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**RELATIONSHIPS AND SIGNIFICANCE OF THE
SUBSILL INTRUSIONS AT MASKWA-DUMBARTON,
BIRD RIVER SILL, MANITOBA.**

by

Paul J. Nagerl

**A thesis submitted to the
Faculty of Graduate Studies and Research
in partial fulfilment of the
requirements for the degree of
Master of Science**

Department of Earth Sciences

**Carleton University
Ottawa, Ontario
December, 1991**

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acceptance of the thesis**

**Relationships and significance of the
subsill intrusions at Maskwa-Dumbarton,
Bird River Sill, Manitoba.**

**submitted by Paul J. Nagerl, B.Sc.,
in partial fulfilment of the requirements for
the degree of Master of Science**

A handwritten signature in black ink, appearing to read 'D.H. Watkinson', written over a horizontal dashed line.

D.H. Watkinson, thesis supervisor

A handwritten signature in black ink, appearing to read 'F. Michel', written over a horizontal dashed line.

F. Michel, chairman

Department of Earth Sciences

Carleton University

December, 1991

Abstract

A suite of mafic and ultramafic rocks has been identified stratigraphically below the Bird River Sill at the Maskwa-Dumbarton property in southeastern Manitoba. Rocks of this subsill suite are comprised of peridotite, pyroxenite, diabasic-textured gabbro and diorite. This suite is less deformed, possesses a lower grade metamorphism and has differing chemical compositions and differentiation trends from those of the Bird River Sill suite. This subsill suite appears to crosscut the Bird River Sill at the Maskwa-Dumbarton property.

Deformation of the Bird River Sill suite may be partly attributed to tectonism during late intrusion of subsill lithologies. The principal metamorphism of the Bird River Sill ultramafic rocks at Maskwa-Dumbarton produced the mineral assemblages forsterite - dolomite - talc and forsterite - diopside - tremolite - talc. These mineral assemblages indicate amphibolite facies metamorphism. The subsill ultramafic rocks remain largely unaffected by metamorphism. Alteration minerals in these latter rocks are primarily serpentine and talc. Remnant primary olivines (Fe_{62-64}) were observed only in subsill ultramafic rocks whereas serpentized metamorphic olivine only was recognized in the Bird River Sill ultramafic rocks. Spinel (*sensu lato*) is the only primary mineral common to both the Bird River Sill and subsill suites. Primary spinel has lower Mn and higher Ti contents than does BRS spinel. Whole-rock chemical data projected onto an AFM diagram indicate divergent differentiation trends for rocks of the Bird River Sill and subsill suites. Late mafic dykes intruding the granitic pluton underlying the sill and late cross-faulting of the Bird River Sill are spatially associated with the subsill suite.

The sequence of events that produced the intrusive rocks at Maskwa-Dumbarton is:

- (i) intrusion of magma generating the Bird River Sill mafic-ultramafic rocks into the Lamprey Falls Formation,
- (ii) hydration and carbonatization of the Bird River Sill ultramafic rocks localized in the area of the Maskwa West deposit,
- (iii) regional amphibolite facies metamorphism and generation of metamorphic olivine at Maskwa-Dumbarton, and
- (iv) regional serpentization of the Bird River Sill ultramafic rocks and intrusion of the subsill suite.

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This study was initiated by R.W. Talkington and R.B. Band of Falconbridge Limited, and by D.H. Watkinson of Carleton University. Both R.W. Talkington and D.H. Watkinson provided technical guidance during the study. Falconbridge Limited is gratefully acknowledged for providing financial support and unrestricted access to information for the duration of this project.

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CHAPTER I: INTRODUCTION

General Statement

The Bird River Sill (BRS) is located in southeastern Manitoba approximately 110km northeast of Winnipeg (figure 1). The Maskwa-Dumbarton property of Maskwa Nickel Chrome Mines Limited lies west of Bird Lake, directly north of Bird River, in the Nopiming Provincial Park and is transected by Provincial Highway 315. Access to the study area is attained from Hwy. 315 by foot traverse along grid lines cut at 400 ft. spacing or by numerous logging roads.

Although the presence of a distinct suite of intrusive rocks stratigraphically below the sill has been noted (Coats et al., 1979; Trueman, 1980), its significance and relationships to the BRS has not been well documented. This intrusive suite of rocks may represent a feeder dyke system to the BRS (Trueman, 1980); the intrusions crosscut a sulphide-facies iron formation proximal to the Dumbarton Ni-deposit suggesting assimilation of sedimentary sulphur thus indicating possible genetic similarities to the Delta Sill of the Cape Smith belt (Giovenazzo et al., 1990). This region contains ultramafic and mafic units which are interpreted to represent conduits to volcanic flows or feeders to a sill respectively, and may host economically significant Ni-PGE deposits. Sedimentary sulphur was assimilated and thus incorporated in the Dumbarton nickel ores in a process similar to that which is suggested for the Thompson orebodies of the Manitoba Nickel Belt. Sulphides of the Dumbarton orebody occur along a granite-andesite contact adjacent to a banded iron formation and are isolated from the BRS intrusive rocks at the present erosion level. The nickel tenor of sulphides in this orebody is high indicating a magmatic component to these sulphides probably related to the BRS.

Percentage outcrop in the study area is less than 5% partly due to the low-weathering nature of the serpentinized peridotite. Relief is low (<20m) and outcrop is commonly mantled by swamps which prevail in the region largely as a result of poorly developed drainage and past 'clear-cut' logging operations. Over 90% of the diamond drill core from the area is unavailable.

Since the discovery of base metals at the BRS in 1917, two Ni-Cu deposits at the Maskwa-Dumbarton property have been mined. Ore from these past producers was milled at Consolidated Faraday's Gordon Lake Mine in Ontario.

Figure 1 Location of the Bird River greenstone belt and study area (a) in eastern Manitoba, (b) off highway 315 east of Winnipeg, and (c) northeast of Lac du Bonnet.

Previous Work

Geologic investigation in the Bird River area began in 1898 (Tyrell, 1900). Geologic studies were continued by Moore (1913) and, following the discovery of Ni-Cu sulphides, by Colony (1920; 1921) and McCann (1921). Regional mapping was conducted by Cooke (1922) and Wright (1926; 1932). Subsequent discovery of chromite in the BRS resulted in investigation by Bateman (1942; 1945) and Brownell (1942).

The BRS is most recently described by Trueman (1971;1980), Scoates et al. (1986, 1988) and Williamson (1990). Descriptions of base metal sulphides in the Bird River area are given by Karup-Møller and Brummer (1971), Juhas (1973), and Coats et al. (1979). Stratigraphy, platinum-group elements, and chromitite of the BRS are discussed by Ohnenstetter et al. (1986), Watkinson et al. (1982) and Talkington et al. (1983). Petrologic studies within the Bird River area were conducted by Butrenchuk (1970) and Coats and Buchan (1979). Local structural studies in the Bird River area were undertaken by Trueman (1971; 1980).

Method

The primary objective of this thesis is to examine the subsill intrusive suite of rocks in an attempt to establish the significance of its possible relationships to the BRS. Secondary objectives include possible elucidation of relationships of mineralization at the Maskwa Pit to the subsill suite. Three possibilities were suggested for the nature of the subsill intrusive suite. This suite may represent:

- (i) a feeder-dyke system for the BRS,
- (ii) a related suite intruding the BRS, or
- (iii) a distinctly different suite intruding the BRS.

Both field and laboratory studies were utilized to achieve these objectives. Field work was completed over a period of three weeks during the summer of 1988. Mapping at a scale of 1:4800 was required to augment previous mapping of the study area by G. Harper of Falconbridge Ltd. (1975). Mapping efforts were concentrated on outcrops containing rocks of the subsill suite. Subsequently, diamond drill core was examined where available. Representative samples were collected for petrographic examination and microprobe analyses. Other areas of the BRS were examined to establish the extent of lithologies identified at the Maskwa-Dumbarton property of the BRS.

CHAPTER II: REGIONAL GEOLOGY

Bird River Subprovince

The Bird River Sill (BRS) is located in the Bird River subprovince of the Superior Structural Province, Canadian Shield (figure 2). The sill intrudes the Rice Lake Group of the Archean Bird River greenstone belt (Moore, 1913; Penner & Clark, 1971). The Rice Lake Group comprises a supracrustal sequence of Archean metavolcanic and metasedimentary rocks including metamorphosed mafic to felsic volcanic rocks and both clastic and chemical sedimentary rocks (Trueman, 1980). This sequence was intruded by synvolcanic intrusions and bounded by syntectonic and post-tectonic plutons. Deformation and resulting cross-faulting has separated the sill into discrete blocks (Williamson, 1990).

Rice Lake Group

The Rice Lake Group is subdivided into six formations described by Trueman (1980); the Eaglenest Lake, Lamprey Falls, Peterson Creek, Bernic Lake, Flanders Lake, and Booster Lake Formations (figure 3). The Eaglenest Lake formation comprises primarily volcanic rocks, pebbly wacke and volcanic sandstone, and lesser biotite schist and amphibolite (Trueman, 1980). The Eaglenest Lake Formation is bounded by an intrusive contact with the Lac du Bonnet Quartz Monzonite and the Lamprey Falls formation in the north and by a fault in the south. A banded iron Formation is located proximal to the northern fault boundary. Rocks of the Lamprey Falls Formation consist of mafic volcanic rocks and related hypabyssal intrusions. Volcanic rocks include pillowed basalt, tuff, hyaloclastite, aquagene breccia, megacrystic basalt, porphyritic and amygdaloidal basalt, and iron formation (Trueman, 1980). Pillowed basalt dominates. The Lamprey Falls formation is also bounded by granitic intrusions and faults. The Peterson Creek formation is characterized by felsic flows and clastic volcanic rocks including flow-banded rhyolite, rhyolite breccia, rhyolite tuff, and epiclastic felsic sandstone of rhyolitic detritus (Trueman, 1980). These rocks are in fault contact with the rocks of the Bernic Lake Formation. The Bernic Lake Formation consists of basalt, andesite, dacite, rhyolite, iron formation, conglomerate, wacke and sandstone (Trueman, 1980). This formation is infolded with the Peterson Creek Formation in the north and located as a separate entity in the core of the Bird River greenstone belt. Rocks of the Flanders Lake Formation include polymict metaconglomerate and related arenite (Trueman, 1980). These rocks occur in the eastern part of the belt and are

Figure 2

Location of the Bird River greenstone belt in the Bird River subprovince of the Superior Structural Province showing the general regional geology of the area. Inset shows location of Bird River subprovince with respect to other subprovinces of the Superior Province.

METAVOLCANIC & METASEDIMENTARY ROCKS

INTRUSIVE ROCKS

Figure 3

Stratigraphic subdivision of the metasedimentary and metavolcanic rocks and classification and distribution of the intrusive rocks of part of the Bird River greenstone belt (after Trueman, 1980).

interpreted to overlie part of an angular unconformity with the Peterson Creek and Bernic Lake Formations. The Booster Lake Formation consists primarily of greywacke-mudstone turbidite and minor iron formation (Trueman, 1980). It is also fault-bounded. Rocks of the above formations have been folded, faulted, and metamorphosed in the greenschist to amphibolite facies. The BRS intrudes basalt of the Lamprey Falls Formation, the second oldest of the six formations that constitute the Bird River greenstone belt.

Intrusive rocks of the Bird River area are synvolcanic, syntectonic, and late-tectonic (Trueman, 1980). The synvolcanic intrusions comprise hypabyssal gabbro of the Lamprey Falls and Bernic Lake Formations, and the BRS. The Maskwa Quartz Diorite and Marijane Lake plutons comprise the syntectonic intrusions. The Lac du Bonnet Quartz Monzonite is a late-tectonic intrusion. The Great Falls pluton is late- to post-tectonic. The Bird River greenstone belt is bounded to the north by the Maskwa Quartz Diorite pluton, to the east by the Marijane Lake pluton, and to the south by the Lac du Bonnet Quartz Monzonite pluton. The upper contact of the BRS is interpreted to be a fault, separating anorthositic gabbro of the sill from debris flows containing anorthositic gabbro and metabasalt inclusions of the Lamprey Falls Formation (Trueman, 1980). Where the sill is absent, a fault contact separates the Lamprey Falls Formation from the Bernic Lake Formation stratigraphically below.

The BRS and the Rice Lake Group are folded into an eastward-plunging anticline (Trueman, 1980). The core of this anticline contains the late- to post-tectonic granodiorite to quartz diorite Great Falls pluton (McRitchie, 1971). Juhas (1973) suggested that the Bird River Sill is penecontemporaneous with, and possibly comagmatic with, the mafic volcanic rocks of the Rice Lake Group.

Turek and Peterman (1971) determined the ages of the Rice Lake - Beresford Lake greenstones as 2345 ± 100 Ma by Rb-Sr whole-rock methods. Geochronological Rb-Sr whole-rock studies by Penner and Clark (1971) indicate an age of 2650 ± 35 Ma for the Bird River volcanic rocks, 2640 ± 135 Ma for the Maskwa Lake Quartz Diorite, 2635 ± 25 Ma for the Cat Lake Quartz Diorite, and 2495 ± 180 Ma for the Lac du Bonnet Quartz Monzonite. However, Timmins et al. (1985) determined the age of the Maskwa Lake batholith as 2779 ± 32 Ma using U-Pb zircon methods. Farquharson (1975) has subsequently determined the ages of the Lac du Bonnet Quartz Monzonite and associated metamorphism as 2680 ± 91 Ma by Rb-Sr whole-rock methods. The mafic series gabbro of the BRS has been dated by U-Pb zircon methods at 2745 ± 5 Ma (Timmins et al., 1985). A proposed schematic geologic evolution of the area is given in figure 13.

Bird River Sill

The BRS is a large differentiated mafic-ultramafic layered intrusion of peridotitic to anorthositic composition with an exposed total east-west strike length of approximately 24 km (Albino and Robb, 1982; Juhas, 1973). The average thickness of the sill is 900m (locally 1800m), dips are typically near-vertical south, and strike is characteristically east to northeast. Facing in pillowed volcanic rocks and the disposition of peridotitic to gabbroic and anorthositic rocks indicate younging toward the south (Trueman, 1971). At the Maskwa-Mayville property, located in the northern opposite limb of a regional anticline, facing directions from pillowed volcanic flows indicate younging towards the north.

Williamson (1990) describes the BRS as three lithological series totalling 822 metres in thickness each divided into zones and subzones based on mapping at the Chrome property. The Ultramafic series at the stratigraphic base of the sill contains the contact zone, megadendritic zone, layered zone, massive peridotite zone and chromitiferous zone. The Transition series comprises the lower peridotite, gabbro and upper peridotite zones. The upper Mafic series contains a lower gabbro zone, xenolith zone, quartz gabbro - diorite zone, trondjemite zone and upper gabbro zone. This entire sequence is crosscut by a mafic dyke, part of a feeder system to overlying volcanic rocks (Williamson, 1990). Seven rock types composing forty-five layers are described by Trueman (1971). From the base upwards these include 19 serpentinized peridotite layers, 18 interbanded chromite and serpentinized peridotite layers, a pyroxenite layer, and 7 gabbro, anorthositic gabbro, anorthosite layers. This data is also obtained largely from the Chrome property of the sill. No direct stratigraphic correlation can be made with similar units at Maskwa-Dumbarton due to poor exposure and increased deformation at the latter.

Northwest and southeast trending faults are prominent in the Bird River greenstone belt with apparent horizontal displacement as much as 5km. The faults do not appear to extend across the central sedimentary units of the belt (Coats et al., 1979). Strike-slip faults are also evident. A palinspastic reconstruction of the BRS given by Trueman (1980) indicates a distinct feeder zone. Juhas (1973) and Trueman and Turnock (1975) outlined three periods of regional folding and placed the grade of metamorphism in the upper greenschist to lower amphibolite facies.

CHAPTER III MASKWA-DUMBARTON PROPERTY

General Statement

The Maskwa-Dumbarton property hosts the intrusive subsill suite of this study. The Property is located on the Bird River Sill (BRS) immediately east of the junction of Hwys. 314 and 315. It is situated between the Page property to the west, the Ore Fault property to the north and the Petra-Bar property to the east, extends approximately 5.5 km east-west along the strike of the BRS and is nearly 2.2 km at its widest extent (figure 4). Interest in the Maskwa-Dumbarton property is high due to the presence of Ni-Cu as well as Cr and PGE deposits. It is the site of two past producing mines, namely the Maskwa open pit and Dumbarton underground operations as well as numerous exploration pits, trenches, and more than 200 diamond drill holes. Geologic interpretation of this area is based subequally on outcrop, diamond drill hole and magnetic data. One cluster of drill holes at the Dumbarton mine site and another at the Maskwa open pit are the result of past attempts at delineating ore deposits. A third cluster is concentrated around copper-rich rocks east of the Dumbarton mine. Recent diamond drill holes confirm anomalous platinum group element (PGE) values and indicate anomalous gold contents. Past mining operations yielded approximately 1,539,290 tonnes averaging 0.81% Ni from the Dumbarton mine and 365,730 tonnes averaging 1.16% Ni from the Maskwa pit (Coats et al., 1979). An estimated 700,000 tonnes of reserves remain beneath the Maskwa open pit.

Lithology

The BRS at Maskwa-Dumbarton occurs between rocks of the Lamprey Falls Formation to the north and the Bernic Lake Formation to the south. It is composed of peridotite to pyroxenite, gabbro to anorthositic gabbro and rare anorthosite which may be distinguished magnetically (figure 5 and 6). The gabbro is stratigraphically above the peridotite. The subsill intrusive suite consists primarily of pyroxenite, diabase-textured gabbro, medium-grained gabbro, and rare peridotite. Numerous late mafic dykes cut the region in the area of the subsill.

Mafic volcanic rocks of the Lamprey Falls Formation are massive in the map area. Metasedimentary rocks of the Bernic Lake Formation were not observed but were recorded in diamond drill logs and in previous geologic surveys. A medium-grained, grey to pink granite to granodiorite of the Maskwa Pluton is the prevailing rock underlying the sill in the Maskwa-Dumbarton area. Assigned field classification of units was retained in this text.

Figure 4

Location of some mining exploration properties in the Bird River Sill and geology of the area.

Figure 6

Geologic map of the Maskwa-Dumbarton property. Sample locations, diamond drill hole locations, and structural data are provided in figure 14.

-SYMBOLS-

- ==== Highway
- trail or Bush Road
- Power Line
- ~~~~~ Pond, Lake, River
- ~~~~~ Swamp
- Grid
- ✕ Mineralized Showing

BARRINGER G.M. 102 MAG
E. NILSSON, CENTRAL GEOPH
JUNE - JULY 196

0 500
metres

102 MAGNETOMET
 L GEOPHYSICS LIM
 JULY 1968

Figure 6

Total magnetic field contour
 map of the Maskwa-Dumbarton
 property.

500 1000
 metres

Lithologies of the Bird River Sill

Peridotite:

Peridotite of the BRS suite ranges in thickness from 180m to 360m at surface, reflecting a probable true thickness of between 100-200m at Maskwa-Dumbarton, and constitutes the exposed base of the sill. Peridotite weathers very low and thus remains largely unexposed at Maskwa-Dumbarton. The weathered surface is buff tan but may also appear black to light grey with increasing spinel content. The original minerals have been almost entirely converted to a metamorphic assemblage. Major mineral constituents include serpentine, tremolite, chlorite, talc, carbonate, spinel, and sulphides. The sole remaining relict primary phase is chromite cores of some secondary zoned spinel.

The peridotite hosts a Ni-Cu sulphide deposit at the Maskwa open pit where it is in sharp contact with footwall volcanic rocks. East of Maskwa, at the Dumbarton mine, economic Ni-Cu sulphide ore in metavolcanic rocks is interpreted to be in contact with pyroxenite of the subsill suite. The BRS peridotite is overlain by anorthositic gabbro over the entire strike length on the property.

The peridotite is variably deformed and offset by numerous resulting faults. Deformation is reflected by dismembered, displaced, and folded chromitite units. Deformation appears most extensive near the western, better exposed part of the property (approx. grid location 68 + 00W 40 + 00S) adjacent to the subsill suite. At this location, extensive shearing and faulting have almost entirely obscured primary layering and texture in the peridotite. In other areas palimpsest textures are well preserved. Chromitite layers are boudinaged and sheared in a few outcrops. In the eastern part of the property, although also extensively deformed, peridotite contains distinctive chromitite layers several centimetres thick and continuous to several metres.

Petrographically, peridotite is characterized by subhedral to euhedral, equant to oval serpentine and carbonate pseudomorphs after cumulus olivine poikilitically enclosed by clinopyroxene. The margins of individual olivine grains and olivine partings are lined with fine-grained anhedral magnetite. At the Maskwa pit retrograde mesh-textured lizardite blades after metamorphic olivine have been described as rosettes by Coats and Buchan (1979). These occur as dark green bladed aggregates to 2 cm in length. Lizardite pseudomorphous after metamorphic olivine also radiates from fractures. Pyroxene is pervasively altered to tremolite. Chlorite is commonly associated with magnetite and chromium spinel and also occurs as streaks along shears. Chromium spinel is a common accessory and occurs as subhedral grains predominantly near the stratigraphic top of the peridotite. Individual grains may exceed 500µm in size but are generally much smaller. Fractures in chrome spinel are common and are infilled with sulphide.

Rare optical zoning and bright inclusions of $<2\mu\text{m}$ in size are also observed. Sulphides are pyrrhotite and chalcopyrite which also commonly occupy the interstices between olivine. Rare chalcopyrite blebs are found in chrome spinel. Some disseminated fine-grained magnetite is spatially associated with sulphides. Pervasive talc-carbonate alteration obscures layering common in other areas of the sill. Carbonate is found as a pervasive alteration in some specimens but only as vein material in others. Carbonate veins cross-cutting the peridotite represent a final carbonatization event. Rare dunitic parts are pervasively altered to serpentine and magnetite and subsequently to the talc, magnesite and dolomite. Modal abundances of opaque minerals and degree of carbonate alteration vary considerably from one location to another.

The ultramafic rocks of the BRS suite at Maskwa-Dumbarton are also described by Coats et al. (1979) and Coats & Buchan (1979).

Pyroxenite:

Pyroxenite of the BRS suite in the study area was observed only in drill core; it is situated stratigraphically above the peridotite at the base of the anorthositic gabbro (Juhas, 1973). The pyroxenite is altered primarily to tremolite and is interpreted to represent hercynite with minor poikilitically enclosed olivine.

Anorthositic Gabbro:

Anorthositic gabbro constitutes the exposed top of the BRS at Maskwa-Dumbarton. It is in sharp contact with the ultramafic part of the sill, separated from the peridotite by a thin layer of pyroxenite observed only in drill core. Anorthositic gabbro weathers high relative to the adjacent ultramafic rocks, is medium- to very coarse-grained, and rarely pegmatitic. It is composed primarily of plagioclase (An_{20-70} ; Appendix I, Table 12), comparable to plagioclase near the upper contact of anorthositic gabbro described by Karup-Møller and Brummer (1971), calcic amphibole (Appendix I, Table 13), and may contain rare biotite and epidote. Zircon is present as an accessory (Karup-Møller and Brummer, 1971).

Anorthositic gabbro appears spotted or mottled on the weathered surface. Amphibole occurs as elongate grains or as oikocrystic grains enclosing plagioclase. Amphibole is pervasively altered to a very fine-grained secondary variety with biotite. Plagioclase occurs as anhedral to subhedral interlocking laths several millimetres in length containing randomly scattered prismatic amphibole. Spinel and associated chlorite and carbonate are rare. Spinel consists of intimate intergrowths of fine-grained ilmenite and lesser magnetite. Large subhedral to euhedral red garnets in anorthositic gabbro were located near grid location 76 + 00E 9 + 00S.

These are 3mm to 1.5cm in diameter, associated with a prominent 2 metre wide shear and interpreted to result from metamorphism of magma that underwent assimilation of, and contamination by country rock. Mafic patches and areas of anorthosite are contained within anorthositic gabbro. Anorthosite is light grey to white, massive, and composed of plagioclase, fine amphibole aggregates with biotite and appears to grade into anorthositic gabbro.

Anorthositic gabbro contains numerous shears of varied magnitude but is otherwise relatively undeformed.

Subsill Lithologies

Peridotite:

Peridotite of the subsill suite was found in a few outcrops only (approximately grid 36+00W 10+00S). This rock is an orthocumulate wehrlite containing cumulus olivine with interstitial pyroxene. Cumulus textures are preserved. Primary olivine in one sample has an average composition of Fo₇₈ (Appendix I, Table 5). Olivine is equant, subhedral and fine-grained. Pyroxene is clinopyroxene with bastite alteration. Serpentinization of olivine and pyroxene has affected 60-80% of the mode.

Pyroxenite:

Pyroxenite of the subsill suite is varied in modal composition and includes olivine pyroxenite locally grading to lherzolite and wehrlite. These lithologies are massive to weakly foliated and occur together within a single modally complex outcrop or within unimodal homogeneous outcrops. Pyroxenite occurs as medium- to coarse-grained dark grey to black, olive green, or rusty brown rock in outcrop. It consists of pyroxene, amphibole, olivine, rare feldspar, rare quartz, and opaque minerals. Clinopyroxene and/or orthopyroxene are present. Pleochroic green amphibole occurs as an alteration product of pyroxene. Olivine (Fo₈₈₋₉₄, Appendix I, Table 5) is partially to completely hydrated to serpentine. Opaque minerals comprise fine-grained disseminated magnetite, pyrrhotite, chalcopyrite, and pyrite. Magnetite is commonly observed at olivine and pyroxene grain boundaries and along parting planes and cleavage traces. Rare carbonate alteration of pyroxene is observed.

A granite xenolith in pyroxenite similar to granitic rocks from the Maskwa Lake pluton is located at approximate grid location 36+00E 3+00N and may indicate that this pyroxenite postdates intrusion of the Maskwa Pluton. However, at another location within the subsill a contact breccia of gabbroic fragments in granitic rock indicates the reverse indicating a complex intrusive history of the area.

Diabase-Textured Gabbro:

Diabase-textured gabbro of the subsill suite is found predominantly in the western part of the map area intruding medium-grained gabbro of the subsill suite. A sharp well-defined chilled contact with medium-grained gabbro is observed at approximate grid location 57 + 00W 30 + 00S.

Diabase-textured gabbro is grey-black and consists of acicular plagioclase laths averaging approximately 3mm in length in approximately equal modal proportion with amphibole. Plagioclase (An_{50-70} , Appendix I, Table 12) occurs as partially saussuritized subhedral grains. Amphibole is secondary after clinopyroxene and commonly occurs as optically continuous grains interstitial to interlocking plagioclase laths. A subophitic to ophitic texture distinguishes this gabbro from others in the area. Rare biotite was observed in some samples spatially associated with amphibole. Fine-grained magnetite and ilmenite occur along cleavage traces of pyroxene. Sulphide minerals are pyrite and pyrrhotite and are spatially related to the oxides. Variations in this gabbro comprise relative changes in modal plagioclase versus amphibole abundances and significant changes in modal abundances of sulphides from trace to 3 percent over a few centimetres.

Medium-Grained Gabbro:

This field category can be reclassified to diorite based upon a few mineral analyses. It occurs as a white and green medium- to coarse-grained rock also consisting of approximately equal proportions of plagioclase and amphibole. This diorite is pegmatitic at 58 + 00W 29 + 50S. Amphibole is characteristically dark green and occurs as an alteration of clinopyroxene. Plagioclase grains (An_{30-50} , Appendix I, Table 12) appear blocky unlike those of the diabase-textured gabbro. Again, biotite was found spatially associated with amphibole in some samples. Locally more mafic or more felsic patches are common. Less common fine-grained patches in this unit are interpreted to represent a variety of the medium-grained gabbro/diorite but may also represent massive andesite xenoliths.

Magnetite, ilmenite, pyrrhotite, pyrite, and chalcopyrite constitute the opaque minerals. These occur as anhedral disseminated blebs. At approximate grid location 70 + 00W 30 + 00S (Wento showing) a significant increase in the chalcopyrite mode is accompanied by the presence of covellite rims on chalcopyrite. Rare plagioclase phenocrysts to 1cm in size were observed in the medium-grained gabbro at approximate grid location 4 + 00W 1 + 00N.

Volcanic and Sedimentary Rocks

Interflow sulphide-facies iron formation with cherty interbedded sedimentary rocks, felsic flows, massive andesite and pillowed volcanic rocks of the Lamprey Falls Formation comprise the volcanic and metasedimentary suite of rocks at Maskwa-Dumbarton. Prominent massive sugary textured, milky white, sulphide-bearing quartz veins are spatially associated with the felsic volcanic rocks. Volcanic rocks are described in detail by Juhas (1973).

One sulphide facies iron formation situated parallel to, and stratigraphically below, the entire strike length of the BRS at Maskwa-Dumbarton is all but absent in the area of the proposed feeder dyke. Field evidence indicates that this iron formation was crosscut by the subsill intrusive suite. Assimilation of this sulphide from this iron formation by subsill lithologies may have caused increased partitioning of chalcophile elements into an immiscible sulphide liquid and therefore be of economic significance. Abundant crustal-derived sulphur may concentrate chalcophile elements from a large volume of magma passing through a feeder zone. Other sedimentary rocks of the study area were not visited. These occur in the southern part of the map area and consist primarily of quartzite, greywacke, arkose, and finely-bedded argillite of the Bernic Lake Formation (Karup-Moller and Brummer, 1971).

Granitic Rocks

Granitic rocks in the study area belong to the Maskwa Lake Quartz Diorite pluton as described by Carlson (1958), McRitchie (1971), and Trueman (1980). Several varieties of granitic rocks are observed. These are medium- to coarse-grained, weather to a light grey, pink or white colour and are cut by numerous dykes and veins. Very coarse-grained and pegmatitic patches are also observed.

Late Dykes

Abundant mafic gabbroic dykes located predominantly in the northwestern portion of the study area strike north-west and dip near-vertically. Similar north-east trending dykes are less common. Mafic dykes vary in composition, thickness, and texture. Rare composite, xenolithic or porphyritic dykes were recognized. A granitic xenolith presumed to have originated from the Maskwa Lake pluton was recognized in one dyke located northwest of the Maskwa open pit. The frequency and size of mafic dykes increases towards the western part of the study area. Rare felsic dykes are tan buff to grey, aphanitic, massive, and porphyritic.

Structure

The regional structure of the study area involving four deformational events in the area of the BRS is described by Trueman (1980).

In the Maskwa-Dumbarton area, stratification in the BRS area is manifested by bedding in a prominent sulphide-facies iron formation and by layering displayed in the BRS suite of rocks. In general, bedding and layering strike east-west and dips are steep to nearly vertical to the south. Measured foliations in the northern part of the property are also dominantly east-west. Pillowed lava and layering in the BRS indicate tops to the south. Layering in the subsill suite area is irregular.

Faulting, shearing, and folding are extensive in the Maskwa-Dumbarton area. A penetrative fabric in the BRS ultramafic rocks is parallel to strike. Deformation is concentrated in serpentized peridotite of the BRS suite particularly in the vicinity of the subsill suite of rocks. Prominent NNW faulting may be interpreted using total magnetic field data due to the contrasting magnetic signatures of ultramafic and mafic rocks of the area. Faults producing offsets are responsible for some of the structural complexity in the area. The subsill lithologies show no dominant trends and appear coincident with a major NNW trending fault displacing the Maskwa-Dumbarton portion of the BRS from the Page property. Observed contacts between the subsill lithologies are sheared. Minor folds recognized in the study area are presumed to be parasitic to the regional folding described by Trueman (1980).

Geochemistry

Whole-rock chemistry (X-ray Assay Labs, Lakefield Research Labs and Bondar-Clegg Ltd.) and electron microprobe analyses (Carleton University) were performed on selected samples to identify possible compositional similarities or differences between rocks of the subsill and BRS suites. Details of sampling procedures and analytical techniques are given in Appendix I. Samples from the study area and other BRS locations including the Page, Chrome, Mayville and National-Ledin properties were incorporated. All Fe is calculated as FeO. Rock geochemistry of the BRS and of the subsill suites were compared. Differences in chemical compositions are described below and are somewhat dependent on the following assumptions;

- (i) the original rock was homogeneous prior to alteration, and
- (ii) no major addition or removal of material took place during alteration apart from H_2O and CO_2 .

Mineralogically similar samples were chosen for comparison when possible to satisfy assumption (i), and when available, samples of the largest convenient size were submitted to satisfy assumption (ii). BRS and subsill ultramafic samples are distinctly differentiated cumulates and therefore do not represent an original liquid. Whole-rock data are presented on oxide wt.% Al_2O_3 - FeO + TiO_2 - MgO and wt.% $Na_2O + K_2O$ - Al_2O_3 - MgO ternary plots (figure 7 and 8). Spinel compositions are presented on a TiO_2 versus MnO binary plot (figure 9). Additional data are listed in Appendix I.

Major Element Geochemistry

Subsill ultramafic and gabbroic rocks, BRS ultramafic and gabbroic rocks, and volcanic rocks examined occupy distinctly different but overlapping fields when data are projected onto the diagrams Al_2O_3 - FeO + TiO_2 - MgO and $Na_2O + K_2O$ - Al_2O_3 - MgO. Only weakly divergent differentiation trends are evident. However, it is doubtful that the anhydrous compositions calculated for these samples reflect the original oxide component abundances since hydration/carbonatization, particularly observed in BRS suite lithologies, often results in the loss and/or addition of components such as K^+ , Na^+ , F, Mn and Cl (D.H. Watkinson, person. comm., Best, 1982). The effects of Mn in olivine and carbonates or F and Cl in amphibole and talc are unknown at Maskwa-Dumbarton. Therefore, although the samples plot along well-defined fields, some samples may be altered to such a degree that their position on the diagram does not represent an original sample composition relative to other samples. In this way alteration and metamorphism make geochemical classification of rocks difficult. Additionally, simple ternary

plots ignore the relative abundances of other oxides and invoke closure limiting statistical analyses. To this end, the geochemistry of all samples described below is intended as an aid only to provide support for observation made in the field.

Subsill mafic and ultramafic rocks show relatively constant compositions in contrast to the BRS suite and characteristically higher Fe/Mg ratios of the ultramafic rocks in contrast to the BRS ultramafic suite. However, the Fe/Mg ratios of the mafic rocks are relatively higher in the BRS suite. The expanded nature of BRS suite data fields projected onto these ternary diagrams may represent a more extended differentiation process. Gabbros from both suites project onto separate fields of the ternary plots. The range in composition of minor oxides (MnO , TiO_2 , P_2O_5) is much more restricted in subsill lithologies than in rocks of the BRS suite indicating possible redistribution of the latter due to hydrothermal activity or thermal gradients associated with metamorphism. Subsill rocks contain relatively less P_2O_5 , greater TiO_2 than do BRS units.

Al_2O_3 - $\text{FeO} + \text{TiO}_2$ - MgO Plot:

Rocks of the BRS suite occupy 4 fields which may be distinguished by sample location and sulphide content as well as rock type. The data show compositional variation among similar lithologies from different BRS localities. That is, Petra-Bar and National-Ledin gabbros do not coincide with those found at Maskwa-Dumbarton. Ultramafic lithologies show relatively low total iron content with the exception of 3 samples which contain iron sulphides. Gabbros project onto 2 fields. The anorthositic gabbro directly overlying the ultramafic unit at Maskwa-Dumbarton shows Al enrichment and is much more differentiated than similar gabbros from the Petra-Bar and National-Ledin properties. Mayville property gabbros project onto both fields.

Rocks of the subsill suite occupy only 2 fields. Subsill suite ultramafic rocks are less magnesian while the gabbros are more magnesian than those of the BRS suite. Diabase-textured gabbros and medium-grained gabbros of the subsill suite could not be distinguished.

Volcanic rocks at Maskwa-Dumbarton occupy 2 fields projected onto this ternary plot. Pillowed volcanic rocks are less magnesian and more iron-rich than both BRS and subsill units. Some massive flows have similar compositions to subsill ultramafic units. Late cross-cutting mafic dykes appear unrelated.

$\text{Na}_2\text{O} + \text{K}_2\text{O}$ - Al_2O_3 - MgO Plot:

This projection shows significant overlap between the ultramafic lithologies, volcanic units and some subsill gabbros. Subsill ultramafic rocks are slightly enriched in Na and K relative to BRS ultramafic units. Subsill gabbros occupy two separate fields. Two texturally dissimilar gabbros identified in the field may be distinguished.

Figure 7

Ternary Al_2O_3 - $\text{FeO} + \text{TiO}_2$ - MgO whole-rock oxide weight percent plot for Bird River Sill and subsill suite lithologies.

Figure 8 Ternary $\text{Na}_2\text{O} + \text{K}_2\text{O} - \text{Al}_2\text{O}_3 - \text{MgO}$ whole-rock oxide weight percent plot for Bird River Sill and subsill suite lithologies.

Rare Earth Geochemistry

Thirteen samples were submitted for rare earth element determinations. Data are presented as Table 16. Ultramafic rocks contain low abundances of REE as expected and have relatively flat chondrite-normalized abundances. Results indicated an enrichment in LREE with respect to HREE and significant depletion in Sm. REE trends were considered inconclusive due to their irregular distributions.

Mineral Chemistry

Minerals analyzed by an EDS on a Cambridge microprobe instrument include olivine, chlorite, serpentine, spinel, feldspar, amphibole and clinopyroxene. Available samples were analyzed for their major constituents in an attempt to establish similarities or differences that may allude to their genetic evolution and thus the relationship of the BRS and subsill suites.

Analyses of olivine are presented in Table 5. Primary olivine was found only in rocks of the subsill suite. Microprobe examination of olivine in rocks of the subsill suite show consistent Fe/Mg ratios and composition Fo_{88-94} . Examination of BRS lithologies revealed only serpentinized metamorphic olivines or olivine pseudomorphs in pervasively carbonatized dunites. Coats and Buchan (1979) located a single isolated grain of unserpentinized metamorphic olivine with composition Fo_{88} (location unknown). NiO contents varied from 0.20 - 0.37 wt.% and are considered normal for undepleted olivines. Compositional heterogeneities within a single sample were not encountered.

Analyses of chlorite are presented in Table 10. Chlorite of the subsill suite only were examined. All chlorite contains Cr_2O_3 in the range 0.01 - 0.97 wt.%. In comparison, chlorites of the BRS suite from the Petra-Bar locality contained Cr_2O_3 in the range 0.41 - 2.40 wt.% (Dumaresq, 1989).

Analyses of serpentine are presented in Table 11. Samples from the BRS suite indicated elevated Cr, Al and Ti contents and may be attributed to exchange with Fe from adjacent spinel. No other distinct geochemical differences could be established between BRS and subsill serpentines.

Spinel analyses are presented in Tables 6 - 9. Spinel is the only primary mineral common to both the BRS and the subsill suite of rocks thus permitting a direct comparison between the two. Subhedral to euhedral spinel in ultramafic pyroxenites and serpentinites thought to represent primary phases only were examined. Both cores and rims of spinel were analyzed to establish any zoning, if present, and to compare possible differences in degree of alteration.

All spinels examined from the study area are chromium-bearing magnetites and iron chromites with the exception of sample Nss-s1 which is essentially pure magnetite. Mole percent

end member chromite varies between 5.08 and 50.53. The most pristine chromium spinel from the BRS contained higher proportions of Cr and Mg and lower concentrations of Ti than those examined from the subsill. Chromites from the Chrome property (BRS type-locality) contained an order of magnitude greater Al_2O_3 and Cr_2O_3 and thus appear less altered. Ni trends are not clearly defined but appear to be relatively increased in concentration in spinel of the BRS suite.

Spinel data show an increase in Fe and decrease in Cr, Ti and Zn at the rims of individual grains. This is interpreted to result from Cr and Al transfer from spinel into adjacent serpentine and Fe transfer from this serpentine into spinel. The net result of this reaction is the transformation of serpentine into chlorite and chromium spinel into magnetite. This hypothesis is supported by the presence of subtle zoning of the spinel from relatively Cr-rich cores to Fe-rich rims and the presence of anomalously high Cr in serpentine and chlorite. The driving force for this transformation may be attributed to nearby intrusions and increased metamorphic grade since Al and Ti are thought to be relatively immobile at low temperatures.

Spinel mineral data projected on the TiO_2 versus MnO binary plot compose separate fields for BRS and subsill lithologies (figure 9). Although BRS and subsill spinel occupy a common origin their differentiation trends show a clear divergence with respect to MnO and TiO_2 compositions. Standard Al - Cr - Fe^{+3} and Cr - 2Ti - Al ternary plots for spinel compositions were not used due to the very low Al contents of the spinel, possibly resulting from the metamorphic effect described above.

Analyses of feldspar are presented in Table 12. Feldspar compositions were variable among individual samples and within single samples. Anorthite content of the plagioclase examined was An_{36-78} . No significant chemical differences could be established between feldspars of contrasting lithologies.

Analyses of amphibole are presented in Table 13. Amphiboles examined from subsill pyroxenites contained lower concentrations of Al, Mg and Fe than those representative of subsill gabbros. All amphiboles analyzed belong to the tremolite group.

Analyses of clinopyroxene are presented in Table 14. Pyroxene compositions of subsill pyroxenites only were examined. All pyroxenes analyzed are chromian diopsides.

MINERAL ANALYSES OF CHROMIUM SPINEL

Figure 9 Binary MnO versus TiO₂ mineral chemistry plot for Bird River Sill and subsill spinel.

Metamorphism

Regional metamorphism in the Bird River area was studied by Butrenchuk (1970). Metamorphism of the BRS is described by Juhas (1973), Coats & Buchan (1979), and Trueman (1980). Metamorphic grade is described as upper greenschist facies increasing eastward to lower amphibolite facies in the vicinity of the study area. This discussion will be limited to the metamorphic assemblages of the BRS and subsill suites at Maskwa-Dumbarton.

Mineral assemblages in the ultramafic part of the BRS at Maskwa-Dumbarton as described by Juhas (1973) include antigorite + chlorite $\pm$ tremolite $\pm$ carbonate; antigorite + chlorite + talc $\pm$ tremolite $\pm$ carbonate; olivine + tremolite $\pm$ talc $\pm$ carbonate $\pm$ chlorite $\pm$ antigorite; tremolite $\pm$ carbonate $\pm$ chlorite; and diopside + olivine + tremolite $\pm$ chlorite. Samples collected by the author indicate that the carbonate present is primarily dolomite with only minor magnesite. These assemblages are derived from an initial serpentinite and their formation is attributed to contact-thermal effects on the Sill by the Maskwa Lake pluton superimposed on regional metamorphism (Coats and Buchan, 1979). Such contact metamorphism would be restricted to the Maskwa-Dumbarton area since metamorphic olivines are not observed elsewhere in the BRS. With the exception of chromium spinel, no primary mineral was observed in the BRS ultramafic rocks during the present study. In contrast primary minerals including olivine, pyroxene, and spinel are common in ultramafic rocks of the subsill suite. The assemblage in the subsill ultramafic rocks comprises diopside + olivine + antigorite $\pm$ tremolite $\pm$ chlorite $\pm$ talc $\pm$ carbonate. Diopside and olivine are primary minerals.

The observed presence of metamorphic olivine in the BRS suite, subsequently retrogressed to serpentine and the associated metamorphic assemblage talc - magnesite - dolomite at one locality in the study area places the peak grade of metamorphism attained at the upper greenschist to lower amphibolite facies. The presence of blue-green amphibole in volcanic rocks north of Dumbarton and the presence of andalusite and cordierite in pelitic rocks southeast of Maskwa-Dumbarton indicate a maximum regional metamorphic event equal to or exceeding upper greenschist facies (Trueman, 1980). Metamorphic olivine is not recognized in subsill pyroxenites or at other BRS localities. According to Coats & Buchan (1979), prograde metamorphism and the generation of metamorphic olivine at Maskwa-Dumbarton followed an initial serpentinization of primary olivine and CO_2 metasomatism replacing serpentine with talc and magnesite to form metamorphic olivine and dolomite; olivine was subsequently serpentinized. A local source for CO_2 was postulated to be related to proximal felsic volcanism (Coats and Buchan, 1979).

Four possibilities exist for the absence of metamorphic olivine in the subsill pyroxenites and at other BRS localities;

i) spatially limited hydration and carbonatization of some ultramafic rocks occurred at Maskwa-Dumbarton proximal to the Ni deposits (possibly related to generation of Ni-sulphides) followed by regional prograde metamorphism to upper greenschist facies and generation of metamorphic olivine from talc and magnesite and subsequent retrograde hydration, or

ii) regional hydration and carbonatization of the BRS ultramafic rocks followed by regional upper greenschist to amphibolite facies metamorphism. Generation of metamorphic olivine was limited to a part of the Maskwa-Dumbarton area due to the confinement of water elsewhere in the sill by an impermeable envelope of volcanic and sedimentary rocks or due to high H_2O vapour pressure conditions allowing the persistence of serpentine in the surrounding BRS ultramafic rocks, or

iii) regional hydration and carbonatization of the BRS ultramafic rocks followed by spatially limited upper greenschist to amphibolite facies metamorphism and generation of metamorphic olivine at Maskwa-Dumbarton due to some contact effect with the Maskwa Lake pluton and subsequent hydration of olivine to serpentine, and

iv) intrusion of the subsill ultramafic units after amphibolite facies metamorphism and generation of metamorphic olivine.

The BRS ultramafic rocks are laterally continuous over several kilometres and naturally confined by rocks of the Lamprey Falls formation and Bernic Lake formation except at Maskwa-Dumbarton where a part of the sill is in contact with the Maskwa Lake pluton. Exposure of the sill at this location lends itself to the spatially limited first phase of hydration and carbonatization suggested in the first hypothesis. The subsill ultramafic rocks extend beyond the BRS metamorphic olivine zone and thus do not appear related. The second hypothesis may be discounted due to the presence of primary olivine in subsill pyroxenites and the absence of metamorphic olivine elsewhere in the BRS. High H_2O vapour pressure or fluids derived upon prograde metamorphic dehydration reactions confined by geological barriers would preclude the presence of unserpentinized olivine in similarly affected proximal units. The third hypothesis may be discounted due to evidence suggesting regional upper greenschist metamorphism described previously and the lack of evidence for CO_2 metasomatism or a second phase of serpentinization in the ultramafic rocks of the subsill suite and at other BRS localities. Differences in metamorphic grade cannot be attributed to the proximity of the Maskwa Lake pluton unless it postdates intrusion of the subsill lithologies. Timmins et al. (1985) determined the age of the Maskwa Lake pluton at 2779 ± 32 Ma and the mafic series gabbro of the BRS at only 2745 ± 5 Ma. Rocks of both suites are equally near this granitic body. Mafic dykes similar in appearance

and composition to the sub sill gabbros crosscut the Maskwa Lake pluton. Fourthly, the sub sill intrusive suite of rocks appear to postdate the high grade metamorphism but were affected by the second phase of serpentinization. Peridotites and pyroxenites of the sub sill ultramafics are only partially altered and indicate less deformation.

In the system $\text{CaO-SiO}_2\text{-MgO-H}_2\text{O-CO}_2$, assuming 2 kilobars pressure and at low $x\text{CO}_2$ content of the metamorphic fluid, the mineral phases present at varying fluid composition and temperature can be described in figure 10. Assemblages observed in the BRS south of the Dumbarton Mine at Maskwa-Dumbarton are shown labelled 1 to 3 (Juhas, 1973, Coats and Buchan, 1979). These indicate a metamorphic fluid containing $< \sim 0.10$ mole percent CO_2 , whereas assemblages at the Maskwa Pit indicate a fluid composition in the range $0.10 < x\text{CO}_2 < 0.25$ suggesting increased CO_2 metasomatism at Maskwa.

The bulk composition of Maskwa-Dumbarton rocks may be conveniently described in the system $\text{CaO-SiO}_2\text{-MgO-H}_2\text{O-CO}_2$ (figure 11). Ultramafic rocks of the BRS at Maskwa-Dumbarton projected onto the forsterite - dolomite - talc and tremolite - dolomite - talc fields. Observed metamorphic forsterite (presently retrograded to serpentine) is limited to the area of the Maskwa pit where the observed metamorphic minerals are antigorite, talc, dolomite, and magnesite. Antigorite is the result of retrograde hydration of forsterite. The presence of magnesite is the result of metamorphic disequilibrium. At Dumbarton, immediately east of Maskwa-West, the predominant metamorphic minerals are forsterite, diopside, tremolite and talc. It is suggested that the occurrence of these two metamorphic assemblages in such close proximity is a result of early pre-metamorphic spatially limited serpentinization of the BRS ultramafic rocks in the vicinity of the Maskwa open pit as previously outlined in hypothesis one. Assemblages A and B of figure 11 are the result of a step-wise reaction in response to changing CO_2 concentrations of the metamorphic fluid. Tremolite is abundant elsewhere in BRS ultramafic rocks of the study area. Increased CO_2 metasomatism in the area of the Maskwa open pit may be the result of an early serpentinization phase. Mineral assemblages of the sub sill ultramafic rocks do not project onto the dolomite - diopside - talc - magnesite quadrilateral due to a lower degree of metamorphism. Mineral assemblages observed in ultramafic rocks of the BRS are not developed in ultramafic of the sub sill suite.

Figure 10

Calculated phase diagram for the system $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ (modified from Coates and Buchan, 1979; after Trommsdorff and Evans, 1977). Vertical bars 1 to 3 are stable assemblages at Dumbarton (Juhas, 1973) and paths A to B and C to E represent two possible metamorphic evolutions for the present assemblage at Maskwa-West.

Figure 11

Common ultramafic derived metamorphic minerals in the system $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ projected onto the $\text{CaO-SiO}_2\text{-MgO}$ ternary field. Composition of BRS and subaill ultramafic rocks are outlined accordingly.

A - BRS Maskwa-West metamorphic mineral assemblage

B - BRS Dumbarton metamorphic mineral assemblage

Mineralization

Ni-Cu-Fe sulphides are found in the map area at the site of two previously mined Ni-Cu deposits, at several showings, in iron formation and in prominent quartz veins. Disseminated sulphides are observed locally in rocks of the subsill suite. Sulphide mineralization is discussed in detail by Juhas (1973). Late quartz veins spatially associated with late felsic dykes yielded anomalously high Au concentrations.

Two past producers of Ni ore at Maskwa-Dumbarton are the Dumbarton mine and Maskwa West open pit. Production of Cu-Ni ore from the Dumbarton mine totalled 1,539,290 metric tons grading 0.81% Ni (1969-74). The Maskwa West deposit produced 365,730 metric tons of disseminated ore at 1.16% Ni and 0.20% Cu. Sulphide assemblages at Maskwa West are pyrrhotite - pentlandite - pyrite - chalcopyrite. An oxidized assemblage of marcasite - pyrite - violarite - chalcopyrite persisted to approximately 40m depth and constituted the bulk of production from the open pit. Oxidized assemblages are the result of supergene alteration or O_2 generated during carbonate alteration and are characterized by 'high-sulphur' minerals (Eckstrand, 1975). The Maskwa West deposit is situated immediately east of the thickest accumulation of subsill lithologies. Trueman (1971) suggested a magmatic origin for this deposit by pooling of dense sulphide liquid into a paleo-depression near a proposed feeder dyke.

A sulphide-facies banded iron formation parallel to the base of the BRS at Maskwa-Dumbarton, and continuous over its entire strike length, is truncated and absent at the site of this proposed feeder dyke where subsill lithologies dominate and appear to crosscut the BRS. Several sulphide showings in this region (Wento, Beaver, and Cup Anderson) may represent assimilated remnants of this iron formation. These contain uneconomic concentrations of Cu-rich sulphides.

Field data indicate that three sulphide showings occur within or proximal to the subsill intrusive suite. Empirical observations suggest that the concentration of sulphides may be related to the assimilation of iron formation in this area. Assimilation of silica and sulphur can induce sulphur saturation of a magma and permit fractionation of chalcophile elements into an immiscible sulphide liquid (Naldrett, 1989). Formation of sulphide concentrations at the Wento and Beaver showings by this method is suggested by the author.

Chromium spinel is found in rocks of both suites. Concentrations of these spinel are restricted to BRS ultramafic lithologies. Chromium spinel occurs as disseminated equant subhedral grains or as distinct massive layers largely disrupted by later deformation. Chromium spinel is pervasively altered to magnetite. Chromium is not economically significant in either the subsill or BRS suite at Maskwa-Dumbarton but is of economic interest in other areas of the BRS.

CHAPTER IV DISCUSSION

Examination of the subsill suite at Maskwa-Dumbarton suggests a multiple intrusive history for the area. General setting, field observations, alteration and deformation, metamorphic grade, sulphide mineralization, geochemistry and geophysical response were considered in evaluating the relationships of the BRS and subsill suites.

General Setting

Location of the subsill intrusive suite and thus the proposed feeder dyke of the BRS is coincident with a major NNW-trending fault which separates the Maskwa-Dumbarton and Page properties. The BRS at Maskwa-Dumbarton forms a coplanar unit interrupted only by less prominent faults with similar trends. Metasedimentary and metavolcanic units hosting the BRS at Maskwa-Dumbarton are conformable whereas the subsill lithologies show no dominant trends. This may result if the subsill underwent less deformation than the BRS and would be the case if it post-dated the BRS. Intense folding would eventually transpose all affected units into structural conformity.

Field Observations

The author recognized the distinctly different nature of the subsill lithologies to the BRS suite of rocks. Field observations show a greater degree of deformation, faulting and occurrence of sulphides in the vicinity of the subsill pyroxenites and gabbros in the western part of the property. A prominent sulphide-facies, banded iron formation which parallels the base of the BRS at Maskwa-Dumbarton is absent in this region and is interpreted to be crosscut by subsill lithologies as indicated by field observations and ground EM conductors. In addition, there is an increase in the frequency of late mafic dykes in this area where the subsill lithologies truncate the BRS. A multiple intrusive nature of the subsill in the area of the proposed feeder dyke was noted and also alluded to by Springer (1949).

Pyroxenites of the subsill suite have a limited lateral extent, observed only at Maskwa-Dumbarton. Subsill pyroxenites contain no plagioclase and thus differ from BRS pyroxenite at the Chrome property (type-locality) where they contain up to 10% modal plagioclase. Field relations indicate that the diabase-textured gabbro of the subsill suite intrudes the medium-grained gabbro of the subsill suite. No other clear contact relationships involving the rocks of the subsill suite were observed in this study but several indirect relationships were observed by the author and in previous studies. Juhas (1973) recognized certain ultramafic bodies which did

not appear to belong to the Bird River Sill (BRS) proper. Based on petrological studies, Juhas (1973) believed these to be genetically related to the BRS but did not reconcile whether they represented apophyses, separate intrusions, or faulted blocks. Juhas (1973) also described the gabbroic and pyroxenitic intrusion north of the Maskwa pit as post Maskwa Lake pluton "unaffected by the first wave of regional metamorphism". Karup-Moller & Brummer (1971) recognized a subsill suite distinct from the BRS at Maskwa-Dumbarton but also suggested a common origin. Springer (1949) noted that "... there occurs a large number of fine- to medium-grained diabasic bodies which were intruded as sills." Karup-Moller and Brummer (1971) also recognized a granitic block in subsill gabbro and a chilled margin to gabbro at the granite contact at one locality suggesting that this gabbro is younger, and described the numerous mafic dykes as possible feeders to these gabbros. If the dykes do represent such feeders then, since they clearly crosscut the Maskwa Lake pluton, the texturally similar subsill gabbro (the diabase-textured gabbro) must also postdate the granitic pluton.

A cross-cutting trend of the subsill rocks across the BRS peridotite is indicated in the geological interpretation (figure 5), but does not dissect the BRS at the present erosion level. A clear differentiation trend from peridotite to anorthositic gabbro can be observed in the field in the BRS suite of rocks (Williamson, 1990). No such trend was recognized among rocks of the subsill suite. Rocks similar to the subsill gabbros were also observed at the National-Ledin property of the BRS. Both gabbros of the subsill suite appear spatially associated with felsic and mafic dykes in the region. A composite stratigraphic section for the Maskwa-Dumbarton area is presented in figure 12.

Apparent weakly metamorphosed enclaves in the BRS peridotite may represent preserved parts of the BRS proper. However, the paucity of such enclaves in other portions of the BRS and the chemical similarities of these rocks with subsill lithologies suggests that they represent intruded subsill rocks. Additionally, it is difficult to imagine that igneous olivine of the subsill suite survived the extensive alteration described in the BRS ultramafic rocks.

Alteration and Deformation

Alteration and deformation evident in the BRS lithologies contrasts with those observed in the subsill suite. The BRS peridotite in the area of the proposed feeder dyke/subsill intrusive suite at Maskwa-Dumbarton is more deformed. This may be due to a competency contrast between the BRS peridotite and subsill lithologies or preceded the intrusion of the subsill. Extensive carbonatization and pervasive serpentinization observed in BRS ultramafic rocks is not prominent in the subsill ultramafic lithologies. As well, intense shearing and faulting pervasive in BRS lithologies is not recognized in the subsill intrusive suite.

Figure 12

Composite stratigraphic section for the Maskwa-Dumbarton property. Subsill units are intrusive into the pillowed volcanic and massive flow ($\pm$ sedimentary) strata. The felsic dykes are probably related to post subsill magmatism.

Metamorphic Grade

The metamorphic grade in portions of the BRS peridotite was set at upper greenschist to amphibolite facies indicated in part by the presence of metamorphic olivine, dolomite and talc, subsequently serpentinized and carbonatized (Coats and Buchan, 1979). In contrast to the BRS ultramafic rocks, exposed proximal subsill pyroxenites, outcropping less than 500m distant, indicate only lower greenschist facies metamorphism. Relict primary olivine and associated serpentine alteration of olivine in the subsill ultramafic rocks indicate a metamorphic history differing from that of the BRS suite.

If the metamorphism is modelled by the system $\text{CaO-MgO-SiO}_2\text{-H}_2\text{O-CO}_2$ the presence of serpentine indicates that the fluid phase present during metamorphism contained little CO_2 , because serpentine is stable only at very small $x\text{CO}_2$ values (Coats and Buchan, 1979; Trommsdorf & Evans, 1977; Winkler, 1974). The principal phases recognized at the Maskwa pit are forsterite, talc and dolomite which limit the $x\text{CO}_2$ to greater than ~ 0.10 . At more than 10 mole percent CO_2 in this fluid the stable assemblages are magnesite and quartz or magnesite and talc. Thus, assuming low $x\text{CO}_2$ in a homogeneous fluid, two possibilities exist for the formation of a forsterite + dolomite + talc assemblage as observed at Maskwa-Dumbarton and outlined by Coats and Buchan (1979; figure 10);

(i) serpentine $\rightarrow$ talc + carbonate $\rightarrow$ forsterite

path A - B of figure 10, or

(ii) forsterite + diopside $\rightarrow$ tremolite + carbonate $\rightarrow$ tremolite + dolomite $\rightarrow$ talc + dolomite

path C - E of figure 10.

The absence of tremolite as a significant phase in the Maskwa West ultramafic rocks favours the first sequence of reactions. However, both metamorphic paths for the BRS serpentinites indicate amphibolite facies metamorphism.

The presence of serpentine in ultramafic rocks of both suites suggests that the metamorphic fluid contained similar low $x\text{CO}_2$ content. However, amphibolite facies metamorphism is not apparent in subsill ultramafics. Petrologic and field evidence suggests a greater initial abundance of olivine in BRS ultramafic lithologies. In the presence of sufficient volumes of the same low $x\text{CO}_2$ - H_2O bearing metamorphic fluid, all olivine in both suites should

have been hydrated. Complete serpentinization and carbonatization of subsill olivine-bearing units may have been avoided if they were protected by enclosing impermeable units precluding any access to the metamorphic fluid or if intrusion of the subsill ultramafic rocks took place subsequent to initial serpentinization and carbonatization. Spatially limited hydration and carbonatization of the subsill ultramafic suite, as previously outlined for the BRS ultramafics under metamorphism, is tenuous given the geometry of the ultramafic units at Maskwa-Dumbarton. Subsill ultramafic olivine pyroxenites are interpreted to underlie and crosscut the BRS ultramafics. Entirely enclosing volcanic and granitic units to the subsill are not apparent.

Sulphide Deposits

The metal association of the sulphide deposits hosted in the BRS is $\text{Cr-Ni} \pm \text{Cu-PGE}$ and is distinctly different from the $\text{Cu} \pm \text{Ni-Au}$ association of sulphide showings in the subsill and appear spatially related to higher grade carbonatized areas. Increased sulphide concentration at the Maskwa pit can be traced into underlying volcanic units. Based on field observations it is suggested that the subsill-hosted sulphide showings are a result of sulphide saturation due to assimilation, in part, of a banded iron formation which is truncated by subsill lithologies in this region.

Geochemistry

Whole-rock and mineral chemistry conducted on selected samples show differing elemental abundances and divergent differentiation trends among BRS and subsill lithologies. Analyses of individual samples represent only a single point in the differentiation history of its original bulk composition. Whole-rock data shows that subsill gabbros contain a greater proportion of Mg and less Al, Fe & Ti than BRS gabbros. Minor oxides MnO , TiO_2 and P_2O_5 show more restricted ranges in rocks of the subsill while Na and K are relatively enriched. Subsill gabbros define 2 fields on the $\text{Na}_2\text{O} + \text{K}_2\text{O} - \text{Al}_2\text{O}_3 - \text{MgO}$ projection and discriminate the 2 gabbros observed in the field. Although ultramafic rocks of the BRS show consistent compositions, gabbros from other BRS properties do not contain the same oxide proportions as at Maskwa-Dumbarton and appear less differentiated. The greater variation in composition of BRS lithologies suggests a greater degree of differentiation or may indicate more alteration during metamorphism resulting in redistribution of the elements. The latter is supported by an increased distribution of oxide abundances in Maskwa-Dumbarton BRS lithologies relative to similar lithologies at other BRS properties such as Petra-Bar and National-Ledin.

Mineral chemistry showed a variation in olivine composition from Fo_{68-84} , anomalous Cr in chlorites and serpentines, and divergent differentiation trends in spinel. The range in Fo

contents of olivine gives some indication of differentiation in subsill lithologies. Cr and Mg contents were greater in spinel of the BRS indicating an earlier differentiate or different bulk composition than subsill spinel. This observation is supported by divergent trends on a MnO versus TiO₂ projection. Individual spinel are zoned suggesting element exchange with adjacent minerals. This is supported by elevated Cr, Al & Ti concentrations in serpentine and elevated Cr in chlorite. This zoning is more prominent in spinel from the BRS ultramafics and may be the result of higher metamorphic grade in this unit at Maskwa-Dumbarton.

Geophysical Response

Total magnetic field data were used to distinguish mafic and ultramafic lithologies and horizontal loop electromagnetic data were used when interpreting faults. Ultramafic rocks of the BRS were marginally more magnetic than those of the subsill. The shape of the magnetic response was significantly different. Response from BRS ultramafic lithologies was indicative of an elongate body conformable with the regional strike whereas the subsill response was irregular in shape. As stated previously, this may be interpreted to result from varying degrees of deformation as would be expected if the subsill intrusive suite postdated the BRS. Major faults were clearly indicated by breaks in numerous HLEM conductors.

CHAPTER V CONCLUSION

The bulk of all evidence presented above suggests that the subsill intrusive body at Maskwa-Dumbarton comprises a distinct suite of rocks related only spatially to the rocks of the BRS. This subsill suite intrudes the BRS and does not appear to represent a feeder dyke to the BRS as suggested by Coats et al. (1979) and Trueman (1981). It is the author's contention that the differences between the BRS and subsill intrusive suites, based primarily on field evidence and metamorphic history, are an indication of time separated intrusions. Evidence in support of this conclusion combines field relations, metamorphic grade, degree of deformation, whole-rock oxide abundances and spinel, chlorite, serpentine and olivine compositions. The subsill suite comprises at least 2 gabbros, the diabasic-textured and medium-grained gabbros, which show clear cross-cutting relationships and are therefore separated in time. The subsill pyroxenite is more enigmatic but, based on metamorphic grade, spinel compositions and the presence of primary olivine, is also suggestive of a distinctly separate intrusion. A proposed schematic evolution of the area is presented in figure 13.

Field relations at Maskwa-Dumbarton indicate that the subsill rocks crosscut the BRS. In the area of the proposed feeder dyke, multiple intrusions of the subsill lithologies are recognized. BRS lithologies in this area show greater deformation and significantly higher metamorphic grade than subsill lithologies. Apparent differences in metamorphic grade may result from enclaves unaffected by metamorphic fluids due to retention of water in an envelope of impermeable rocks. However, this interpretation is not favoured due to the presence, and close spatial relationship, of primary olivine-bearing subsill ultramafic and high grade BRS ultramafic rocks. The two suites show differing whole-rock oxide proportions and divergent differentiation trends. Geochemical heterogeneities between BRS and subsill lithologies may result from relative depletion of elements from the same source of different feeders from a stratified magma source giving rise to apparent bulk compositions. However, this does not explain the reverse Fe/Mg relationship between the mafic and ultramafic rocks of both suites. The apparent cross-cutting nature of subsill lithologies into the BRS is supported by observed cross-cutting relationships in subsill gabbros.

Mineralogical evidence from the study area and adjacent BRS localities suggests serpentinization of BRS ultramafic rocks took place after regional metamorphism. BRS peridotites and dunites at Maskwa-Dumbarton only were hydrated prior this metamorphism, leading to the generation of metamorphic olivine during regional metamorphism. Subsequent regional serpentinization affected all BRS ultramafics and in part affected the subsill ultramafics.

Figure 13 Proposed schematic evolution of the BRS and subsill intrusive suite at Maskwa-Dumbarton.

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APPENDIX I - TABLES

Analytical Results

Eighty-eight samples were submitted for whole-rock and precious metal analyses to Bondar-Clegg Ltd., X-ray Assay Laboratories Ltd. and Lakefield Research Ltd. An additional 15 samples were forwarded to Carleton University for semi-quantitative electron microprobe analysis. Samples c39703 to c39776 were collected at Maskwa-Dumbarton by R. Talkington. Samples prefixed nss- were collected by the author at Maskwa-Dumbarton, unless otherwise noted. Other sample data was retrieved from literature as noted also in tables 1-16. Sample numbers correspond with location numbers shown in figure 14.

Geochemical Analyses

Whole-rock samples were crushed to -200 mesh. A 100 mg sample was fused with lithium metaborate in a graphite crucible at 1000°C in a muffle furnace. The resultant glass bead was dissolved in 10% HCl and analyzed by atomic emission spectrometry on an Atcom 1100 Jarrell-Ash (DCP). Detection limits are 0.01% for WR majors and 10ppm for WR minors. LOI was determined by gravimetric method. Detection limit is 0.05%. Ni and Cu analyses were done by XRF at X-ray Assay Laboratories Ltd. (XRAL), by HNO₃-HCl-HF-HCO₄ extraction and flame AA at Bondar-Clegg Ltd. and by XRF at Lakefield Research Laboratories using a Philips PW1404 x-ray fluorescence instrument. Values below 0.1% were checked by AAS using a Perkin Elmer PE5000 Atomic Absorption Spectrophotometer. Detection limits are 10ppm. Rare earth element (REE) determinations were carried out by XRAL using ICPMS. Whole-rock and REE analyses are listed in the accompanying tables.

Microprobe Analyses

Minerals were analyzed by the energy dispersive method (EDS) using a Cambridge Microscan V Electron Microprobe operated at a 20kV accelerating potential and an absorbed current of 9nA measured on an amphibole standard. Counting times varied between 100 and 150 seconds. Computer program EDDI developed at the Geological Survey of Canada for analyses of rock forming minerals was used to quantify the EDS spectra. Natural and synthetic mineral standards were utilized. Detection limits were approximately ± 0.1 oxide wt.% for all elements. All analyses were conducted by Peter Jones at Carleton University in Ottawa.

Table 1 WHOLE-ROCK DATA

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	C38703	C38704	C38705	C38706	C38708	C38709	C38710	C38711	C38712	C38713	C38714	C38715	C38716	C38717	C38718	C38719
SiO ₂	50.73	49.72	48.81	48.82	51.06	49.61	50.14	68.03	46.81	49.94	38.63	44.74	46.28	46.73	46.03	51.85
Al ₂ O ₃	13.95	2.88	16.84	14.43	4.31	7.08	18.11	15.35	15.30	14.88	0.83	3.71	2.20	2.11	2.08	4.08
Fe ₂ O ₃	3.03	33.94	3.23	3.51	3.86	3.92	11.58	1.40	2.75	3.72	35.77	14.32	11.18	10.37	9.90	3.96
FeO	10.01	0.00	8.67	10.42	9.81	10.46	0.00	3.01	9.59	9.95	0.00	0.00	6.82	5.99	6.31	9.13
MgO	8.31	2.78	8.20	7.97	19.21	14.69	6.97	1.71	11.93	7.06	14.16	35.96	26.23	25.13	29.23	15.52
CaO	9.64	9.64	10.29	11.12	10.66	12.17	11.08	2.69	9.21	8.40	8.23	0.87	6.85	9.11	6.28	14.20
Na ₂ O	2.36	0.32	2.13	2.16	0.22	0.71	2.29	4.52	0.97	2.92	0.04	0.05	0.06	0.05	0.04	0.28
K ₂ O	1.02	0.19	1.30	0.46	0.07	0.31	0.58	2.54	2.73	1.47	0.04	0.02	0.03	0.02	0.02	0.14
TiO ₂	0.72	0.17	0.38	0.86	0.46	0.78	0.99	0.56	0.50	1.31	2.16	0.17	0.31	0.28	0.28	0.50
P ₂ O ₅	0.07	0.02	0.03	0.07	0.05	0.07	0.06	0.12	0.04	0.11	0.08	0.02	0.03	0.03	0.02	0.04
MnO	0.16	0.33	0.12	0.18	0.29	0.20	0.18	0.07	0.17	0.24	0.26	0.14	0.20	0.18	0.21	0.28
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	C38720	C38721	C38722	C38723	C38724	C38725	C38726	C38727	C38728	C38729	C38730	C38732	C38733	C38734	C38735	C38742
SiO ₂	52.17	50.19	47.70	45.46	56.23	44.89	49.72	50.97	50.97	50.17	51.73	49.34	45.86	50.68	49.71	51.28
Al ₂ O ₃	2.28	14.34	2.93	1.98	12.87	2.10	3.59	14.10	14.41	14.78	14.57	13.97	16.27	3.72	7.48	3.85
Fe ₂ O ₃	3.10	3.43	7.79	13.26	3.22	11.30	4.63	4.03	3.24	4.43	4.35	5.53	4.04	4.50	3.77	3.32
FeO	7.42	9.80	7.57	6.21	9.25	5.76	7.37	9.87	8.77	9.45	8.91	10.75	10.30	8.79	8.56	8.82
MgO	18.46	8.23	24.44	26.32	4.72	30.81	19.69	6.77	8.04	6.77	6.75	6.25	6.95	16.86	15.79	19.20
CaO	15.78	9.65	8.91	6.23	6.65	4.54	14.11	10.58	10.99	9.99	8.22	8.17	13.33	14.20	12.73	12.77
Na ₂ O	0.18	2.64	0.02	0.02	5.01	0.07	0.18	1.98	2.58	2.09	2.50	2.78	1.04	0.36	1.02	0.15
K ₂ O	0.06	0.68	0.02	0.02	0.21	0.03	0.06	0.26	0.19	0.83	1.50	1.17	0.38	0.11	0.19	0.07
TiO ₂	0.30	0.73	0.35	0.26	1.45	0.28	0.39	1.21	0.62	1.13	1.11	1.53	1.32	0.47	0.52	0.46
P ₂ O ₅	0.03	0.06	0.04	0.03	0.14	0.03	0.04	0.10	0.04	0.10	0.10	0.13	0.11	0.04	0.02	0.04
MnO	0.22	0.25	0.22	0.20	0.25	0.19	0.22	0.23	0.25	0.26	0.26	0.38	0.30	0.27	0.21	0.24
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 2 WHOLE-ROCK DATA

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	C39744	C39745	C39746	C39747	C39748	C39749	C39751	C39752	C39753	C39754	C39756	C39757	C39760	C39761	C39762	C39763
SiO ₂	50.34	51.01	45.48	48.35	85.90	88.29	48.83	56.33	48.15	54.57	49.17	54.16	51.10	51.87	48.49	47.37
Al ₂ O ₃	16.01	15.76	24.99	26.64	2.62	2.01	14.60	14.48	14.76	15.45	15.68	15.90	14.49	15.00	15.64	15.12
Fe ₂ O ₃	3.02	3.03	5.28	2.10	6.85	6.45	3.12	2.96	3.26	3.11	5.91	3.12	5.53	3.60	2.82	3.63
FeO	7.45	7.07	1.84	2.52	0.00	0.00	8.16	6.54	10.08	5.69	10.18	7.95	10.16	10.30	8.07	9.67
MgO	8.51	8.68	3.01	2.95	1.83	1.42	10.87	5.54	10.04	5.21	5.15	5.51	5.12	5.00	10.48	10.28
CaO	11.98	11.41	17.03	13.72	2.18	1.38	11.48	7.93	9.28	11.18	7.67	8.20	8.45	9.81	12.10	11.69
Na ₂ O	1.56	1.89	1.52	2.92	0.12	0.10	1.62	3.90	1.54	2.82	3.09	3.97	2.90	3.10	1.26	1.14
K ₂ O	0.34	0.38	0.33	0.31	0.26	0.17	0.62	0.51	2.18	0.47	1.99	0.17	1.16	0.31	0.38	0.32
TiO ₂	0.51	0.49	0.39	0.39	0.13	0.09	0.50	1.42	0.49	1.08	0.84	0.80	0.74	0.75	0.51	0.51
P ₂ O ₅	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.16	0.04	0.18	0.10	0.06	0.07	0.06	0.04	0.04
MnO	0.24	0.24	0.09	0.06	0.08	0.06	0.17	0.23	0.20	0.18	0.22	0.16	0.28	0.20	0.21	0.23
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	C39764	C39765	C39766	C39769	C39770	C39771	C39772	C39773	C39774	C39776	C39776	N99-47	N99-96	N99-92	N99-156	N99-170
SiO ₂	48.14	47.99	47.66	47.26	49.62	51.27	49.74	42.71	33.77	43.17	44.11	54.54	38.25	53.17	45.85	61.38
Al ₂ O ₃	14.74	14.29	15.54	2.94	17.18	13.77	15.16	9.09	5.32	13.12	2.07	3.45	7.22	13.64	4.44	15.07
Fe ₂ O ₃	3.61	3.52	3.64	9.35	4.25	5.23	4.04	12.74	26.25	7.61	12.84	0.87	14.78	1.07	10.02	0.83
FeO	9.02	9.96	10.00	5.52	9.40	12.97	9.60	12.54	12.89	13.12	6.90	8.63	5.97	11.89	7.01	6.99
MgO	10.53	10.56	8.86	24.74	4.81	4.83	7.30	10.91	9.80	6.92	27.51	16.87	29.72	5.73	25.61	3.43
CaO	11.43	10.86	11.81	9.46	10.61	5.47	9.81	10.81	11.11	14.02	6.15	14.52	3.73	8.75	6.34	5.13
Na ₂ O	1.33	1.32	1.39	0.10	1.98	1.73	2.63	0.53	0.39	0.53	0.02	0.31	0.00	2.52	0.00	4.59
K ₂ O	0.43	0.70	0.28	0.04	0.95	2.98	0.27	0.18	0.11	0.29	0.02	0.11	0.00	0.99	0.00	1.63
TiO ₂	0.49	0.49	0.52	0.35	0.94	1.46	1.04	0.26	0.18	0.90	0.22	0.37	0.14	1.43	0.37	0.81
P ₂ O ₅	0.04	0.04	0.04	0.03	0.08	0.14	0.08	0.03	0.02	0.03	0.03	0.09	0.00	0.55	0.18	0.00
MnO	0.24	0.27	0.26	0.21	0.18	0.15	0.33	0.20	0.16	0.29	0.23	0.26	0.19	0.26	0.18	0.14
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Maskwe-Dumberton property data.

Table 3 WHOLE-ROCK DATA

NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)																		
N88-172	N88-176	N88-177	N88-178	WA4105 Wentz	76-87 @340'	76-87 @563'	85-170	87-556	838-164	848-149	868-206	888-120	J63-12	J63-14	J63-31			
SiO ₂	61.43	53.63	49.81	55.88	40.16	40.83	42.76	40.89	40.73	50.76	52.57	50.23	48.38	50.44	50.90	44.92		
Al ₂ O ₃	15.21	13.46	14.73	14.26	2.11	1.33	1.53	2.33	2.66	2.91	3.03	3.23	2.57	2.53	2.41	6.09		
Fe ₂ O ₃	1.38	2.14	0.73	1.48	21.17	12.88	14.19	12.08	9.24	7.34	1.74	4.76	5.81	4.23	3.73	7.50		
FeO	6.02	10.91	15.51	10.09	24.69	4.95	4.85	4.40	3.63	5.21	10.58	7.80	7.98	7.87	5.25	4.79		
MgO	3.23	5.16	7.09	4.50	2.29	26.19	34.61	37.86	41.32	17.03	19.91	20.75	22.20	18.71	18.48	28.89		
CaO	5.83	9.91	6.52	7.14	8.46	13.21	1.56	1.59	1.84	15.50	10.07	11.49	12.16	15.15	18.38	7.01		
Na ₂ O	4.45	2.46	2.32	3.13	0.17	0.02	0.01	0.05	0.04	0.34	0.36	0.20	0.10	0.13	0.16	0.06		
K ₂ O	1.39	0.43	1.61	1.56	0.12	0.02	0.01	0.01	0.02	0.09	0.83	0.66	0.05	0.05	0.02	0.05		
TiO ₂	0.78	1.57	1.26	1.42	0.47	0.12	0.13	0.34	0.13	0.38	0.35	0.37	0.34	0.38	0.28	0.23		
P ₂ O ₅	0.14	0.07	0.17	0.30	0.04	0.28	0.23	0.31	0.24	0.24	0.18	0.30	0.18	0.26	0.17	0.29		
MnO	0.14	0.26	0.25	0.24	0.32	0.17	0.12	0.14	0.15	0.20	0.38	0.21	0.23	0.25	0.22	0.17		
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		

NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)																		
J63-44	J63-67	J64-20C	J64-23A	J64-24B	J65-6A	J65-19	J65-25	N88-131°	N88-139°	N88-142°	N88-145°	N88-144°	ERS° (CN)	19°	24°			
SiO ₂	51.71	37.09	55.01	41.64	41.99	39.36	48.91	44.99	55.05	52.62	51.29	54.42	50.83	49.86	42.49			
Al ₂ O ₃	3.00	2.97	1.68	2.42	2.90	6.50	2.10	2.60	15.68	16.67	15.83	13.98	15.57	19.33	26.98			
Fe ₂ O ₃	2.98	13.94	2.08	11.52	12.74	11.48	4.32	9.48	0.98	1.46	0.10	1.09	1.40	0.00	0.55			
FeO	7.84	4.31	7.99	5.29	9.34	2.94	7.77	4.39	7.40	7.92	9.59	8.99	9.23	6.03	4.32			
MgO	18.64	39.92	19.65	35.82	23.02	34.46	22.30	28.63	6.28	6.13	8.59	6.13	7.40	15.68	10.45			
CaO	14.70	0.93	12.69	2.58	8.70	4.42	13.58	8.93	8.39	10.30	11.38	11.37	11.03	7.82	11.99			
Na ₂ O	0.26	0.02	0.17	0.02	0.11	0.04	0.07	0.08	4.20	3.25	1.86	2.22	2.82	1.64	2.83			
K ₂ O	0.02	0.00	0.02	0.02	0.04	0.00	0.02	0.05	0.73	0.52	0.41	0.43	0.59	0.64	0.39			
TiO ₂	0.40	0.20	0.21	0.18	0.44	0.21	0.29	0.26	1.14	0.82	0.53	1.08	0.95	-	-			
P ₂ O ₅	0.21	0.48	0.22	0.37	0.52	0.40	0.40	0.39	0.01	0.17	0.21	0.10	0.00	-	-			
MnO	0.24	0.16	0.28	0.14	0.20	0.19	0.24	0.20	0.14	0.14	0.21	0.18	0.18	0.02	-			
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			

Meekwe-Dumbarton data except for: ° Petra-Bar property
 ° Chrome property

Table 4
WHOLE-ROCK DATA

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	NB-136 ^a	NB-136 ^b	WA11017 25 ^c	WA1101 ^a	WA1102 ^a	WA1103 ^a	WA1104 ^a	WA1111 ^a	WA1112 ^a	WA1113 ^a	WA1114 ^a	WA1115 ^a	WA1116 ^a	WA1117 ^a	WA1118 ^a	WA1119 ^a
SiO ₂	41.59	49.51	40.96	49.88	49.47	50.83	46.73	58.42	61.63	52.86	55.19	49.68	47.29	49.25	51.03	49.94
Al ₂ O ₃	6.73	2.44	5.73	23.49	16.36	15.10	16.65	16.59	15.15	15.24	13.50	14.83	15.80	14.02	15.48	15.21
Fe ₂ O ₃	10.74	8.48	8.81	0.04	1.67	1.28	1.77	0.90	1.15	1.11	1.81	2.41	3.03	2.20	3.20	2.35
MgO	4.99	3.40	3.80	5.71	11.19	10.88	13.05	7.96	7.19	10.81	9.35	10.54	9.96	11.38	10.24	11.04
CaO	3.62	9.14	0.85	13.16	7.72	7.88	8.14	5.24	4.47	6.18	6.26	7.62	7.44	8.73	6.25	9.91
Na ₂ O	<0.1	<0.1	<0.1	2.20	2.18	1.81	2.62	4.17	3.76	3.09	2.56	2.19	1.75	1.56	1.56	1.54
K ₂ O	0.05	0.04	0.06	0.26	0.15	0.26	0.32	0.29	0.54	0.37	0.13	0.15	0.11	0.19	0.17	0.19
TiO ₂	0.13	0.08	0.15	--	0.87	0.90	1.08	0.86	0.77	1.02	0.95	0.95	1.01	0.94	1.25	0.99
P ₂ O ₅	0.02	0.02	0.02	--	0.00	0.04	0.18	0.03	0.32	0.00	0.06	0.41	0.00	0.10	0.00	0.35
MnO	0.16	0.19	0.16	--	0.21	0.24	0.35	0.13	0.12	0.33	0.24	0.33	0.22	0.23	0.23	0.16
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)

	NORMALIZED WEIGHT PERCENT (recalculated to 100% volatile-free)															
	NB-64	NB-174	NB-174	74-41	76-94	WA18364	NB-75	WA18320	M-20 ^d	M-20 ^d	M-21 ^d	M-20 ^d	M-21 ^d	M-20 ^d	M-21 ^d	M-20 ^d
SiO ₂	44.96	61.51	54.78	26.84	32.45	29.09	49.43	54.69	43.51	46.29	50.21	40.42	40.42	40.42	40.42	40.42
Al ₂ O ₃	6.74	9.34	11.57	0.91	0.77	1.10	3.02	9.75	8.07	25.62	14.57	10.02	14.57	10.02	14.57	10.02
Fe ₂ O ₃	32.76	19.16	21.42	42.39	33.41	30.16	13.19	25.79	15.04	7.03	12.76	14.78	12.76	14.78	12.76	14.78
FeO	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
MgO	2.74	6.17	6.39	18.69	29.78	25.06	19.57	1.85	28.12	4.69	7.72	30.46	7.72	30.46	7.72	30.46
CaO	9.79	1.76	2.89	10.63	3.19	13.53	12.11	4.46	4.72	13.99	11.44	3.60	11.44	3.60	11.44	3.60
Na ₂ O	1.65	0.93	1.52	0.01	0.05	0.1	1.81	2.64	0.05	1.23	1.92	0.05	1.92	0.05	1.92	0.05
K ₂ O	0.70	0.59	0.59	0.04	0.05	0.03	0.10	0.13	0.02	0.56	0.20	0.03	0.20	0.03	0.20	0.03
TiO ₂	0.38	0.16	0.49	0.03	0.06	0.09	0.37	0.64	0.20	0.41	0.88	0.24	0.41	0.88	0.24	0.24
P ₂ O ₅	0.03	0.16	0.16	0.11	0.10	0.09	0.17	0.11	0.07	0.07	0.11	0.09	0.11	0.09	0.11	0.09
MnO	0.23	0.22	0.19	0.11	0.12	0.21	0.23	0.04	0.20	0.11	0.19	0.20	0.11	0.19	0.19	0.20
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Maskwa-Dumarton property data except for:

- ^a Petro-Bar property
- ^b Chroma property
- ^c National-Leadin property
- ^d Mayville property

Table 5 OLIVINE COMPOSITION (Mg,Fe²⁺,Mn,Ni)₂ [SiO₄] - MICROPROBE DATA

		NORMALIZED WEIGHT PERCENT																	
		N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81	N88-81		
		O81-1	O81-2	O81-3	O81-4	O81-5	O81-6	O81-7	O81-8	O81-9	O81-10	O81-11	O81-12	O81-13	O81-14	O81-15	O81-16		
SiO ₂		37.08	37.39	37.11	37.15	37.41	37.04	37.33	37.22	39.78	39.82	40.18	37.25	38.16	37.32	36.74	23.22		
MgO		34.27	34.06	34.89	35.13	35.64	35.23	35.73	36.13	43.70	43.62	43.30	37.32	36.74	37.32	36.74	23.22		
FeO		27.43	27.48	26.82	26.72	25.92	26.73	25.92	25.63	15.81	15.73	15.61	23.50	23.22	23.50	23.22	1.56		
Mn		0.94	0.88	0.93	0.77	0.82	0.77	0.81	0.76	0.49	0.46	0.58	1.56	1.56	1.56	1.56	0.37		
NiO		0.28	0.18	0.25	0.23	0.21	0.23	0.21	0.26	0.22	0.37	0.33	0.37	0.32	0.37	0.32	0.32		
ATOMIC FORMULA (4 oxygen basis)																			
Si		0.994	1.001	0.992	0.991	0.994	0.989	0.992	0.989	1.004	1.005	1.013	0.984	1.004	0.984	1.004			
Mg		1.370	1.359	1.390	1.398	1.412	1.402	1.416	1.431	1.644	1.641	1.627	1.470	1.440	1.470	1.440			
Fe		0.615	0.615	0.600	0.597	0.576	0.597	0.577	0.569	0.334	0.332	0.329	0.519	0.511	0.519	0.511			
Mn		0.021	0.020	0.021	0.017	0.018	0.017	0.018	0.017	0.011	0.010	0.012	0.035	0.035	0.035	0.035			
Ni		0.006	0.004	0.005	0.005	0.005	0.005	0.004	0.006	0.004	0.007	0.007	0.008	0.007	0.008	0.007			
TOTAL*		2.012	1.998	2.016	2.017	2.011	2.021	2.015	2.023	1.993	1.990	1.975	2.032	1.993	2.032	1.993			
Fe		68	68	69	69	70	69	70	71	83	83	82	72	72	72	72			
ATOMIC FORMULA (4 oxygen basis)																			
SiO ₂		39.50	39.87	39.84	40.05	39.08	38.59	38.87	38.92	38.41	38.46	38.53	37.93	37.93	37.93	37.93			
MgO		44.69	44.48	44.09	44.37	41.27	41.38	41.58	41.88	39.67	38.98	39.77	39.91	39.91	39.77	39.91			
FeO		14.99	14.85	15.13	14.70	19.00	18.20	18.93	18.63	20.79	21.51	20.74	21.31	21.31	20.74	21.31			
Mn		0.57	0.54	0.64	0.61	0.43	0.54	0.42	0.52	0.39	0.74	0.69	0.80	0.80	0.69	0.80			
NiO		0.25	0.26	0.30	0.27	0.22	0.29	0.20	0.25	0.24	0.31	0.27	0.25	0.25	0.27	0.25			
ATOMIC FORMULA (4 oxygen basis)																			
Si		0.995	1.003	1.003	1.006	1.001	0.992	0.996	0.997	0.996	1.000	0.998	0.986	0.986	0.998	0.986			
Mg		1.678	1.666	1.655	1.661	1.576	1.586	1.589	1.591	1.533	1.511	1.535	1.546	1.546	1.535	1.546			
Fe		0.316	0.312	0.319	0.309	0.407	0.413	0.406	0.399	0.451	0.468	0.449	0.463	0.463	0.449	0.463			
Mn		0.012	0.012	0.014	0.013	0.009	0.012	0.009	0.011	0.020	0.016	0.015	0.013	0.013	0.015	0.013			
Ni		0.005	0.005	0.006	0.005	0.004	0.006	0.004	0.005	0.005	0.006	0.006	0.005	0.005	0.006	0.005			
TOTAL*		2.011	1.994	1.994	1.988	1.996	2.017	2.008	2.006	2.009	2.001	2.005	2.027	2.027	2.005	2.027			
Fe		83	84	83	84	79	79	79	79	76	76	77	76	76	77	76			

*(Mg,Fe,Mn,Ni)

Table 6 SPINEL COMPOSITION (Fe^{+2} , Mg, Mn, Ni, Zn)(Cr, Fe^{+3} , Ti, Al) $_2$ O_4 - MICROPROBE DATA

NORMALIZED WEIGHT PERCENT																	
	N88-67 CR67-1	N88-67 CR67-2	N88-67 CR67-3	N88-67 CR67-4	N88-67 CR67-5	N88-67 CR67-6	C38715 CR715-1	C38715 CR715-2	C38715 CR715-3	C38715 CR715-4	C38715 CR715-5	C38715 CR715-6	N88-68 CR68-1	N88-68 CR68-2	N88-68 CR68-3	N88-68 CR68-4	
	rim	core	rim	core	rim	core	rim	core	rim	core	rim	core	rim	rim	core	core	
TiO ₂	1.13	2.41	0.95	2.27	2.42	2.65	0.10	0.37	0.20	0.32	0.65	1.23	0.13	0.18	0.22	0.24	
Al ₂ O ₃	0.00	0.11	0.00	0.00	0.00	0.07	0.00	0.10	0.00	0.00	0.16	0.11	0.00	0.00	0.00	0.05	
Cr ₂ O ₃	9.87	30.61	10.01	18.16	20.12	26.47	9.53	23.50	8.43	13.64	27.93	35.94	6.35	5.40	5.42	5.99	
Fe ₂ O ₃	56.86	33.47	57.03	46.51	44.16	37.27	59.09	44.39	60.01	54.58	39.38	30.33	62.26	63.14	63.20	62.39	
FeO	31.38	30.84	31.16	31.26	31.30	31.31	30.83	28.86	30.79	29.87	28.69	28.19	31.01	31.01	30.65	31.19	
MgO	0.19	0.77	0.12	0.68	0.58	0.77	0.00	0.30	0.00	0.20	0.48	0.83	0.00	0.00	0.29	0.01	
MnO	0.30	0.97	0.43	0.71	0.83	0.96	0.42	1.68	0.42	0.95	1.91	2.18	0.22	0.17	0.13	0.13	
NiO	0.27	0.24	0.23	0.16	0.26	0.19	0.03	0.09	0.04	0.14	0.00	0.09	0.03	0.10	0.09	0.00	
ZnO	0.00	0.58	0.07	0.25	0.33	0.31	0.00	0.71	0.11	0.30	0.80	1.10	0.00	0.00	0.00	0.00	
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	
ATOMIC FORMULA (32 oxygen basis)																	
Ti	0.260	0.544	0.221	0.519	0.551	0.602	0.023	0.085	0.048	0.075	0.147	0.278	0.031	0.041	0.052	0.054	
Al	0.000	0.039	0.000	0.000	0.000	0.025	0.000	0.037	0.000	0.000	0.057	0.039	0.000	0.000	0.000	0.017	
Cr	2.388	7.286	2.424	4.352	4.822	6.312	2.312	5.644	2.045	3.299	6.683	8.542	1.543	1.312	1.315	1.455	
Fe ⁺³	13.092	7.595	13.136	10.611	10.079	8.459	13.643	10.149	13.860	12.553	8.968	6.864	14.396	14.506	14.582	14.421	
	15.740	15.454	15.781	15.482	15.452	15.398	15.978	15.915	15.953	15.927	15.855	15.723	15.970	15.959	15.949	15.947	
Fe ⁺²	8.030	7.765	7.978	7.930	7.935	7.899	7.907	7.334	7.904	7.634	7.263	7.087	7.967	7.973	7.860	8.011	
Mg	0.066	0.345	0.055	0.306	0.263	0.344	0.000	0.135	0.000	0.090	0.215	0.369	0.000	0.000	0.132	0.004	
Mn	0.079	0.248	0.114	0.184	0.214	0.246	0.109	0.434	0.107	0.245	0.489	0.553	0.056	0.044	0.035	0.035	
Ni	0.066	0.059	0.057	0.041	0.061	0.046	0.007	0.022	0.011	0.035	0.000	0.022	0.007	0.024	0.022	0.001	
Zn	0.000	0.128	0.015	0.067	0.074	0.069	0.000	0.160	0.025	0.068	0.179	0.244	0.001	0.000	0.000	0.000	
	8.261	8.545	8.219	8.518	8.547	8.604	8.023	8.085	8.047	8.072	8.146	8.275	8.031	8.041	8.049	8.051	
CHROM*	14.76	43.31	15.04	26.04	29.02	37.52	14.45	34.92	12.78	20.37	40.51	50.53	9.64	8.20	8.08	9.09	

* mole percent end member chromite

Maskwa-Dumbarton property data.

Table 8 SPINEL COMPOSITION ($\text{Fe}^{+2}, \text{Mg}, \text{Mn}, \text{Ni}, \text{Zn}$)($\text{Cr}, \text{Fe}^{+3}, \text{Ti}, \text{Al}$) $_2 \text{O}_4$ - MICROPROBE DATA

NORMALIZED WEIGHT PERCENT												
	C39718 CR718-1	C39718 CR718-2	C39718 CR718-3	C39718 CR718-4	N88-81 CR81-1	N88-81 CR81-2	C397188 CR718-8	P-8° WA4223	P-8° WA4235	P-8° WA4238	P-8° WA4240	P-8° WA4243
							core	core	core	core	core	core
TiO_2	0.60	0.71	0.59	1.78	0.44	2.53	3.00	0.27	0.61	0.73	1.08	1.11
Al_2O_3	0.12	0.00	0.00	0.00	0.11	0.00	0.00	0.04	0.19	0.23	0.41	0.10
Cr_2O_3	11.70	9.87	8.50	14.35	0.44	0.15	18.15	12.35	27.16	29.86	12.73	13.78
Fe_2O_3	55.81	57.71	59.31	51.04	87.62	63.93	44.95	56.27	41.23	39.27	54.38	53.15
FeO	31.45	30.79	30.98	31.76	31.08	33.16	31.99	29.70	26.79	27.02	28.31	30.30
MgO	0.00	0.25	0.25	0.22	0.14	0.00	0.31	0.75	2.29	2.12	1.77	0.85
MnO	0.23	0.25	0.17	0.39	0.04	0.14	0.60	0.47	1.26	1.43	0.74	0.36
NiO	0.00	0.31	0.20	0.29	0.13	0.09	0.37	0.12	0.20	0.10	0.32	0.15
ZnO	0.09	0.11	0.00	0.17	0.00	0.00	0.73	0.03	0.27	0.44	0.23	0.18
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100

ATOMIC FORMULA (32 oxygen basis)

Ti	0.137	0.163	0.136	0.408	0.104	0.586	0.687
Al	0.045	0.000	0.000	0.000	0.041	0.000	0.000
Cr	2.831	2.388	2.058	3.461	0.106	0.037	4.362
Fe^{+3}	12.853	13.287	13.669	11.720	15.645	14.791	10.264
	15.866	15.838	15.863	15.589	15.896	15.414	15.313
Fe^{+2}	8.052	7.882	7.937	8.102	7.991	8.527	8.136
Mg	0.000	0.113	0.111	0.099	0.067	0.000	0.142
Mn	0.061	0.065	0.042	0.101	0.012	0.036	0.155
Ni	0.001	0.076	0.049	0.071	0.034	0.021	0.091
Zn	0.020	0.028	0.000	0.040	0.000	0.000	0.183
	8.134	8.162	8.139	8.413	8.104	8.584	8.687

CHROM* 17.69 14.70 12.68 21.35 0.66 0.23 26.70 * mole percent end member

Mankwe-Dumbarton property data except for:

* samples from Petra-Bar property (Dumaseq, 1989), and data from other BRS localities (Watkinson et al., 1982)

Chrome: Chrome property

Page : Page property

Table 9 SPINEL COMPOSITION (Fe^{+2} , Mg, Mn, Ni, Zn) (Cr , Fe^{+3} , Ti, Al)₂ O₄ - MICROPROBE DATA

	NORMALIZED WEIGHT PERCENT			
	N-L 1	N-L 2	Wards 3	Wards 4
	core	core	core	core
TiO ₂	0.23	0.26	0.57	0.50
Al ₂ O ₃	23.33	27.59	19.23	14.66
Cr ₂ O ₃	36.64	35.36	38.26	44.08
Fe ₂ O ₃	5.51	5.48	7.15	6.62
FeO	30.73	21.02	32.62	32.17
MgO	3.00	8.96	1.31	1.12
MnO	0.56	0.34	0.87	0.87
NO	--	--	--	--
ZnO	--	--	--	--
TOTAL	100	100	100	100

Data from other SRS localities (Watkinson et al., 1982)

N-L: National-Ledlin property

Wards: Wards claims

Table 11 SERPENTINE COMPOSITION ($Mg, Fe, Al, Mn, Ti, Cr, Ni$)₂ [(Si, Al)₂ O₅](OH)₂ - MICROPROBE DATA

WEIGHT PERCENT OXIDE																											
	C39716A 8716A-1	C39716A 8716A-2	C39716A 8716A-3	C39716B 8716B-1	C39716B 8716B-2	M102 8102-1	M102 8102-2	M102 8102-3	N98-67 987-1	N98-67 987-2	C39715 8715-1	C39715 8715-2	C39718 8718-1	C39718 8718-2	C39776 8776-1	C39776 8776-2											
SiO ₂	39.67	38.45	39.09	39.78	40.15	39.27	38.80	39.49	38.87	39.48	41.47	41.26	38.97	37.60	36.67	40.54											
Al ₂ O ₃	0.12	2.74	0.08	0.08	0.22	0.12	0.00	0.34	0.03	0.02	2.98	3.47	0.00	0.00	0.66	0.00											
TiO ₂	0.03	0.07	0.03	0.07	0.08	0.08	0.05	0.12	0.10	0.09	0.17	0.13	0.05	0.05	0.00	0.05											
FeO	9.43	9.44	12.93	11.62	9.77	11.50	11.30	11.20	10.81	7.32	3.79	3.70	8.89	10.03	10.57	10.52											
MnO	0.24	0.15	0.38	0.23	0.29	0.01	0.09	0.12	0.22	0.07	0.17	0.19	0.23	0.25	0.21	0.25											
MgO	32.91	33.88	30.30	35.46	34.73	35.67	31.93	35.05	34.08	37.28	36.92	36.49	36.29	35.14	22.68	33.87											
Cr ₂ O ₃	0.01	0.10	0.02	0.02	0.08	0.00	0.07	0.09	0.00	0.06	0.82	0.74	0.04	0.01	0.06	0.00											
NiO	0.00	0.11	0.00	0.14	0.23	0.22	0.21	0.17	-	-	0.10	0.17	0.20	0.26	0.03	0.01											
Cl	0.13	0.06	0.21	0.52	0.78	0.02	0.08	0.10	-	-	-	-	-	-	0.08	0.18											
TOTAL	82.54	85.00	83.05	87.92	86.34	86.89	82.33	86.68	84.11	84.22	86.42	86.15	84.47	83.34	80.96	95.42											

ATOMIC FORMULA (7 oxygen basis)																
	C39716A	C39716A	C39716A	C39716B	C39716B	M102	M102	M102	M102	M102	C39715	C39715	C39718	C39718	C39776	C39776
Si	2.032	1.916	2.034	1.957	1.999	1.938	2.007	1.952	1.969	1.958	1.963	1.958	1.952	1.929	1.941	2.020
Al	0.000	0.084	0.000	0.004	0.001	0.007	0.000	0.020	0.002	0.001	0.037	0.042	0.000	0.000	0.041	0.000
	2.032	2.000	2.034	1.961	2.000	1.945	2.007	1.972	1.971	1.959	2.000	2.000	1.952	1.929	1.982	2.020
Al	0.008	0.077	0.006	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.130	0.152	0.000	0.000	0.000	0.000
Ti	0.001	0.003	0.001	0.003	0.003	0.003	0.002	0.005	0.004	0.003	0.006	0.005	0.002	0.002	0.000	0.002
Fe	0.404	0.393	0.562	0.478	0.407	0.475	0.491	0.463	0.458	0.304	0.150	0.147	0.364	0.430	0.468	0.438
Mn	0.011	0.006	0.017	0.010	0.012	0.000	0.004	0.005	0.008	0.003	0.007	0.008	0.010	0.011	0.008	0.010
Mg	2.513	2.516	2.350	2.800	2.577	2.625	2.476	2.582	2.573	2.757	2.606	2.581	2.709	2.877	2.578	2.515
Cr	0.000	0.004	0.001	0.001	0.003	0.000	0.003	0.004	0.000	0.002	0.031	0.028	0.001	0.000	0.003	0.000
Ni	0.000	0.004	0.000	0.008	0.009	0.008	0.009	0.007	-	-	0.004	0.007	0.008	0.011	0.001	0.000
	2.937	3.003	2.937	3.098	3.023	3.112	2.965	3.066	3.044	3.069	2.934	2.928	3.084	3.141	3.059	2.965
Cl	0.011	0.005	0.018	0.043	0.066	0.002	0.007	0.008	-	-	-	-	-	-	0.007	0.015

Table 12 FELDSPAR COMPOSITION - MICROPROBE DATA

		WEIGHT PERCENT OXIDE															
		NBS-123	NBS-123	NBS-123	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108	C397108
		P123-1	P123-2	P123-3	P7108-1	P7108-2	P7108-3	P7108-4	P7108-5	P7108-6	P7108-7	P7108-8	P7108-9	P7108-10	P7108-11	P7108-12	P7108-13
					core	rim	core	rim	core	rim	core	rim	core	rim	core	rim	core
SiO ₂		54.47	53.56	55.44	54.70	59.71	56.55	49.65	49.00	49.75	49.47	59.14	50.78	55.45	51.18	55.98	49.39
Al ₂ O ₃		29.31	30.16	28.58	29.11	26.28	28.37	31.31	31.27	30.94	32.44	26.45	31.83	28.32	31.31	28.35	32.53
Na ₂ O		4.99	4.66	5.53	4.96	7.42	5.66	2.66	3.02	3.28	2.21	6.71	3.39	5.70	3.17	5.60	2.81
CaO		11.69	12.12	10.55	11.43	7.89	10.34	14.90	14.46	14.10	15.36	8.03	14.43	10.27	14.01	10.23	14.84
K ₂ O		0.19	0.16	0.10	0.11	0.20	0.16	0.11	0.15	0.11	0.24	0.16	0.08	0.12	0.13	0.08	0.33
FeO		0.34	0.20	0.12	0.24	0.13	0.12	0.50	0.49	0.65	0.28	0.17	0.08	0.16	0.22	0.06	0.31
TOTAL		100.99	100.86	100.32	100.55	101.43	101.20	98.03	98.39	98.53	98.00	100.66	100.57	100.02	100.02	100.02	100.30
		100.31															
		ATOMIC FORMULA (32 oxygen basis)															
Si		9.763	9.817	9.954	9.923	10.524	10.052	9.073	9.105	9.197	8.951	10.491	9.197	9.985	9.302	10.032	9.008
Al		6.192	6.384	6.047	6.192	5.459	5.943	6.883	6.849	6.741	7.061	5.531	6.785	6.010	6.708	5.988	6.992
		15.955	16.001	16.001	15.985	15.983	15.995	15.256	15.954	15.938	16.012	16.022	15.992	15.995	16.010	16.020	15.998
Na		1.736	1.622	1.926	1.726	2.537	1.952	0.962	1.067	1.176	0.792	2.307	1.190	1.992	1.117	1.947	1.027
Ca		2.245	2.331	2.029	2.199	1.453	1.970	2.957	2.878	2.784	3.040	1.526	2.801	1.981	2.727	1.964	2.900
K		0.044	0.037	0.022	0.026	0.044	0.035	0.027	0.034	0.026	0.057	0.036	0.014	0.028	0.029	0.018	0.077
Fe		4.025	3.990	3.977	3.950	4.034	3.957	3.946	3.999	3.996	3.899	3.860	4.005	4.001	3.873	3.929	4.004
		0.051	0.030	0.019	0.037	0.018	0.018	0.078	0.077	0.101	0.043	0.024	0.011	0.024	0.034	0.006	0.047
An*		56	56	51	56	36	50	75	72	70	78	39	70	50	70	50	72

* mole percent end member anorthite

Meek we-Dumbarton property data.

Table 13 AMPHIBOLE COMPOSITION - MICROPROBE DATA

	WEIGHT PERCENT OXIDE															
	N88-67 A87-1	N88-67 A87-2	N88-68 A88-1	N88-81 A81-1	N88-85 A85-1	N88-123 A123-1	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2
							nm	nm	nm	nm	nm	nm	nm	nm	nm	nm
SiO ₂	56.63	56.60	54.40	58.26	58.16	52.24	51.61	49.60	57.29	58.29	57.32	53.03	53.22	47.19	45.69	58.31
Al ₂ O ₃	0.35	0.07	1.02	0.41	0.40	3.35	3.34	5.75	0.14	0.26	0.00	4.46	2.81	10.34	12.33	0.09
TiO ₂	0.19	0.16	0.18	0.16	0.17	0.26	0.27	0.33	0.17	0.18	0.24	0.25	0.22	0.46	0.47	0.12
MgO	21.92	22.09	18.04	21.66	19.58	14.83	13.35	12.41	22.84	22.98	22.41	15.52	16.52	14.00	10.92	23.11
FeO	2.94	2.95	9.48	3.38	8.03	12.12	15.86	16.35	2.79	2.93	3.94	12.92	12.80	12.43	15.67	3.01
MnO	0.17	0.18	0.33	0.12	0.28	0.13	0.25	0.34	0.24	0.34	0.22	0.41	0.39	0.14	0.35	0.16
Cr ₂ O ₃	0.17	0.15	0.08	0.18	0.09	0.03	0.12	0.06	0.34	0.23	0.13	0.14	0.18	0.20	0.00	0.24
Na ₂ O	0.59	0.00	0.14	0.69	0.00	0.05	0.00	0.30	0.00	0.00	0.00	0.00	0.00	1.17	0.90	0.00
CaO	13.58	13.57	12.73	13.86	13.49	12.63	12.32	12.37	13.57	13.94	13.88	11.37	12.02	12.88	11.84	13.75
K ₂ O	0.08	0.06	0.06	0.07	0.07	0.10	0.11	0.17	0.11	0.11	0.10	0.12	0.08	0.13	0.14	0.04
TOTAL	96.62	95.83	96.43	96.79	98.27	97.30	97.23	97.68	97.29	99.24	98.02	98.22	98.25	98.95	99.31	99.43

	ATOMIC FORMULA (23 oxygen basis)															
	N88-67 A87-1	N88-67 A87-2	N88-68 A88-1	N88-81 A81-1	N88-85 A85-1	N88-123 A123-1	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2	C387108 A7108-1	C387108 A7108-2
Si	7.902	7.944	7.825	7.868	7.876	7.588	7.802	7.319	7.920	7.908	7.908	7.573	7.624	6.784	6.884	7.956
Al	0.057	0.011	0.173	0.068	0.065	0.402	0.398	0.681	0.022	0.041	0.000	0.427	0.376	1.216	1.316	0.014
	7.959	7.955	7.998	7.936	7.941	8.000	8.000	8.000	7.942	7.948	7.908	8.000	8.000	8.000	8.000	7.970
Al	0.000	0.000	0.000	0.000	0.000	0.172	0.181	0.319	0.000	0.000	0.000	0.325	0.098	0.536	0.810	0.000
Ti	0.020	0.016	0.018	0.016	0.018	0.029	0.030	0.036	0.017	0.019	0.025	0.037	0.024	0.049	0.052	0.012
Mg	4.500	4.623	3.868	4.515	4.083	3.215	2.931	2.730	4.666	4.643	4.806	3.305	3.528	3.000	2.382	4.652
Fe	0.343	0.346	1.140	0.395	0.341	1.596	1.954	2.019	0.323	0.332	0.454	1.543	1.534	1.495	1.917	0.340
Mn	0.020	0.022	0.040	0.014	0.033	0.084	0.031	0.042	0.028	0.038	0.025	0.050	0.048	0.017	0.043	0.018
Cr	0.019	0.017	0.008	0.019	0.010	0.003	0.014	0.007	0.037	0.024	0.014	0.015	0.020	0.023	0.000	0.025
	4.962	5.024	5.076	4.959	5.085	5.099	5.141	5.153	5.071	5.057	5.126	5.265	5.253	5.120	5.204	5.047
Na	0.181	0.000	0.038	0.186	0.000	0.015	0.000	0.085	0.000	0.000	0.000	0.000	0.000	0.325	0.254	0.000
Ca	2.030	2.040	1.963	2.077	2.027	1.988	1.944	1.956	2.010	2.026	2.018	1.740	1.846	1.905	1.857	1.990
K	0.014	0.011	0.015	0.013	0.012	0.019	0.021	0.033	0.019	0.018	0.017	0.023	0.016	0.024	0.027	0.007
	2.206	2.061	2.016	2.276	2.039	2.002	1.965	2.074	2.029	2.045	2.036	1.783	1.862	2.334	2.136	1.967

Master-Dumberton property data.

Table 14 CLINOPYROXENE COMPOSITION - MICROPROBE DATA

		WEIGHT PERCENT OXIDE									
		NBB-69 CP69-1	NBB-69 CP69-2	NBB-69 CP69-3	NBB-69 CP69-4	NBB-76 CP76-1	NBB-76 CP76-2	NBB-87 CP87-1	NBB-87 CP87-2	NBB-87 CP87-3	NBB-87 CP87-4
SiO ₂	54.09	54.15	54.18	53.68	53.89	54.60	51.31	52.74	53.75	52.22	
Al ₂ O ₃	1.01	1.02	0.31	1.15	1.24	1.14	1.56	1.09	1.62	1.35	
TiO ₂	0.30	0.34	0.20	0.38	0.39	0.34	0.58	0.38	0.58	0.52	
FeO	5.50	5.68	6.74	7.53	5.76	5.63	6.98	5.93	7.61	7.25	
MgO	18.28	18.44	15.11	15.85	16.12	18.62	15.90	16.27	16.81	16.63	
MnO	0.35	0.31	0.22	0.19	0.28	0.30	0.31	0.31	0.18	0.23	
Cr ₂ O ₃	0.98	1.06	0.78	0.50	1.17	1.18	0.51	0.69	0.67	0.54	
CaO	19.57	20.05	22.68	20.95	20.12	20.61	20.00	21.37	20.79	20.21	
Na ₂ O	0.31	0.28	0.00	0.95	0.13	0.32	0.36	0.00	0.29	0.21	
TOTAL	100.39	101.34	100.23	101.18	101.10	102.74	97.52	98.78	102.30	99.16	

ATOMIC FORMULA (8 oxygen basis)

Si	1.967	1.956	1.997	1.964	1.952	1.947	1.943	1.963	1.941	1.944	
Al	0.033	0.044	0.003	0.036	0.048	0.048	0.067	0.037	0.059	0.066	
	2.000	2.000	2.000	2.000	2.000	1.995	2.000	2.000	2.000	2.000	
Al	0.010	0.000	0.010	0.014	0.005	0.000	0.013	0.011	0.010	0.003	
Ti	0.008	0.008	0.006	0.011	0.011	0.008	0.016	0.011	0.016	0.015	
Fe	0.167	0.172	0.208	0.230	0.174	0.168	0.221	0.185	0.230	0.226	
Mg	0.991	0.993	0.830	0.864	0.978	0.990	0.897	0.903	0.905	0.923	
Mn	0.011	0.009	0.007	0.006	0.008	0.008	0.010	0.010	0.005	0.007	
Cr	0.028	0.030	0.023	0.014	0.034	0.033	0.015	0.020	0.019	0.016	
	1.215	1.213	1.084	1.139	1.211	1.208	1.172	1.140	1.185	1.190	
Ca	0.763	0.776	0.896	0.821	0.781	0.788	0.811	0.852	0.805	0.806	
Na	0.022	0.020	0.000	0.067	0.009	0.022	0.027	0.000	0.020	0.015	
	0.785	0.796	0.896	0.888	0.790	0.810	0.838	0.852	0.825	0.821	

Mackwe-Dumbarton property data.

Table 15
TRACE ELEMENT DATA

Sample#	Ni %	Cu %	Pt g/t	Pd g/t	Zn ppm	Co ppm	Rb ppm	Sr ppm	Se ppm	Ba ppm	S %
WA18320	0.52	0.66	-	-	65	430	<5	16	41	-	9.58
WA18324	1.70	0.047	-	-	22	760	<5	17	<5	-	37.7
WA18325	1.20	0.235	-	-	90	950	15	24	<5	-	20.3
WA18364	1.79	1.11	0.23	1.58	89	670	16	11	22	51	7.44
N88-64-	-	0.41	-	-	110	100	<5	17	<5	-	0.51
N88-64-4	0.038	9.70	-	-	2400	590	8	16	<5	-	33.5
N88-75-1	0.606	0.052	-	-	210	180	<5	17	<5	-	4.67
N88-174-1	0.015	0.74	-	-	175	215	<5	21	25	-	1.13
N88-174-2	0.001	0.24	-	-	165	80	<5	26	32	-	0.59
74-41 @202'	3.30	0.073	-	-	99	1150	42	16	<5	-	15.7
76-94 @563'	1.20	0.315	-	-	215	470	12	16	<5	-	6.89
AA-20 (n=31)#	0.08	0.019	0.01	0.03	-	91	15	<5	<5	16	0.29

Meekwa-Dumbarton property data except for:

' Meyville property

Table 16 RARE EARTH ELEMENT DATA

Sample#	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Dy ppm	Er ppm	Lu ppm
C39704	5 (6.15)	2.6 (4.36)	0.6 (3.13)	0.3 (4.16)	1.2 (4.63)	1.5 (4.62)	1.0 (4.69)	0.2 (6.19)
C39710	7 (8.61)	7.2 (12.06)	2.3 (11.98)	0.8 (11.08)	3.9 (15.06)	4.6 (14.15)	3.2 (15.02)	0.4 (12.38)
C39714	<1	<0.5	<0.5	<0.1	<0.5	<0.5	<0.5	<0.1
C39715	1 (1.23)	0.5 (0.84)	<0.5	<0.1	<0.5	<0.5	<0.5	<0.1
C39716	5 (6.15)	2.8 (4.69)	<0.5	0.2 (2.77)	0.6 (2.32)	0.7 (2.15)	<0.5	<0.1
C39717	8 (9.84)	6.2 (10.39)	1.3 (6.77)	0.2 (2.77)	0.8 (3.09)	0.7 (2.15)	<0.5	<0.1
C39718	4 (6.15)	2.7 (4.52)	0.6 (3.13)	0.1 (1.39)	0.7 (2.70)	0.7 (2.15)	<0.5	<0.1
C39719	8 (9.84)	6.2 (10.39)	1.3 (6.77)	0.6 (8.31)	1.8 (6.95)	1.3 (5.85)	0.8 (3.76)	<0.1
C39720	5 (6.15)	3.5 (5.86)	0.7 (3.65)	0.3 (4.16)	1.0 (3.86)	0.8 (2.46)	<0.5	<0.1
C39725	9 (11.07)	4.7 (7.87)	0.7 (3.65)	0.2 (2.77)	0.9 (3.47)	0.9 (1.85)	<0.5	<0.1
C39726	8 (9.84)	5.2 (8.71)	0.8 (4.17)	0.4 (5.54)	1.1 (4.25)	1.1 (3.38)	<0.5	<0.1
C39748	57 (70.11)	22.3 (37.35)	4.1 (21.35)	1.0 (13.85)	3.8 (14.67)	2.8 (8.62)	1.1 (5.16)	<0.1
C39749	48 (59.04)	19.5 (32.66)	3.4 (17.71)	0.7 (9.70)	3.2 (12.36)	1.9 (5.85)	0.6 (2.82)	<0.1
chondrite*	0.813	0.587	0.192	0.0722	0.259	0.325	0.213	0.0323

Maskwa-Dumbarton property data.

Bracketed figures are chondrite normalized values.

* Medusa et al., 1973.

SAMPLE REFERENCE

C39703	fine- to medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39704	metavolcanic: analysis by XRAL Laboratories
C39705	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39706	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39708	metavolcanic: analysis by XRAL Laboratories
C39709	metavolcanic: analysis by XRAL Laboratories
C39710	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39711	felsic dyke: analysis by XRAL Laboratories
C39712	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39713	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39714	metaperidotite of the Bird River Sill suite: analysis by XRAL Laboratories
C39715	metaperidotite of the Bird River Sill suite: analysis by XRAL Laboratories
C39716	wherlite of the Subeill suite: analysis by XRAL Laboratories
C39717	medium-grained olivine pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39718	medium-grained olivine pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39719	coarse-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39720	fine-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39721	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39722	fine-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39723	medium-grained olivine pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39724	metavolcanic: analysis by XRAL Laboratories
C39725	olivine pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39726	fine-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39727	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39728	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39729	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39730	chill margin of gabbro of the Subeill suite: analysis by XRAL Laboratories
C39732	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39733	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39734	fine-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39735	coarse-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39742	medium-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39744	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39745	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39746	rodingite of the Bird River Sill suite: analysis by XRAL Laboratories
C39747	anorthositic gabbro of the Bird River Sill suite: analysis by XRAL Laboratories
C39748	quartz vein: analysis by XRAL Laboratories
C39749	quartz vein: analysis by XRAL Laboratories
C39751	chill margin of gabbro of the Subeill suite: analysis by XRAL Laboratories
C39752	chill margin of gabbro of the Subeill suite: analysis by XRAL Laboratories
C39753	coarse-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39754	coarse-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39756	pillowed metavolcanic: analysis by XRAL Laboratories
C39757	pillowed metavolcanic: analysis by XRAL Laboratories
C39760	pillowed metavolcanic: analysis by XRAL Laboratories
C39761	pillowed metavolcanic: analysis by XRAL Laboratories
C39762	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39763	chill margin of gabbro of the Subeill suite: analysis by XRAL Laboratories
C39764	chill margin of gabbro of the Subeill suite: analysis by XRAL Laboratories
C39765	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39766	diabase-textured gabbro of the Subeill suite: analysis by XRAL Laboratories
C39769	metavolcanic: analysis by XRAL Laboratories
C39770	medium-grained gabbro of the Subeill suite: analysis by XRAL Laboratories
C39771	metavolcanic: analysis by XRAL Laboratories
C39772	metavolcanic: analysis by XRAL Laboratories
C39773	pillowed metavolcanic: analysis by XRAL Laboratories

Maskwa-Dumbarton property samples

SAMPLE REFERENCE (continued)

C39774	coarse-grained pyroxenite of the Subeill suite: analysis by XRAL Laboratories
C39775	pillowed metavolcanic: analysis by XRAL Laboratories
C39776	pyroxenite of the subeill suite: analysis by XRAL Laboratories
N88-47	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-64-3	altered pyroxenite (Wento showing): analysis by Lakefield Research Laboratories
N88-64-4	massive sulphide (Wento showing): analysis by Lakefield Research Laboratories
N88-67	olivine pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-69	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-75-1	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-76	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-81	olivine pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-85	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-86	metaperidotite of the BRS suite: analysis by Lakefield Research Laboratories
N88-87	pyroxenite of the subeill suite: analysis by Lakefield Research Laboratories
N88-92	mafic dyke: analysis by Lakefield Research Laboratories
N88-123	gabbro: analysis by Lakefield Research Laboratories
N88-131*	gabbro from the Petra-Bar property: analysis by Lakefield Research Laboratories
N88-136A*	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
N88-136B*	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
N88-139*	gabbro from the Petra-Bar property: analysis by Lakefield Research Laboratories
N88-142*	mafic dyke from the Petra-Bar property: analysis by Bondar-Clegg Laboratories
N88-144*	gabbro from the Petra-Bar property: analysis by Lakefield Research Laboratories
N88-145*	metapyroxenite from the Petra-Bar property: analysis by Bondar-Clegg Laboratories
N88-156	metaperidotite of the BRS suite: analysis by Bondar-Clegg Laboratories
N88-170	mafic dyke: analysis by Lakefield Research Laboratories
N88-172	mafic dyke: analysis by Lakefield Research Laboratories
N88-174-1	andesite (Cup Anderson showing): analysis by Lakefield Research Laboratories
N88-174-2	andesite (Cup Anderson showing): analysis by Lakefield Research Laboratories
N88-176	gabbro of the subeill suite: analysis by Lakefield Research Laboratories
N88-177	mafic dyke: analysis by Lakefield Research Laboratories
N88-178	gabbro of the subeill suite: analysis by Lakefield Research Laboratories
WA4101 ²	gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4102 ²	gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4103 ²	metavolcanic: analysis by Bondar-Clegg Laboratories
WA4104 ²	mafic dyke: analysis by Bondar-Clegg Laboratories
WA4105 ²	pyroxenite of the Subeill suite: analysis by Bondar-Clegg Laboratories
WA4111 ²	mafic dyke: analysis by Bondar-Clegg Laboratories
WA4112 ²	gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4113 ²	metavolcanic: analysis by Bondar-Clegg Laboratories
WA4114 ²	metavolcanic: analysis by Bondar-Clegg Laboratories
WA4115 ²	gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4116 ²	gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4117 ²	pegmatitic gabbro of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4118 ²	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
WA4119 ²	mafic dyke: analysis by Bondar-Clegg Laboratories
WA11017	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
B5-170	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
B7-556	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
B38-164	pyroxenite of the subeill suite: excerpted from Juhas, 1973
B48-149	pyroxenite of the subeill suite: excerpted from Juhas, 1973
B69-206	pyroxenite of the subeill suite: excerpted from Juhas, 1973
B69-420	pyroxenite of the subeill suite: excerpted from Juhas, 1973
J63-12	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973

Maskwa-Dumbarton property samples except for:

* Petra-Bar property

² National-Ledin property

SAMPLE REFERENCE (continued)

J63-14	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
J63-31	metaperidotite of the BRS suite: excerpted from Juhas, 1973
J63-44	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
J63-67	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
J64-20C	metaperidotite of the BRS suite: excerpted from Juhas, 1973
J64-23A	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
J64-24B	pyroxenite of the Subeill suite: excerpted from Juhas, 1973
J65-6A	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
J65-19	metaperidotite of the BRS suite: excerpted from Juhas, 1973
J65-25	metaperidotite of the BRS suite: excerpted from Juhas, 1973
BRS(CM)*	chilled basal contact: excerpted from Trueman, 1980
76-97 @340	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
76-94 @563	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
74-41 @202'	metaperidotite of the Bird River Sill suite: analysis by Lakefield Research Laboratories
75-514	metagabbro - Bernic Lake formation: excerpted from Trueman, 1980
75-576	hypabyssal metagabbro - Bernic Lake formation: excerpted from Trueman, 1980
19°	metaperidotite of the Bird River Sill suite: excerpted from Juhas, 1973
24°	gabbro of the Bird River Sill suite: excerpted from Juhas, 1973
25°	gabbro of the Bird River Sill suite: excerpted from Juhas, 1973
M102-130	metaperidotite of the Bird River Sill suite: analysis by Bondar-Clegg Laboratories
N-L 1°	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
N-L 2°	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Wards 3	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Wards 4	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Page 18	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Page 19	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Chrome 157°	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
Chrome 167°	excerpted from Watkinson et al., 1982: microprobe analysis by Carleton University
WA18320	Dumbarton banded iron formation: analysis by Lakefield Research Laboratories
WA18324	massive pyrrhotite (Dumbarton ore): analysis by Lakefield Research Laboratories
WA18325	semi-massive pyrrhotite (Dumbarton ore): analysis by Lakefield Research Laboratories
WA18364	mineralized metaperidotite (Maskwa ore): analysis by Lakefield Research Laboratories
M-20 (n=3)°	ultramafic pyroxenite: analysis by Lakefield Research Laboratories
M-20 @118'°	leucogabbro: analysis by Lakefield Research Laboratories
M-20 @501'°	ultramafic pyroxenite: analysis by Lakefield Research Laboratories
M-21 @22'°	mafic volcanic: analysis by Lakefield Research Laboratories
WA4223°	metaperidotite: analysis by Bondar-Clegg Laboratories
WA4235°	metaperidotite: analysis by Bondar-Clegg Laboratories
WA4239°	metaperidotite: analysis by Bondar-Clegg Laboratories
WA4240°	metaperidotite: analysis by Bondar-Clegg Laboratories
WA4243°	metaperidotite: analysis by Bondar-Clegg Laboratories

Maskwa-Dumbarton property samples except for:

- * Petra-Bar property
- * National-Ladin property
- * Chrome property
- # Mayville property

2

of/de

2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
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044

040
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041

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Map for Map
Pocket - Copy 1
Paul Regard
M. S.
San Francisco
California, U.S.

20N 8L

820

820

Map for Map
Book - copy 1
Paul Kaper
M. Se
Earl McEnroe
Carlton V.

20N BL

920

-SYMBOLS-

- Highway
- Trail or Bush Road
- Power Line
- Pond, Lake, River
- Swamp
- Grid
- Mineralized Showing

Geology Legend

- 1 GRANITIC INTRUSIONS
- 2 DIABASE-TEXTURED GABBRO
- 3 MEDIUM-GRAINED GABBRO
- 4 PYROXENITES
- 5 ANORTHOSITIC GABBRO
- 6 PYROXENITE
- 7 METAPERIDOTITE
- 8 METAVOLCANICS

1 GRANITIC INTRUSIONS

2 DIABASE-TEXTURED GABBRO

MBOLS-

- Highway
- Trail or Bush Road
- Power Line
- Pond, Lake, River
- Swamp
- Grid
- Mineralized Showing

Geology Legend

INTRUSIONS

BASE-TEXTURED GABBRO
MEDIUM-GRAINED GABBRO
OXENITES

} Subell Suite

ORTHOSITIC GABBRO
OXENITE
TAPERIDOTITE

} Bird River Sill Suite

AVOLCANICS

MASKWA DUMBARTON PROPERTY

Geological Interpretation

INTRUSIONS

BASE-TEXTURED GABBRO
MEDIUM-GRAINED GABBRO

} Subell Suite

1 GRANITIC INTRUSIONS

INTRUSIONS

2 DIABASE-TEXTURED GABBRO

-TEXTURED GA

3 MEDIUM-GRAINED GABBRO

GRAINED GABB

4 PYROXENITES

NITES

5 ANORTHOSITIC GABBRO

OSITIC GABBRO

6 PYROXENITE

NITE

7 METAPERIDOTITE

RIDOTITE

8 METAVOLCANICS

LCANICS

9 METASEDIMENT

DIMENT

Station/sample location

ample location

Fracture/joint (strike & dip, vertical)

/ joint (strike &

Shear/fault (strike & dip, vertical, dip unk

nt (strike & dip

Foliation (strike & dip, vertical, dip unk

(strike & dip, v

Mafic dyke

ke

Iron formation

ation

Diamond Drillhole

Drillhole

INTRUSIONS

Subell Suite

Subell Suite

POSITIC GABBRO
 BLANITE
 BRIDOTITE

} Bird River Sill Suite

Bird River Sill Suite

MASKWA DUMBARTON PROPERTY

Geological Interpretation

Sample Data

Diamond Drillhole Location

sample location

0 400 600 1200H

vertical) joint (strike & dip, vertical)

cal, dip unknown (strike & dip, vertical, dip unknown)

dip unk (strike & dip, vertical, dip unknown)

30

ation

Drinking

END

24.12.92

FIN