gabbrodolerite is comparable to the Noril'sk and Talnakh intrusions (Naldrett et al., 1992) and of other gabbro intrusions such as the Insizwa Complex Waterfall Gorge deposit in the Transkei (Scholtz, 1936; Lightfoot et al., 1994); - in the case of Noril'sk and Insizwa, formation of sulphide mineralisation is believed to involve an open system process where the intrusions represent the solidified remains of horizontal conduits which fed magma to either high crustal level sills or an overlying succession of volcanic rocks; - similarity in the disseminated sulphides and the association with gabbroic rocks at these locations suggest that exploration efforts may be enhanced by a better understanding of the petrological and geochemical relationships between the different intrusions and basaltic rocks of the northern margin of the Keweenawan Rift.
Petrology and composition of the lavas	- Noril'sk lava sequence contains two horizons of picritic lavas; - these lavas appear to be low-Mg tholeiites which are enriched in cumulus olivine unlike the true high-MgO liquids represented in for example the West Greenland Tertiary continental flood basalts; - Noril'sk picritic lavas are associated with mineralised intrusions and may attest to the presence of hot primitive melts perhaps derived from a mantle plume.	- picritic lavas have been recognised in the Mamainse Point sequence (Lightfoot et al., in prep.) and high-Mg lavas are recognised in the Osler Group Volcanic (OGV) (Lightfoot et al., 1991); - the only other non-equivocal high-Mg intrusions are located in the Nipigon plate (Sutcliffe, 1987, 1989); - extent of picritic lavas in the OGV remains uncertain.

Feature	*Noril'sk Exploration Model*	*Implications for Keweenawan Exploration in Ontario*
Sulphide mineralogy, form, and base and precious metal distribution	- Noril'sk deposits contain in excess of 555 million tons of sulphide @ 2.7 wt.% Ni (Naldrett and Lightfoot, 1993); - Ni , Cu, and PGE sulphide mineralisation occurs as: i) massive sheets up to 40 m thick of pyrrhotite, cubanite, mooihoekite, chalcopyrite and pentlandite - economic mineralisation occurs associated with the base and roof of the intrusions, but some mineralisation occurs within dykes which may be feeders to sills or the overlying succession of volcanic rocks of the Siberian Trap (Lightfoot et al., 1994; Hawkesworth et al.,1995); ii) blebs (<2 cm diameter) of pyrrhotite, pentlandite, and chalcopyrite - much of the blebby sulphide is in the taxitic gabbrodolerite and the overlying picrite and picritic gabbrodolerite (Naldrett et al., 1992); iii) disseminations of chalcopyrite and pyrrhotite in gabbro, picrite, and taxite; - sulphide sheets and blebs show evidence of in-situ fractionation into pyrrhotite and pentlandite-rich lower portions and chalcopyrite-rich upper portions, possible as a result of fractionation of a sulphide liquid (Naldrett et al. 1994); - immiscible sulphide liquid fractionates to produce a Ni-rich monosulphide solid solution cumulate and expulsion of the Cu- and PGE-rich trapped liquid as a residual fractionated liquid.	- sulphide mineralisation recognised in Keweenawan of Ontario and Minnesota; - largest deposits are the 4 billion tons of disseminated Ni-Cu-sulphide in troctolites of the Duluth Complex, Minnesota; - deposits appear subeconomic in the present market, but are likely to attract exploration interest based on the possible presence of massive footwall copper deposits of the type found at Sudbury and Noril'sk (Naldrett et al., 1994); - smaller deposits of magmatic Ni, Cu, and PGE are known in the Crystal Lake Gabbro (Great Lakes Nickel Deposit: 45 million tons at 0.334% Cu and 0.183% Ni) and the Port Coldwell Complex (Fleck Resources Ltd. (Two Duck Lake) occurrence: 37 million tons at 0.31% Cu, 0.04% Ni, 251,000 oz Pt, 1.001.000 oz Pd, 84,000 oz Au, and 43,000 oz Rh; - disseminated and patchy sulphide mineralisation associated with dykes and sills in the Thunder Bay Region (Geul, 1970; 1973; Smith and Sutcliffe, 1987, 1989); - these styles of disseminated mineralisation are encouraging for exploration, viz: 1. Disseminated to blebby sulphides (Chaschuk Property) hosted in medium-grained gabbro similar to gabbrodolerites at Noril'sk, and the association of patchy to disseminated chalcopyrite-rich mineralisation is a feature of sulphides associated with pegmatoids of Crystal Lake Gabbro. 2. Presence of sulphides at the margins of the Pigeon River dykes suggest local interaction of magma with crust, but more massive pods exist, and significant mineralisation east of Noril'sk in the Imangda Region is associated with a dyke, whereas a large sulphide body is also known to be associated with a dyke in the West Greenland flood basalt province at Igdlakunguaq.

Feature	***Noril'sk Exploration Model***	***Implications for Keweenawan Exploration in Ontario***
Geochemistry of lavas associated with intrusions	- 3,000 m sequence of lavas at Noril'sk subdivided into nine Formations based on petrology and geochemistry; - two of the formational units consist of picritic and tholeiitic rocks (the Gudchichinsky and Tuklonsky - Lightfoot et al., 1993), but the major portion termed the Upper Sequence consists of tholeiitic lavas which show evidence for variable interaction with crustal rocks; - Lightfoot et al. (1990, 1993, 1994) suggest that one of the lowermost Formations of the Upper Sequence (the Nadezhdinsky) is heavily contaminated by sialic crust as evidence by the elevated SiO_2 (52-56 wt.%), La/Sm (3-6), and radiogenic Sr-isotopic signature ϵ_{Sr}(UR) at 250 Ma=+20 to +80 (Lightfoot et al., 1993); - contaminated lavas appear to be derived by contamination of an evolved picritic lava of the Tuklonsky Formation (Lightfoot et al., 1994), and the lavas show a progressive upwards decline in degree of contamination that is attributed to mixing of contaminated Nadezhdinsky magma with a less contaminated Mokulaevsky Formation magma type; - most contaminated Nadezhdinsky Formation lavas are depleted in Ni, Cu, and PGE (Naldrett et al., 1992), and this is attributed to fractional removal of an immiscible sulphide liquid; - Naldrett et al. (1992) suggest that it is the contamination process which triggers segregation of immiscible sulphides; - the sulphides were concentrated in the Talnakh and Noril'sk intrusions which acted as conduits for flood basalt magmatism (Naldrett et al. 1995).	- Keweenawan Osler Volcanic Group (OVG) succession is in excess of 3000 m thick, and is subdivided into three Formations (Lightfoot et al., 1991); - one formation is a 1150 m thick series of aphyric to plagioclase porphyritic hackly to blocky jointed sequence of thick (5-30 m) amygdaloidal resistant flows - these have been geochemically typed in the Nipigon Straight, but appear on petrological grounds to extend along strike for at least 50 km and make up the resistant outer portions of the Black Bay Peninsula, St. Ignace Island, Battle Island and Cobinosh Island (shown as dykes on OGS map 2285); - lavas of the OVG dip into Lake Superior at about 5-15 degrees, and constitute only the most basal portion of a package which may approach 20 km in thickness within the center of Lake Superior Basin (Cannon et al., 1989); - the Central Formation flows show an upward decline in SiO_2 and La/Sm similar to that found in contaminated Nadezhdinsky Formation lavas at Noril'sk; - implies (Lightfoot et al. 1991) the Central Formation flows were strongly contaminated; - Naldrett and Lightfoot (1993) proposed that the same group of flows have anomalously low Ni, attributed to segregation of magmatic sulphide; - volume of contaminated and Ni-depleted magma in the OVG is of the same order of magnitude to that found in the Nadezhdinsky Formation of Noril'sk Region; - on these grounds, a very large target containing Ni, and presumably also Cu and the PGE may exist in the intrusions which acted as conduits to these flood basalt lavas.

Feature	*Noril'sk Exploration Model*	*Implications for Keweenawan Exploration in Ontario*
Comagmatic intrusions - conduits for flood basalt magmatism	- Noril'sk and Talnakh intrusions were open system conduits which fed magma to surface to generate the Siberian Trap (Naldrett et al. 1995); - chambers acted as horizontal conduits through which magma travelled, depositing cumulate olivine and acting as a trap for dense magmatic sulphides formed either at a deeper level or by local interaction of magma with evaporitic sediments; - chemical composition of the intrusions is more close to that of the Mokulaevsky than to the Nadezhdinsky magma types (Naldrett et al. 1995); - if sulphides were removed from Ndezhdinsky magma type, then why do the mineralised intrusions have geochemical signatures of relatively uncontaminated Mokulaevsky type magmas? - this appears to be the case because all Nadezhdinsky silicate magma was expunged from the system and replaced by Morongovsky and Mokulaevsky magma; - these later batches of magma enriched the sulphides in Ni, Cu, and PGE, and account for presence of less contaminated magma in association with sulphides.	- is very little work to indicate which Keweenawan intrusions are comagmatic with OVG volcanics, and which intrusions might be open system conduits feeding Central Formation basalt sequence; - picritic rocks of Nipigon Plate area may be linked to the Lower Sequence of OVG based on their mafic compositions and Gd/Yb ratios; - furthermore, the Logan Sills may be equivalent to some of the least contaminated Central Formation.
Sulphur source	- at Noril'sk, evaporitic sediments of the Tunguska epicontinental sequence provide a source reservoir for S; - S isotope studies of these rocks confirm that much of the sulphur in the ores has a similar isotopic signature when compared to the evaporitic sediments.	- studies of the Duluth troctolites and disseminated sulphides indicate that the S isotope signature of the sulphides carrying Ni and Cu are comparable to that of the footwall sediments in many of the intrusions (Mainwaring and Naldrett, 1974); - S/Se data for the Crystal Lake Gabbro and footwall sediments are reported by Eckstrand and Cogulu (1986).
Structural controls and setting of the mineralisation	- Noril'sk Region: virtually all mineralised intrusions are associated with major fault zones such as the Noril'sk-Kharaelakh, North Kharaelakh, and Imangda Fault lines; - many of the faults of the region are mantle-penetrating structures (Rempel 1994); - these faults localised the eruption of lavas and emplacement of magmas (Naldrett et al. 1992); - isopachs showing the thickness of Nadezhdinsky lavas are thickest in a region corresponding to the emplacement of known Low Talnakh type intrusions (Lightfoot et al., 1994) which suggests that the distribution of contaminated and Ni-Cu-PGE depleted lavas can be used to narrow down the number of intrusions that are likely targets for mineralisation.	- distribution of contaminated Central Formation lavas in the OVG is partly constrained, and suggests that exploration should focus on the region in which these contaminated lavas are erupted; - however, as the Keweenawan volcanics are either heavily eroded at the margins of Lake Superior or hidden beneath the lake, exploration efforts should not exclude the intrusive rocks of the Thunder Bay and Nipigon Plate regions, many of which may be comagmatic with the OVG; - Cannon et al. (1989) present the only useful structural information for the Lake Superior Region, and indicates that the basin evolved by subsidence along a series of normal faults parallel to the margin of the graben; - are also a number of transcurrent fault structures such as the Thiel Fault which appears to have localised the emplacement of the Port Coldwell Complex, and possibly also the north-northwest trending Arrow River dykes and major dykes cutting the OVG on St. Ignace Island and the Black Bay Peninsula; - the presence of major structures at surface may well be obscured by water in the Nipigon, Moffat, and Simpson Straights.

Feature	***Noril'sk Exploration Model***	***Implications for Keweenawan Exploration in Ontario***
Geophysical data	- Geophysical studies including gravity, magnetic, and seismic approaches have made important contributions to the definition of mineralised targets in the Noril'sk Region; - much of the geology is exposed at surface or can be reconstructed from major drilling programs throughout the Noril'sk Region.	- Geophysical studies of the northern margin of the Keweenawan suggest that the major gravity and aeromagnetic anomalies corresponding to the North Shore intrusive and volcanic systems extend eastward through the Thunder Bay Region and thence through Nipigon Bay extending towards Schreiber; - some of the anomalies are associated with the OVG and provide exciting exploration targets, but very little information is available on the possible structural controls; - valuable information may well be added from radarsat imaging of the region.

Table 2. Log of drill core from the Chaschuck Property, Thunder Bay Region.

Box No	Intersection (feet)	Description
24	575-605	Medium to fine-grained gabbro, fining upwards, with small cm sized pegmatoidal patches giving a local vari-textured appearance.
24	605-608	Coarse-grained (1 cm) vari-textured gabbro pod in medium grained gabbro.
24-25	608-615	Medium-grained equigranular textured gabbro.
25-26	615-637	Medium-grained mottles gabbro with troctolitic feldspar-mafics textures.
26-28	637-690	Mottled coarse-grained gabbro with troctolitic zones. Limited amount of clinopyroxene.
28-29	690-715	Coarse-grained gabbro with mafic wisps of clinopyroxene and clusters of plagioclase.
29	715-740	Medium-grained subophitic textured gabbro
29	740-742	Fine-grained chilled gabbro with no sulphide content.
29-30	742-750	Fine-grained shale of the Animikie
		NOT LOGGED
34	835-836	Fine-grained diabase with felsic fragments, grades into shales. Contact at c. 836 ft.
34	836-838	Diorite breccia with chert-quartzite, shale fragments. Acicular hornblende.
34	838-844	Breccia with leucocratic matrix.
34	844-847	Dark mottled gabbro with granophyric patches. Gabbro is medium grained.
34-35	847-855	Breccia with fragments of arkose, chert, and shale with dioritic to granophyric matrix.

35	855-859	Granophyric textured gabbro. Felsic pink phase and inclusions of shale 1-3 cm. Felsic leucosomes. Fragments locally associated with <10% sulphide. All sulphide appears to be chalcopyrite.
35	859-870	Inclusion-bearing gabbro with felsic nets and clusters. coarse, 1 cm ophitic plates of clinopyroxene?
35-38	870-934	Increasing mottling defined by feldspar. 6" pegmatoidal pods. Mottled troctolitic texture? Nets of mafics. <1% sulphide. Fabric defined by chloritised joints.
38-39	934-935	Ophitic gabbro with increasing size of ophitic plates upwards. Irregular grainy pyrrhotite but no chalcopyrite. Sulphide content hard to establish, but appears to be several percent. Some pegmatoids at 934-935 ft. with radiating plagioclase and hornblende needles.
39	962-965	Pegmatoidal patches with acicular hornblende and plagioclase.
39-41	965-1010	Coarse-grained ophitic gabbro with <2 cm clinopyroxene plates.
41	1010-1020	Pegmatoidal vari-textured gabbro with coarse 1 cm sized feldspathic patches (<6") with ophitic gabbro between pegmatoidal patches.
41-45	1020-1123	Medium grained gabbro with 1.5 cm clinopyroxene ophitic plates. Disseminated irregular sulphides <1.5 cm blebs. 1-2% sulphide. chalcopyrite to pyrrhotite=20:80.
45	1123-1124	Coarse-grained chlorite-rich alteration zone.
45	1124-1128	Medium grained with clinopyroxene plates and large orthopyroxene poikilocrysts. 2% sulphide, chalcopyrite to pyrrhotite=20:80.
45-46	1128-1149	Medium-grained gabbro with <10% disseminated sulphide; chalcopyrite to pyrrhotite=20:80. Rare blebby sulphides reach 1 cm in size. Chalcopyrite rims with more chalcopyrite at top of bleb. Becomes fine-grained upwards in sequence. Large clinopyroxene plates at 1158 ft.

46-47	1149-1171	Medium-grained to coarse-grained gabbro with amphibole pods in the vari-textured parts. Wispy mafics in gabbro. Granular texture with some ophitic clinopyroxene plates. Regular chlorite veins. 1% sulphide. chalcopyrite to pyrrhotite=80:20.
47-48	1171-1191	Medium-grained gabbro, ophitic texture, stubby to ophitic feldspars appear? 60% felsics. <2% sulphide dominated by pyrrhotite. Texture very granular.
48-50	1191-1225	Vari-textured gabbro (2 mm-1 cm defined by plagioclase and clinopyroxene). Blebby to disseminated sulphides in coarser rock. Finer rock has acicular plagioclase. <5% sulphide chalcopyrite to :pyrrhotite-20 to 80. Blebs of sulphide are fractionated. Coarser patches on scale of 1 ft, and fine grained 6".
50	1225-1237	Medium- coarse grained ophitic gabbro with disseminated to 1 cm blebby sulphide (chalcopyrite top, pyrrhotite base). 3% sulphides 30chalcopyrite:70pyrrhotite. Becoming more vari-textured upwards.
50	1237-1240	Transition acicular feldspar and sub-ophitic matrix 1% sulphide 50chalcopyrite:50pyrrhotite.
50-51	1240-1250	Medium-coarse grained gabbro with acicular plagioclase and subophitic matrix. 1% sulphide. 50chalcopyrite:50pyrrhotite.
51	1250-1256	Medium grained to coarse grained with 1" patches of diabasic-textured gabbro. Minor alteration chlorite veining. Equigranular clinopyroxene plates and cumulate -olivine+plagioclase. Patchy sulphides with 1-3% 50chalcopyrite:50pyrrhotite.
51	1256-1260	Medium-grained gabbro with 2% blebby 30chalcopyrite:70pyrrhotite. Coarsens up through section. Acicular plagioclase well-developed.
51	1260-1261	Chloritoid alteration vein. Spotted gabbro.
51	1261-1266	Medium-grained poikilitic textured gabbro with 2% blebby-disseminations.

Table 3. Assay data for drill core.

Sample number	*Intersection (feet)*	*Co (ppm)*	*Cu (ppm)*	*Ni (ppm)*	*Zn (ppm)*	*S (wt.%)*	*Au (ppb)*	*Pt (ppb)*	*Pd (ppb)*
MC1	1266-1266.5	45	292	95	138	0.27	9	<10	18
MC2	1261-1266	61	328	272	117	0.26	<3	<10	11
MC3	1260-1261	54	228	219	151	0.25	<3	<10	8
MC4	1256-1260	54	129	206	107	0.06	<3	<10	5
MC5	1250-1256	55	232	250	120	0.11	<3	<10	15
MC6	1245-1250	55	146	220	105	0.07	<3	<10	<5
MC7	1240-1245	55	144	216	105	0.06	<3	<10	<5
MC8	1237-1240	55	142	211	108	0.06	<3	<10	<5
MC9	1230-1237	57	139	277	103	0.09	<3	<10	9
MC10	1225-1230	55	187	279	100	0.11	<3	<10	10
MC11	1220-1225	54	272	309	99	0.09	<3	<10	20
MC12	1215-1220	59	281	317	98	0.19	<3	<10	16
MC13	1210-1215	74	924	778	102	0.63	7	<10	60
MC14	1205-1210	52	175	250	103	0.13	<3	<10	11
MC15	1200-1205	74	679	576	105	0.60	4	<10	28
MC16	1195-1200	72	478	452	101	0.44	<3	<10	23
MC17	1191-1195	62	238	275	104	0.28	<3	<10	<5
MC18	1185-1191	57	179	318	97	0.07	<3	<10	12
MC19	1180-1185	59	110	305	97	0.05	<3	<10	<5
MC20	1175-1180	60	139	343	96	0.05	<3	<10	<5
MC21	1171-1175	61	75	390	100	0.05	<3	<10	5
MC22	1165-1171	59	263	379	91	0.13	<3	<10	10
MC23	1160-1165	65	100	459	94	0.04	<3	<10	<5
MC24	1155-1160	66	62	486	93	0.04	<3	<10	6
MC25	1149-1155	72	262	582	93	0.11	4	<10	10
MC26	1145-1149	98	550	736	100	0.80	<3	<10	20

Sample number	*Intersection (feet)*	*Co (ppm)*	*Cu (ppm)*	*Ni (ppm)*	*Zn (ppm)*	*S (wt.%)*	*Au (ppb)*	*Pt (ppb)*	*Pd (ppb)*
MC27	1140-1145	115	816	915	105	1.15	8	<10	25
MC28	1135-1140	79	324	510	97	0.52	<3	<10	19
MC29	1128-1135	81	618	632	93	0.53	5	<10	24
MC30	1120-1128	63	208	408	99	0.15	<3	<10	8
MC31	1115-1120	54	161	296	94	0.05	<3	<10	10
MC32	1110-1115	53	103	252	93	0.05	<3	<10	<5
MC33	1105-1110	53	260	276	94	0.04	<3	<10	12
MC34	1100-1105	51	242	244	95	0.03	<3	<10	6
MC35	1095-1100	60	243	267	104	0.15	<3	<10	<5
MC36	1090-1095	52	95	226	93	0.03	<3	<10	<5
MC37	1085-1090	49	90	210	91	0.03	<3	<10	<5
MC38	1080-1085	51	92	219	90	0.03	<3	<10	<5
MC39	1075-1080	54	97	199	97	0.03	<3	<10	<5
MC40	1070-1075	52	95	233	94	0.03	<3	<10	<5
MC41	1065-1070	51	103	215	95	0.03	<3	<10	<5
MC42	1060-1065	50	96	204	94	0.03	<3	<10	<5
MC43	1055-1060	50	94	203	93	0.03	<3	<10	<5
MC44	1050-1055	50	95	197	93	0.03	<3	<10	<5
MC45	1045-1050	51	104	197	94	0.03	<3	<10	<5
MC46	1040-1045	48	100	206	90	0.05	<3	<10	<5
MC47	1035-1040	49	101	205	91	0.03	<3	<10	<5
MC48	1030-1035	49	104	194	94	0.03	<3	<10	<5
MC49	1025-1030	50	103	188	96	0.06	<3	<10	<5
MC50	1020-1025	49	109	172	99	0.03	<3	<10	<5
MC51	1010-1020	50	113	168	100	0.03	<3	<10	<5
MC52	1000-1010	49	113	164	106	0.05	<3	<10	<5
MC53	990-1000	49	114	163	104	0.04	<3	<10	<5
MC54	980-990	48	105	161	99	0.03	<3	<10	<5
MC55	970-980	50	101	170	97	0.03	<3	<10	<5

Sample number	*Intersection (feet)*	*Co (ppm)*	*Cu (ppm)*	*Ni (ppm)*	*Zn (ppm)*	*S (wt.%)*	*Au (ppb)*	*Pt (ppb)*	*Pd (ppb)*
MC56	960-970	50	117	158	107	0.03	<3	<10	<5
MC57	950-960	51	94	174	96	0.03	<3	<10	<5
MC58	940-950	50	107	163	101	0.03	<3	<10	<5
MC59	930-940	49	106	167	98	0.05	<3	<10	<5
MC60	920-930	51	122	174	104	0.03	<3	<10	<5
MC61	910-920	52	121	178	104	0.03	<3	<10	<5
MC62	900-910	51	123	174	106	0.03	<3	<10	<5
MC63	879-880	52	120	175	105	0.03	<3	<10	<5
MC64	859-870	51	125	159	108	0.04	5	<10	<5
MC65	855-859	141	1809	905	198	2040	21	<10	49
MC66	847-855	38	300	212	161	.83	<3	<10	8
MC67	844-847	31	132	125	255	.89	<3	<10	<5
MC68	838-844	47	366	271	511	2.07	<3	<10	9
MC69	836-838	34	105	133	302	.13	<3	<10	<5
MC70	835-836	33	112	138	226	1.58	<3	<10	<5

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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ISSN 0826-9580
ISBN 0-7778-4520-2