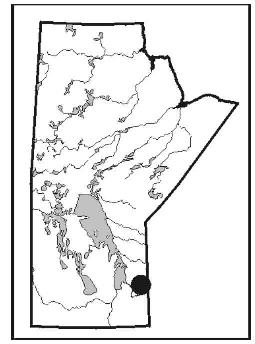
GS-27 PGE-COPPER-NICKEL POTENTIAL OF MAFIC-ULTRAMAFIC INTRUSIONS IN THE BIRD RIVER GREENSTONE BELT (PARTS OF NTS 52L).



by D.C. Peck and P. Theyer

Peck, D.C. and Theyer, P. 1998: PGE-copper-nickel potential of mafic-ultramafic intrusions in the Bird River greenstone belt (parts of NTS 52L); **in** Manitoba Energy and Mines, Geological Services, Report of Activities, 1998, p. 151-160.

SUMMARY

The Bird River greenstone belt hosts two past-producing Ni deposits (Maskwa West and Dumbarton mines, south flank) and has been intermittently explored for stratiform chromite deposits and Cu-Ni (± PGE) sulphide mineralization (north and south flanks). Re-examination of existing geological and geochemical data for the ultramafic series in the Chrome property of the Bird River Sill suggests that reef-type platinum-group element (PGE) mineralization was locally developed. Abrupt decreases in Pd and Pt abundances and significant positive correlations between PGE, Cu and S abundances attest to the formation of immiscible sulphide liquids during the crystallization of olivine + chromite ± pyroxene cumulates in the lower parts of the sill. In comparison to other reef-type PGE occurrences, the sulphide mineralization at the Chrome property displays moderate levels of PGE enrichment (typically 100 to 700 ppb). The results are equivocal with regard to the potential for an economic reef-type deposit in the Bird River Sill. Based on the limited available data, PGE tenors of the Chrome property sulphides are an order of magnitude lower in comparison to economically viable PGE reefs. On the other hand, the large amount of PGE-rich sulphides is impressive (ca. 20% of the ultramafic rocks contain in excess of 100 ppb Pd + Pt) and warrants additional investigation.

Details concerning the chemostratigraphy of the Bird River Sill have emerged from new trace and rare-earth element data. These results suggest that the gabbroic part of the sill crystallized from hyper-feldspathic magmas that were cogenetic with the ultramafic series.

Several Cu-Ni-PGE occurrences exist in the Mayville gabbroic intrusion on the northern flank of the Bird River greenstone belt. The Mayville intrusion is a layered, plagioclase-rich leucogabbroic intrusion that has strong petrological similarities with Archean megacrystic anorthosites. The southern margin of the intrusion comprises a thin pyroxenite unit. Previous exploration has delineated massive to semi-massive Cu-rich (and, locally, PGE-enriched) magmatic sulphide mineralization in gabbroic rocks that occur immediately to the north of the pyroxenite unit. Blebby, disseminated Cu-rich sulphides are also observed from overlying leucogabbro layers. Evaluation of the PGE potential of the north flank of the Bird River belt requires much better documentation of the stratigraphy of the host intrusions and the geochemical characteristics of the sulphide mineralization.

INTRODUCTION

The Bird River Sill (BRS) comprises a ca. 600 m thick, layered ultramafic (dunite + peridotite + minor pyroxenite) and mafic (gabbro, leucogabbro and anorthosite) intrusion that can be traced along strike for >20 km at the southern flank of the Bird River greenstone belt (Fig. GS-27-1). The BRS contains 2 past producing nickel mines (Maskwa and Dumbarton mines, Fig. GS-27-1) and has periodically been explored for chromite (Theyer, 1985). Previous geological investigations of the BRS (e.g., Karup-Moller and Brummer, 1971; Trueman, 1971;

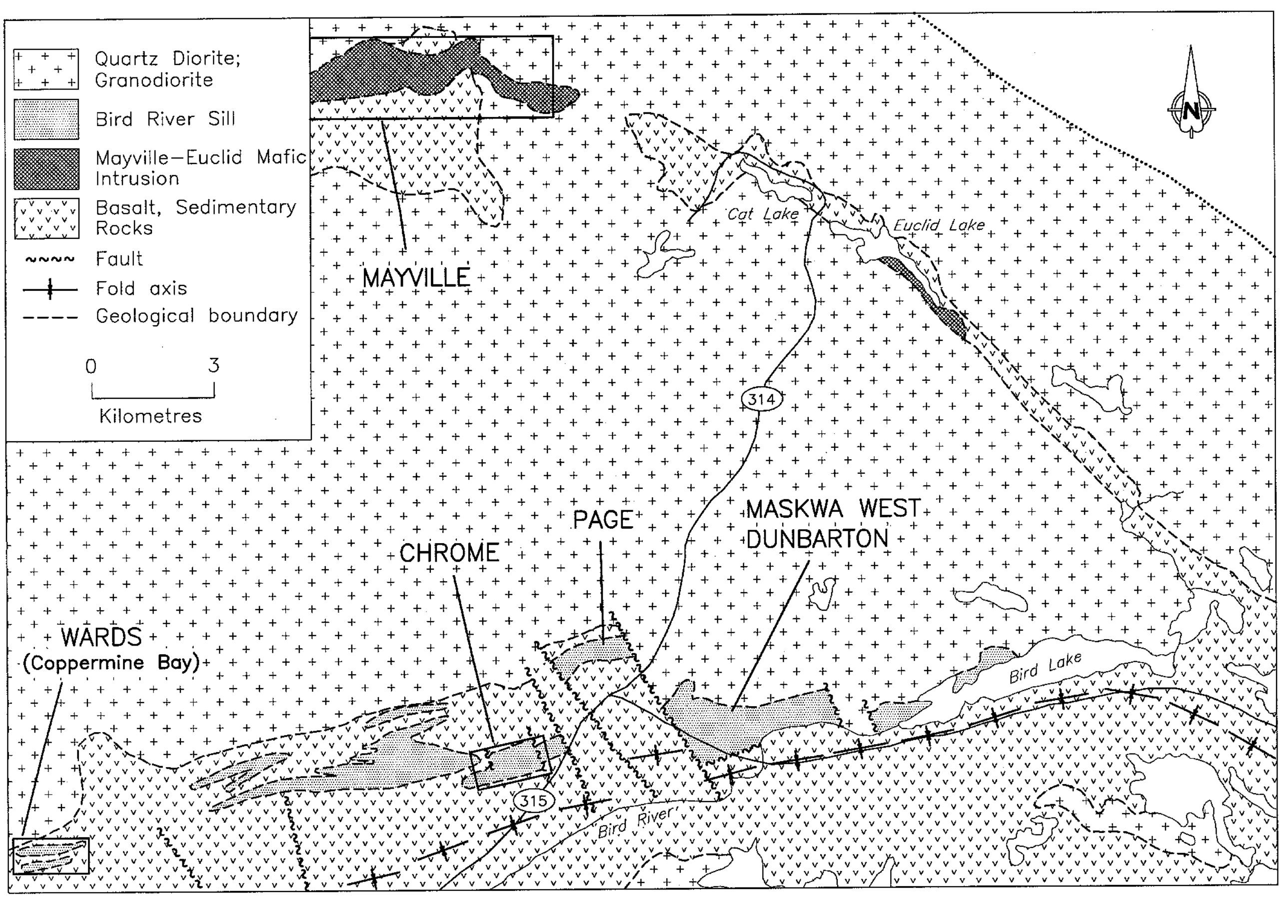


Figure GS-27-1: Bird River greenstone belt, southeastern Manitoba, showing the location of study areas and past-producing mines.

Theyer, 1985, 1991; Talkington et al., 1983; Scoates, 1983; Williamson, 1990) have addressed the mineralogy of stratiform chromite layers, the stratigraphy of the ultramafic series and the characteristics of magmatic sulphide deposits (Maskwa West) and reworked (?) magmatic sulphide deposits (Dumbarton) in the central part of the sill. The majority of the previous work has focused on the Chrome, Page, Mayville and Maskwa West-Dumbarton properties (Fig. GS-27-1).

The current program represents part of an ongoing mapping and lithogeochemical investigation of the mafic and ultramafic rocks of the Bird River greenstone belt. Our principal objective for this program is to investigate the potential for PGE reefs and PGE-rich Cu-Ni sulphide deposits in the layered intrusions on both the north and south flanks of the belt. The investigation will involve detailed mapping of the layering of these intrusions and subsequent chemostratigraphic analysis. Here, we report new field and geochemical observations for the Chrome property and preliminary field observations for the Mayville property and the Coppermine Bay area.

REGIONAL GEOLOGY

The BRS has been dated at 2745 ± 5 Ma (Timmins et al., 1985). The sill occupies the southern flank of a late Archean supracrustal belt - the Bird River greenstone belt, comprising aphyric and plagioclase phyric pillowed and massive flows, gabbro sills, meta-andesite and metasedimentary rocks (greywacke, banded iron formation) cored by apparently older granitic rocks (Great Falls pluton; ca. 2780 Ma, Timmins et al., 1985).

The geology of the mafic-ultramafic rocks of the northern Bird River greenstone belt is poorly understood. However, the BRS in the southern Bird River greenstone belt has been carefully documented through mining, geophysical work, diamond drilling, detailed mapping (Theyer, 1985, 1991; Scoates, 1983; Williamson, 1990), petrologic studies (Theyer, 1991) and mineral potential studies (Theyer, 1985). Theyer (1985) completed a preliminary geochemical study of the BRS, based on samples obtained from two parallel and nearly continuous rock cuts across the ultramafic series of the BRS at the Chrome property (Fig. GS-27-2). These results are re-examined in light of new chemostratigraphic observations (below).

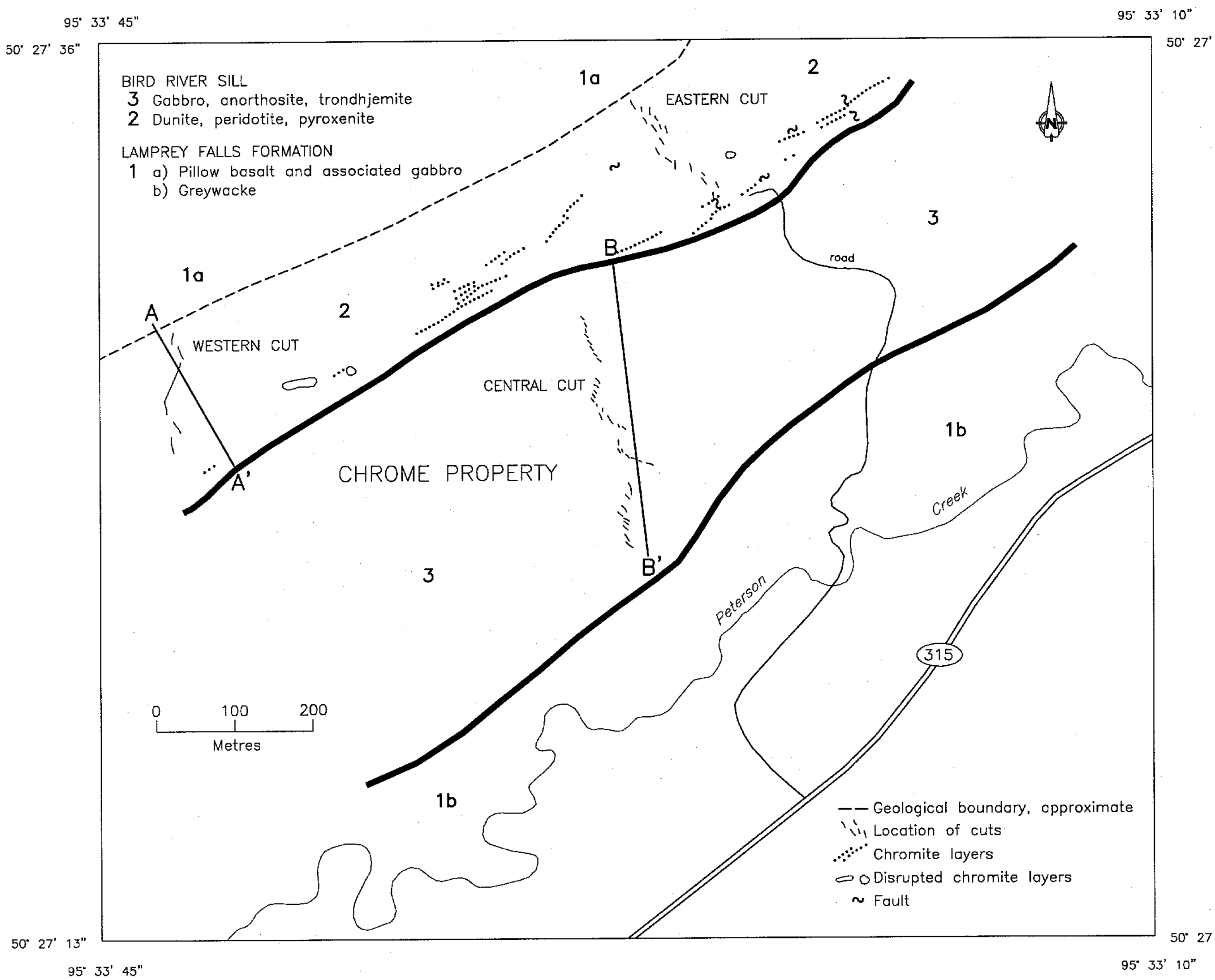


Figure GS-27-2: Simplified geology of the Bird River Sill at the Chrome property. Type section given in Figure. GS-27-3 is based upon section lines A-A' and B-B'. Geology modified from Trueman (1971) and Williamson (1990).

GEOLOGY AND CHEMOSTRATIGRAPHY OF THE BRS AT THE CHROME PROPERTY

The geology and mineral occurrences of the Chrome property, BRS, are described by Trueman (1971), Scoates (1983), Theyer (1985) and Williamson (1990). Previous work focused on the ultramafic series and associated, stratiform chromite layers in the northern part of the sill. The mapping of Williamson (1990) and Theyer (1985, 1991), combined with new field observations for the mafic series (below), provide the basis for a type stratigraphic section for the BRS at the Chrome property (Figs. GS-27-3). The mafic series stratigraphy is principally based on 1:50 scale detailed mapping and associated lithogeochemical studies that were carried out in 1997 (D. Peck, unpublished data). Sampling was carried out at a spacing of ca. 15 m, and overlaps with a series of existing saw cuts (Central Cut, Fig. GS-27-2).

New geochemical data, acquired for both the mafic and ultramafic portions of the BRS at the Chrome property, have been compared with previous mapping and petrologic studies in order to: (1) determine the relationship between the gabbroic and ultramafic units; (2) address the potential for reef-type PGE deposits; and (3) identify the controls on the observed petrochemical variations.

In addition to 23 samples of gabbro collected in 1997, 13 samples were selected from Theyer's (1985) western and eastern cuts for whole-rock lithogeochemical analysis. The new major, minor and trace element data recently acquired for these samples will be reported at a later date. The data are used here in order to demonstrate geochemical trends that are relevant to the PGE potential of the BRS (below). Major and minor element analyses were conducted at Actlabs, Ancaster, Ontario (ICP-OES technique) and rare-earth and trace element analyses were performed at the Geoscience Laboratories, Sudbury (total digestion ICP-MS).

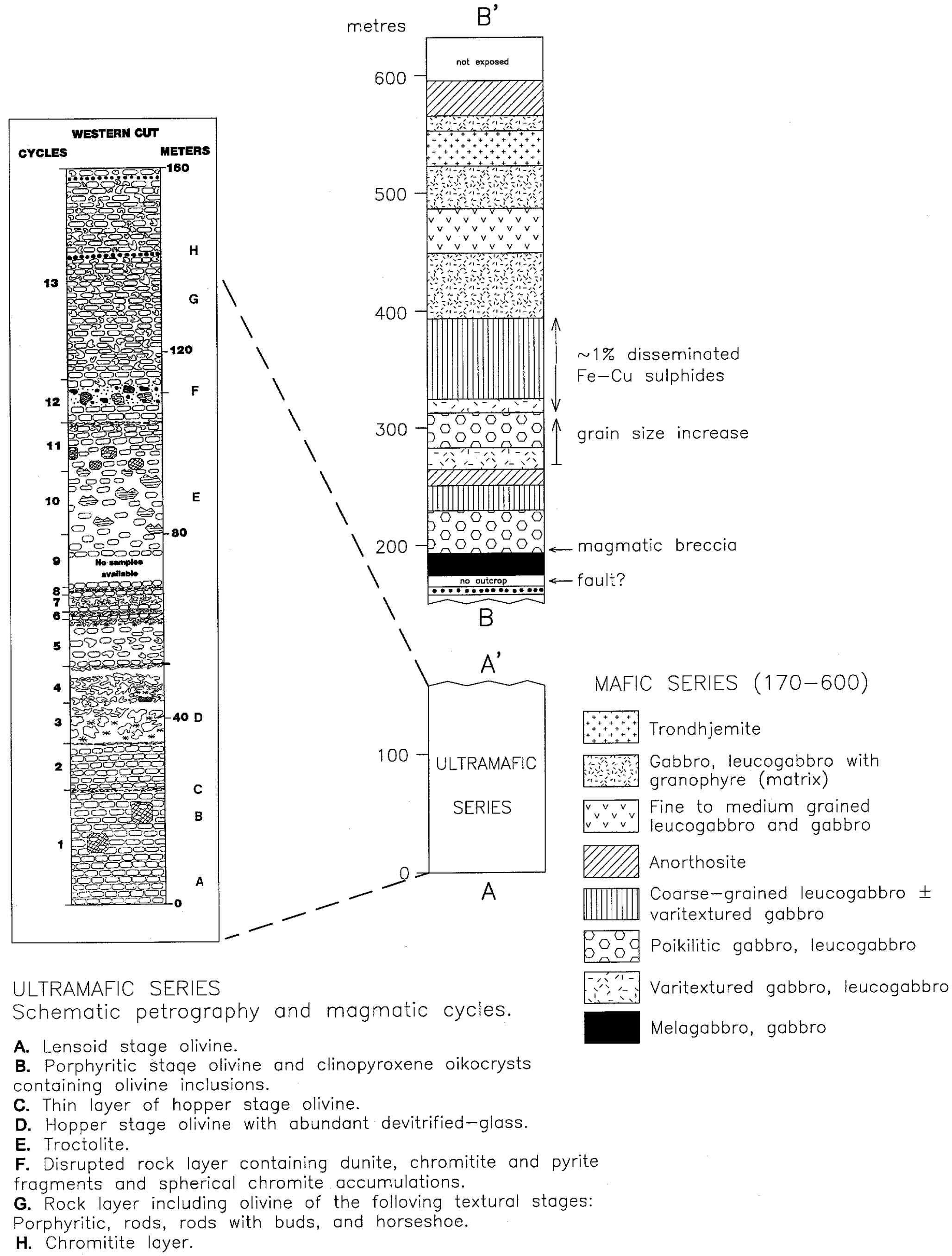


Figure GS-27-3: Type stratigraphic section for the Bird River Sill at the Chrome property. Based on previous mapping of the ultramafic series (Theyer, 1991; Williamson, 1990) and mapping of the mafic series (unpublished data). See Figure GS-27-2 for location of section lines.

Au-Pt-Pd analyses for the gabbroic samples were completed on behalf of Gossan Resources Ltd. using a Pb fire assay - ICP procedure (Geoscience Laboratories, Sudbury).

The BRS, at the Chrome property, comprises a ca. 200 m thick ultramafic series and a ca. 300 - 400 m thick mafic series. As is typical of most exposed segments of the sill, significant movement has occurred along north-trending faults (e.g., Fig. GS-27-1; Williamson, 1990). Peak metamorphism at greenschist facies resulted in the replacement of original olivine and pyroxene by serpentine group minerals and amphibole. Layering features and geochemical trends (Theyer, 1985; Williamson, 1990; this study) suggest that the entire sill is south-facing. The sill is overlain by greywacke and underlain by pillow basalt and associated, relatively thin gabbro intrusions.

The ultramafic series comprises centimetre- to decametre-scale layered dunite + peridotite sequences with minor, associated pyroxenite and feldspathic peridotite and dunite (Fig. GS-27-4). Olivine and chromite represent primocryst minerals. Pyroxenes typically form oikocrysts and, rarely, idiomorphic crystals (primocrysts). Layering in the ultramafic series is typically planar and regular and involves abrupt changes in the modal abundances of olivine and pyroxene (Fig. GS-27-2). Geochemical trends (CaO abundance strongly related to Al_2O_3 content, MgO abundance, despite variable olivine:pyroxene ratios, remains fairly constant throughout the ultramafic series) suggest that the dominant pyroxene formed in the ultramafic series is orthopyroxene. Chromite layers are concentrated within the upper part of the ultramafic series (chromitiferous zone; Figs. GS-27-3, 5; see also Williamson, 1990). They are typically <20 cm thick (maximum of ca. 1 m thick) and have planar, regular contacts with adjacent dunite and peridotite layers. Some of the lowermost chromite layers are disrupted (Fig. GS-27-5) probably due to localized, syn-magmatic deformation (Williamson, 1990).

The mafic series comprises up to ca. 400 m of fine-grained to coarse-grained leucogabbro and subordinate gabbro, melagabbro, anorthosite and trondhjemite. The latter rock type appears, on the basis of increasing abundance of sodic granophyre in the gabbroic rocks beneath the trondhjemite, to be developed from a low density residual liquid generated by prolonged and efficient plagioclase fractional crystallization. Texturally, the mafic series is diverse and includes poikilitic, sub-ophitic, plagioclase porphyritic and plagioclase megacrystic rock types. Some of the gabbroic rocks are varitextured (Fig. GS-27-6) and contain accessory quartz, Fe-Ti oxide and pyrrhotite.

Figure GS-27-4: Modal layering in the ultramafic series, Bird River Sill, Chrome property. A central dunite layer is in contact with adjacent peridotite layers. Photograph taken in the vicinity of the western cut (Fig. GS-27-2).

Figure GS-27-5: Disrupted chromite layers associated with dunite and peridotite near the eastern cut, Chrome property, Bird River Sill.

The relationship between the gabbroic and ultramafic series was investigated with the aid of the new lithogeochemical data. Previous workers recognized rare transitional lithologies within the ultramafic series (feldspathic peridotite and troctolite) but, in general, the contact between the two series is abrupt, and may be faulted. The abrupt transition from ultramafic to mafic compositions is recorded in the major element oxide abundances for the ultramafic and mafic series, which display a major compositional gap (Fig. GS-27-7). The relative abundances of the rare-earth elements (REE) and high field strength elements (HFSE) remain fairly constant throughout the ultramafic series, and the lower parts of the mafic series, and are similar to that of primitive mantle (Fig. GS-27-8). However, there is significant enrichment in several of the more incompatible elements (e.g., La, Ce, U) that, based on preliminary field and geochemical observations, is attributed to increasing abundance of interstitial melts of trondhjemitic composition near the base of the trondhjemite layer (Figs. GS-27-3, 8).

Preliminary chemostratigraphic analysis of the mafic series reveals a steady upward (i.e., southward) increase in SiO_2 and incompatible trace element abundances, and a decrease in Mg/Fe ratios (Fig. GS-27-9). Theyer (1991) defined two petrologically and chemically distinct units in the ultramafic series (lower zone and chromitiferous zone, see Fig. GS-27-3). We also recognize two cycles in the mafic series, one that is ca. 300 m wide and extends from the contact with the ultramafic series to the top of the trondhjemite layer, and the second that occurs immediately above the trondhjemite layer (Fig. GS-27-3).

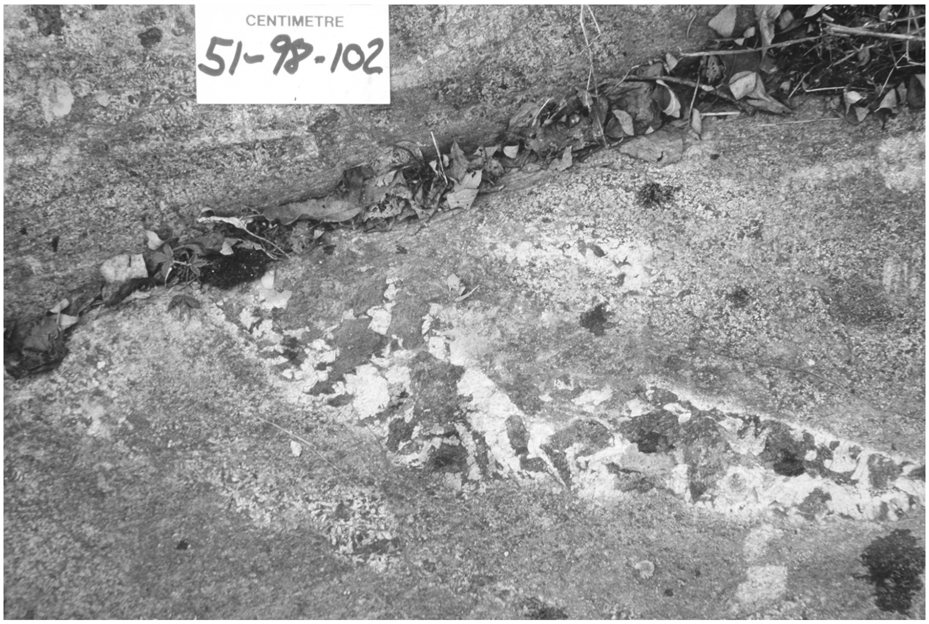


Figure GS-27-6: Varitextured gabbro in the lower part of the mafic series, Chrome property, Bird River Sill.

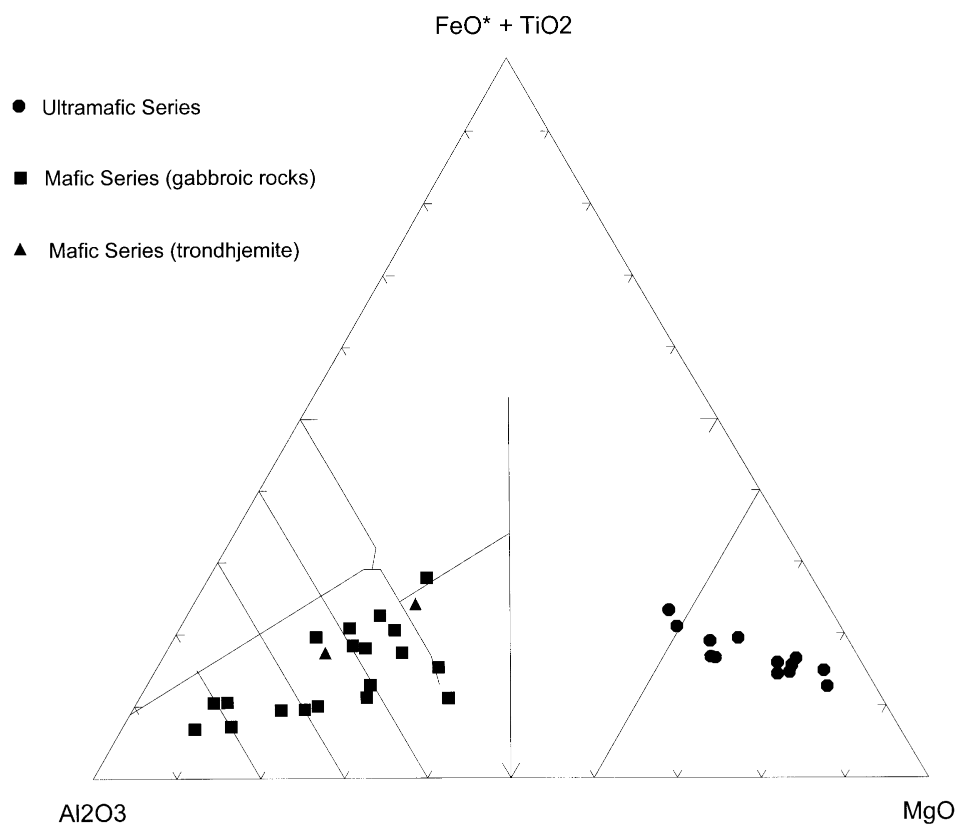


Figure GS-27-7: Jensen cation plot (Jensen, 1976) for mafic and ultramafic rocks from the Chrome property, Bird River Sill (unpublished data).

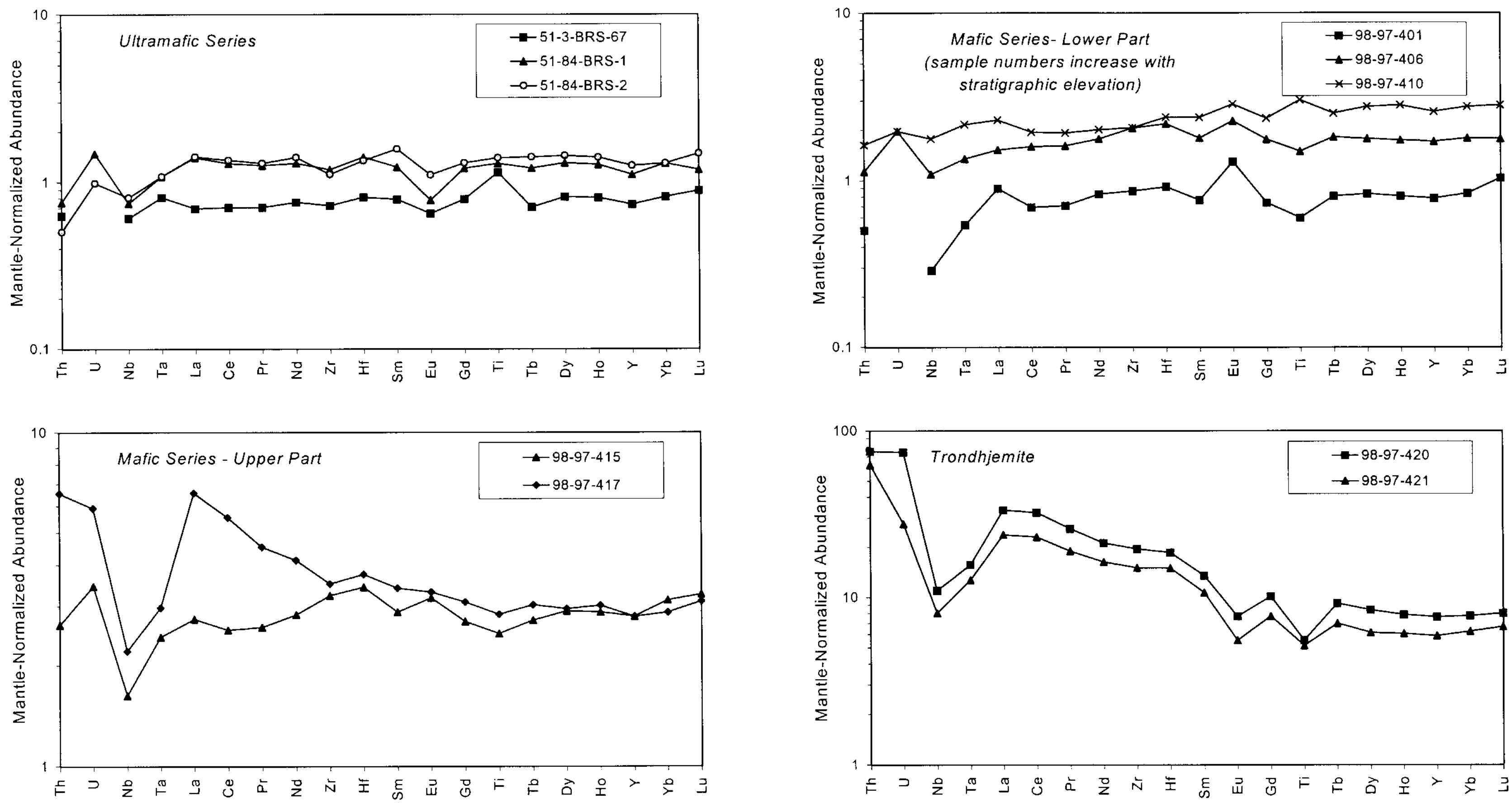


Figure GS-27-8: Primitive mantle normalized spider diagram for representative samples from the ultramafic and mafic series, Chrome property, Bird River Sill (unpublished data, D. Peck and P. Theyer, 1998). Mantle normalizing values are from McDonough and Sun (1995).

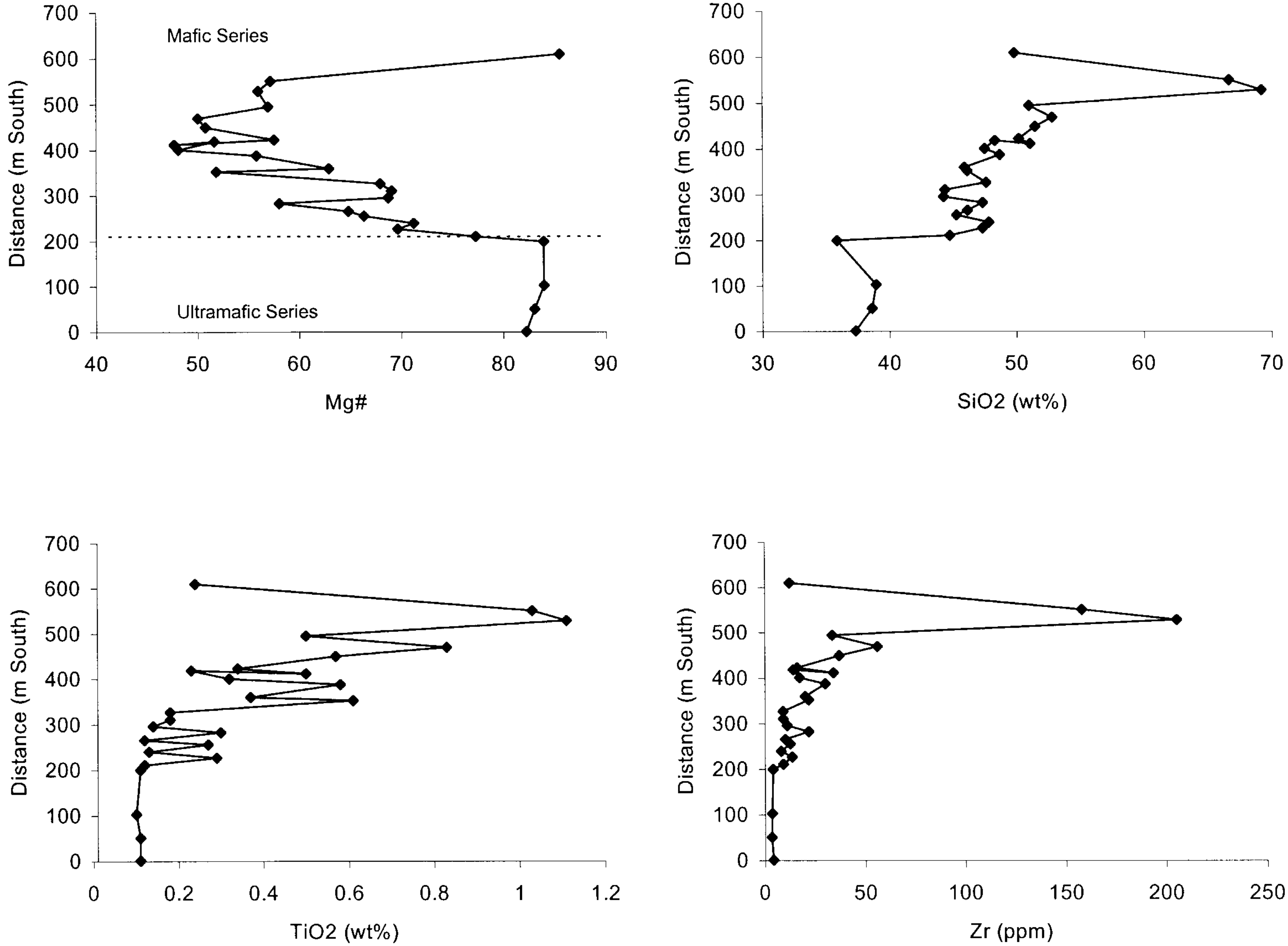


Figure GS-27-9: Variation in major element oxide and trace element abundances with stratigraphic position in the Chrome property, Bird River Sill (unpublished data, D. Peck and P. Theyer, 1998). Distance is measured from the exposed lower part of the ultramafic series along the western and central cuts (Fig. GS-27-2).

In the lower portion of the BRS, quench textures are observed in peridotite and dunite units that imply rapid cooling and disequilibrium crystal growth. This implies that a steep thermal gradient existed between the crystallization front and the resident magma and/or wall rocks. Textural evidence documented by Theyer (1991) indicates the development of quench textures (e.g., hopper and dendritic olivines) interpreted as having formed by supersaturation and disequilibrium growth from a stratified, primitive basaltic magma column. Steep thermal gradients could have developed in the BRS proto-chamber due to a high level of emplacement and low ambient temperatures in the surrounding crust. It is possible that much of the heat released during cooling and crystallization of the ultramafic portions of the BRS was carried upward into the gabbroic part of the sill. Relatively hot, low density and therefore buoyant feldspathic residual magma may have carried heat away from the temporary floor of the chamber, through overlying, more primitive parental magmas, and towards the roof zone. The paucity of feldspar in the ultramafic series could reflect efficient transfer of this rejected, feldspathic magma. Similar models have been proposed to explain the stratigraphy and geochemistry of other stratiform mafic-ultramafic intrusions (Morse, 1988).

PGE Geochemistry

Theyer (1985) provided a nearly continuous geochemical traverse of the ultramafic series at the Chrome property, based on saw cut samples at 50 cm and composite, 2 m intervals (eastern and western cuts, Fig. GS-27-2). These data demonstrate strong PGE enrichment within the ultramafic series. Palladium and Pt (and Au, not shown) are enriched in two wide stratigraphic intervals (34 to 52 m and 95 to 115 m, western cut; see Theyer, 1985; Fig. GS-27-10) within the lower part of the ultramafic series. Similar PGE enrichment is also recognized in a several metre wide, sulphide-bearing, peridotite-dunite sequence within the chromitiferous zone and adjacent to the western cut ("S-cut"; P. Theyer, unpublished data). The observed PGE enrichment in the ultramafic series corresponds with peaks in Cu and, to a lesser degree, Ni and Cr abundances and is only observed in rocks that contain visible sulphides (Theyer, 1985; Fig. GS-27-10). In addition, PGE abundances decrease by two orders of magnitude directly above the lowermost PGE enriched interval (Fig. GS-27-10).

These observations are consistent with the crystallization of small quantities of PGE-enriched immiscible sulphide liquids during the formation of the ultramafic series. The PGE-enriched intervals represent "reef-like" PGE concentrations in that they are stratiform and consist of very small amounts of sulphide mineralization (typically <1%). More work is planned for the Chrome property in order to better define the variability of, and controls on, PGE tenors. Preliminary PGE analyses for the mafic series have not identified significant PGE enrichment, although several samples contain in excess of 30 ppb of Pd and Pt (combined).

RECOMMENDATIONS FOR PGE EXPLORATION IN THE BIRD RIVER SILL

The following recommendations, regarding future exploration for PGE in the BRS, are advanced:

1) The low S and base metal tenor of the mafic series, observed at the Chrome Property, suggests that they do not record a major period of PGE precipitation. Exploration should initially focus on the ultramafic series, where PGE enrichment is observed at three stratigraphic levels. Addition of S from an external source, and/or mixing of the mafic magmas with more primitive magmas, could have triggered S-saturation and the

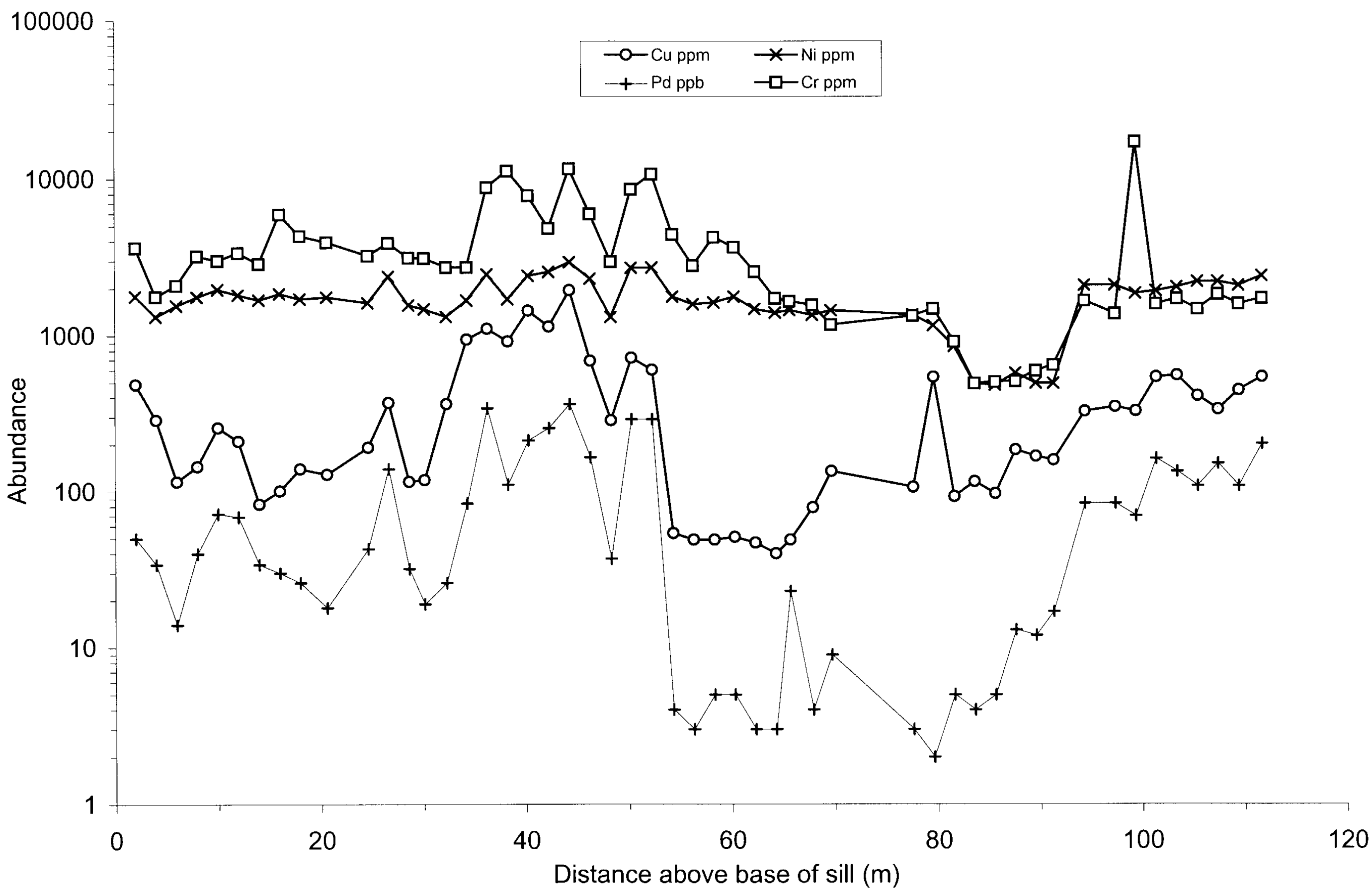


Figure GS-27-10: Variation in Pd, Cu, Ni and Cr abundances with stratigraphic position in the lower part of the ultramafic series (western cut), Chrome property, Bird River Sill (data are from Theyer, 1985). Distance is measured from the exposed lower part of the ultramafic series along the western and central cuts (Fig. GS-27-2).

formation of PGE-enriched "hybrid" layers in the ultramafic parts of the sill. The location of these reef-type PGE occurrences should be reflected in the development of hybrid geochemical compositions in the host rocks or by geochemical trends that indicate crustal contamination.

2) A likely place for a reef-type PGE deposit to have developed in the BRS is along the contact between the mafic and ultramafic series. If this contact represents an original liquid-liquid boundary (not established), and if the two magmas had appropriate chemical and thermal characteristics to allow efficient mixing, then a reef-type deposit could have been developed. Cryptic chemical variations that typically occur near reef-type PGE deposits require additional investigation in the case of the BRS. Existing data (D. Peck and P. Theyer, unpublished) suggest that the mafic series crystallized from S-undersaturated magmas whereas the ultramafic series developed from both S-saturated and S-undersaturated magmas. Future exploration activity should investigate the potential development of hybrid units (troctolite, feldspathic peridotite) near the mafic-ultramafic series boundary. and

3) A major impediment to PGE exploration in the BRS is the lack of a detailed crystallization model. Further petrologic and geochemical studies, combined with detailed mapping, will be required to provide the critical observations needed to develop such a model.

MAYVILLE PROPERTY

Mafic to ultramafic rocks that occur in the northern part of the Bird River greenstone belt (Mayville property and Euclid Lake area, Fig. GS-27-1) are predominantly gabbroic and display petrological similarities to plagioclase-rich gabbroic rocks in the Bird River Sill. Exploration activity dates back to 1917 and has delineated several chromite and Cu-Ni sulphide occurrences, including the Mayville and New Manitoba Cu-Ni deposits and the Hititrite showing, ca. 2 km to the east of the Mayville deposit (Brownell, 1943; Theyer, 1986). Chromite mineralization occurs locally within both the gabbroic and pyroxenitic portions of the Mayville intrusion (J. Chornoby, Exploratus Elementis Diversis, pers. comm., 1998).

Recent exploration by Falconbridge and Exploratus Elementis Diversis has focused on chromite and Cu-Ni-PGE mineralization in the Mayville property. The mineralization primarily occurs near the southern margin of the Mayville intrusion. Cu sulphide mineralization is also recognized in fine-grained gabbroic intrusions within basalt sequences ca. 1 km to the south of the Mayville intrusion (J. Chornoby, pers. comm., 1998). Elevated PGE abundances are reported from samples of semi-massive Cu-Ni sulphide mineralization hosted by gabbroic rocks in the Mayville deposit and Hititrite occurrence (up to 0.6 ppm of combined Pd + Pt; Theyer, 1986), and in pyroxenite from the south-central part of the Mayville intrusion (J. Chornoby, pers. comm., 1998).

Mapping of the Mayville property was completed by Macek (1985) and Falconbridge Ltd. (unpublished). The property is underlain by a >10 km long (east-west dimension) by ca. 600 m to >1 km wide (north-south dimension) mafic to ultramafic intrusion emplaced into a sequence of pillowed and massive aphyric and plagioclase megacrystic basalt. The gabbroic portion of the Mayville intrusion is petrologically similar to Archean megacrystic anorthosite intrusions from the Cross Lake area (see Peck et al., GS-24, this volume). It is also similar to the mafic series of the Bird River Sill.

The gabbroic portion of the Mayville intrusion consists primarily of modally-layered (metre to decametre scale), coarse-grained leucogabbro and subordinate anorthosite and gabbro. The gabbroic rocks are succeeded to the south by a poorly exposed, ca. 400 m thick (drill-defined thickness; J. Chornoby, pers. comm., 1998) pyroxenite unit that comprises medium- to coarse-grained pyroxenite (websterite) and melagabbro. In one location, the pyroxenite is intruded by leucogabbro and varitextured gabbro and an intrusive breccia has developed. Sulphide mineralization that consists of disseminated pyrrhotite and chalcopyrite, is developed within the pyroxenite unit at this location.

Igneous layering in the Mayville intrusion and pillow structures in the underlying basalts indicate that the mafic rocks in this area are consistently north facing (Macek, 1985). Aphyric, plagioclase phyric and plagioclase megacrystic gabbroic dykes that have similar compositions to both the basalts and the Mayville gabbro, are developed several km to the southeast of the Mayville property. These dykes intrude basalt, as well as granitic rocks correlated with the Great Falls pluton. An ca. 100 to 130 m wide fine-grained gabbroic intrusion occurs in the metabasalts directly to the south of the Mayville intrusion. The former locally contains disseminated Fe-Cu sulphide mineralization (Copper Contact zone, J. Chornoby, pers. comm., 1998) and plagioclase phenocrysts.

A small sampling program, designed to provide new geochemical data for sulphide occurrences in the Mayville gabbro, was conducted at the Hititrite showing and along the gabbro-pyroxenite contact at the south end of the Mayville intrusion. Additional sampling was carried out on spatially related basaltic units and the above mentioned mafic dykes.

WARDS PROPERTY (COPPERMINE BAY)

A one day investigation was completed on chromite mineralization and sulphide occurrences in a gabbroic intrusion (herein referred to as the Coppermine Bay intrusion) located at the western end of the south flank of the Bird River greenstone belt (Wards property, (ca. 1 km east-northeast of the north end of Coppermine Bay, Lac du Bonnet) Fig. GS-27-2). The investigation focused on mapping and geochemical sampling of chromite and disseminated sulphide mineralization located near the northern margin (interpreted base) of the Coppermine Bay intrusion. The intrusion is ca. 110 m thick in the area investigated and displays east-trending modal layering. It is emplaced into massive and pillowed basalt flows and has fine-grained chilled margins on both the northern and southern contacts.

The chromite mineralization occurs within a varitextured gabbro layer, ca. 10 m above the base of the intrusion. Massive chromite layers, up to 1 m wide, are locally tightly folded on easterly-trending axial planes and east-plunging axes. The chromite layers were traced along strike for ca. 1 km. Disseminated pyrrhotite and chalcopyrite occur within an overlying disrupted anorthositic layer that contains irregular pods and veins of varitextured gabbro. The sulphide mineralization is exposed in two trenches and is reported to contain up to 1.3 ppm of combined Pd + Pt (Theyer, 1986). Canex Placer reported Pd + Pt abundances of up to 2 ppm (combined) in drill core samples of disseminated sulphide mineralization from the Coppermine Bay intrusion (see Theyer, 1986).

The chromite and sulphide mineralization is overlain by coarse-grained leucogabbro that locally contains plagioclase megacrysts and becomes finer-grained towards the south. At the southern margin of the intrusion, a 2 - 3 m wide, fine-grained gabbro unit is developed.

The Coppermine Bay intrusion has a recognizable and laterally continuous stratigraphy and warrants detailed mapping and geochemical studies in light of the known chromite and sulphide-hosted PGE mineralization.

ACKNOWLEDGEMENTS

The cooperation and technical support provided by Gossan Resources Ltd. and Exploratus Elementis Diversis is gratefully acknowledged. We thank Mr. J. Chornoby for providing an introduction to the geology of the Mayville property, relevant maps and technical reports, and a thorough review of this paper.

REFERENCES

Brownell, G.M.
1943: Maskwa Lake Area Geology; Unpublished report, Stanmore Mining and Smelting Company Ltd.

Jensen, L.S.
1976: A new cation plot for classifying subalkalic volcanic rocks; Ontario Department of Mines, Miscellaneous Paper 66.

Karup-Moller, S. and Brummer, J.J.
1971: Geology and sulphide deposits of the Bird River claim group, southeastern Manitoba; Geoscience Studies in Manitoba; **in** (A.C Turnock ed.) Geological Association of Canada, Special Paper 9, 1971, p.143-154.

Macek, J.J.
1985: Cat Creek; Manitoba Energy and Mines, Preliminary Map 1985C-1, 1:10 000 scale.

McDonough, W.F. and Sun, S.S.
1995: The composition of the earth. Chemical Geology, v. 120, p. 223-253.

Morse, S. A.
1988: Motion of crystals, solute and heat in layered intrusions; Canadian Mineralogist, v. 26, p. 209-224.

Scoates , R.F.J.
1983: A preliminary stratigraphic investigation of the ultramafic zone of the Bird River Sill; **in** Manitoba Energy and Mines, Minerals Division, Report of Field Activities, 1983, p.70-83.

Talkington, R.W., Watkinson, D.H., Whittaker, P.J. and Jones, P.C.
1983: Platinum group mineral inclusions in chromite from the Bird River Sill, Manitoba; Mineralium Deposita, v.18, p.245-255.

Theyer, P,
1985: Platinum-Palladium distribution in ultramafic rocks of the Bird River Complex, Southeastern Manitoba; Manitoba Energy and Mines, Geological Services, Open File Report OF 5-4, 64p.

1986: Platinum group elements in southeastern Manitoba; **in** Manitoba Energy and Mines, Minerals Division, Report of Field Activities, 1983, p.70-83.

1991: Petrography, chemistry and distribution of platinum and palladium in ultramafic rocks of the Bird River Sill, SE Manitoba, Canada; Mineralium Deposita, v. 26, p. 165-174.

Timmins, E.A., Turek, A. and Symons, D.T.A.
1985: U-Pb zircon geochronology and paleomagnetism of the Bird River greenstone belt, Manitoba; GAC-MAC Joint Annual Meeting, 1985, Annual Program with Abstracts, v. 10, p. A62.

Trueman, D.L.
1971: Petrological, structural and magnetic studies of a layered basic intrusion, Bird River Sill, Manitoba; M.Sc. thesis (unpublished), Department of Earth Sciences, University of Manitoba, Winnipeg, Manitoba, 67 p.

Williamson, B.
1990: Geology of the Bird River sill at the Chrome property, southeast Manitoba; Geological Survey of Canada, Open File 2067.