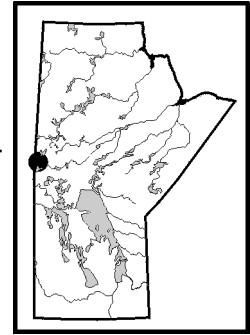


**PLATINUM GROUP ELEMENT INVESTIGATIONS IN THE FLIN FLON  
GREENSTONE BELT: REGIONAL GEOLOGY OF THE MCBRATNEY LAKE  
PGE-AU OCCURRENCE AND PART OF THE MIKANAGAN LAKE SILL  
(NTS 63K13), MANITOBA  
by P. Theyer and T. Heine**



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### SUMMARY

Geological investigations in the Flin Flon greenstone belt oriented toward platinum group elements (PGE) focused on four related topics:

- 1) A detailed investigation of the petrography and mineralogy of the McBratney Lake PGE-Au occurrence was carried out to elucidate the possible origin and formation of this mineralization. Preliminary results, indicating that the mineralization is probably hydrothermal in origin, are presented elsewhere (Olivo et al., GS-12, this volume).
- 2) An investigation of the lithology, composition and age of the Wonderland Lake gabbro was undertaken because it hosts two PGE-bearing sulphide occurrences along its intrusive contact with the Bear Lake basaltic andesite (Theyer, 2001). Preliminary results indicate that the igneous body is a heterolithic magmatic complex. The intrusion is important, as it belongs to a group of pre-Missi, differentiated, mafic to intermediate intrusions (Bailes and Syme, 1989), several of which are spatially associated with PGE mineralization in the Bear Lake Block.
- 3) Geological mapping and sampling of the area adjacent to the McBratney mineral occurrence was undertaken in an attempt to determine the source of the PGE mineralization and to elucidate the particular geological and/or tectonic parameters leading to its formation. Preliminary results indicate that the McBratney mineralization is underlain by mafic, intermediate and felsic volcanic rocks associated with sulphide-bearing horizons, and that gabbro makes up a minor part of the surrounding rock sequence.
- 4) A geological investigation designed to evaluate the PGE potential of other gabbroic bodies in the belt was initiated with the Mikanagan Lake Sill. Shear-hosted sulphide mineralization from the gabbro zone of the sill returned anomalous Pd+Pt concentrations.

### INTRODUCTION

The McBratney Lake PGE-Au occurrence, located approximately 7 km east of Flin Flon, is of significance to mineral explorationists due to its exceptionally high PGE and Au concentrations. The occurrence is also significant because the 'Bear Lake Block' of the Flin Flon greenstone belt, previously known to host two VMS deposits (Cuprus and White Lake mines) and a number of VMS mineral occurrences (Bailes and Syme, 1989), is now also known as a potential host to significant PGE mineralization. The McBratney Lake PGE-Au mineralization, exposed in a pit excavated in 2001, straddles the contact of (?)pre-Missi gabbro and Bear Lake basaltic andesite (Theyer, 2001).

### REGIONAL SETTING

The Flin Flon greenstone belt, which belongs to the juvenile (internal) zone of the Trans-Hudson Orogen (Hoffman, 1988), is a collage of 1.92 to 1.88 Ga tectonostratigraphic assemblages juxtaposed during 1.88 to 1.87 Ga intra-oceanic accretion and subsequent 1.84 to 1.78 Ga terminal collision of the bounding Archean cratons (Lucas et al., 1996). Based on their trace-element contents, volcanic rocks in the Flin Flon greenstone belt are known to include juvenile-arc (approx. 68%), juvenile ocean-floor (approx. 20%), and minor (approx. 12%) oceanic-plateau, ocean-island basalt, 'evolved' plutonic-arc and undivided rocks (Syme and Bailes, 1993; Stern et al., 1995a, b; Syme et al., 1999). Oceanic-arc assemblages include tholeiite, calc-alkaline and rare shoshonite and boninite suites (Stern et al., 1995a) that are almost identical to those forming in modern intra-oceanic arcs (e.g., Gill, 1981). These volcanic assemblages are unconformably overlain by a terrestrial metasedimentary sequence (Missi Group) and are intruded by a complex array of intrusive rocks (Bailes and Syme, 1989). Most of the intrusive rocks in the central Flin Flon greenstone belt predate the Missi Group. In the Flin Flon-White Lake area, Bailes and Syme (1989) defined major fault-bounded blocks, each comprising unique stratigraphic successions (Fig. GS-11-1).

The Bear Lake Block, one of the fault-bounded blocks, is a 5 km thick, east-facing sequence of lava flows and volcanoclastic rocks bounded on the west by the Inlet Arm Fault and on the east by the Northeast Arm Fault (Bailes and Syme, 1989). This block has been subdivided into eleven lithological units, ranging from andesitic basalt to rhyolite and including associated detrital metasedimentary rocks and massive-sulphide deposits. Dominating most of the

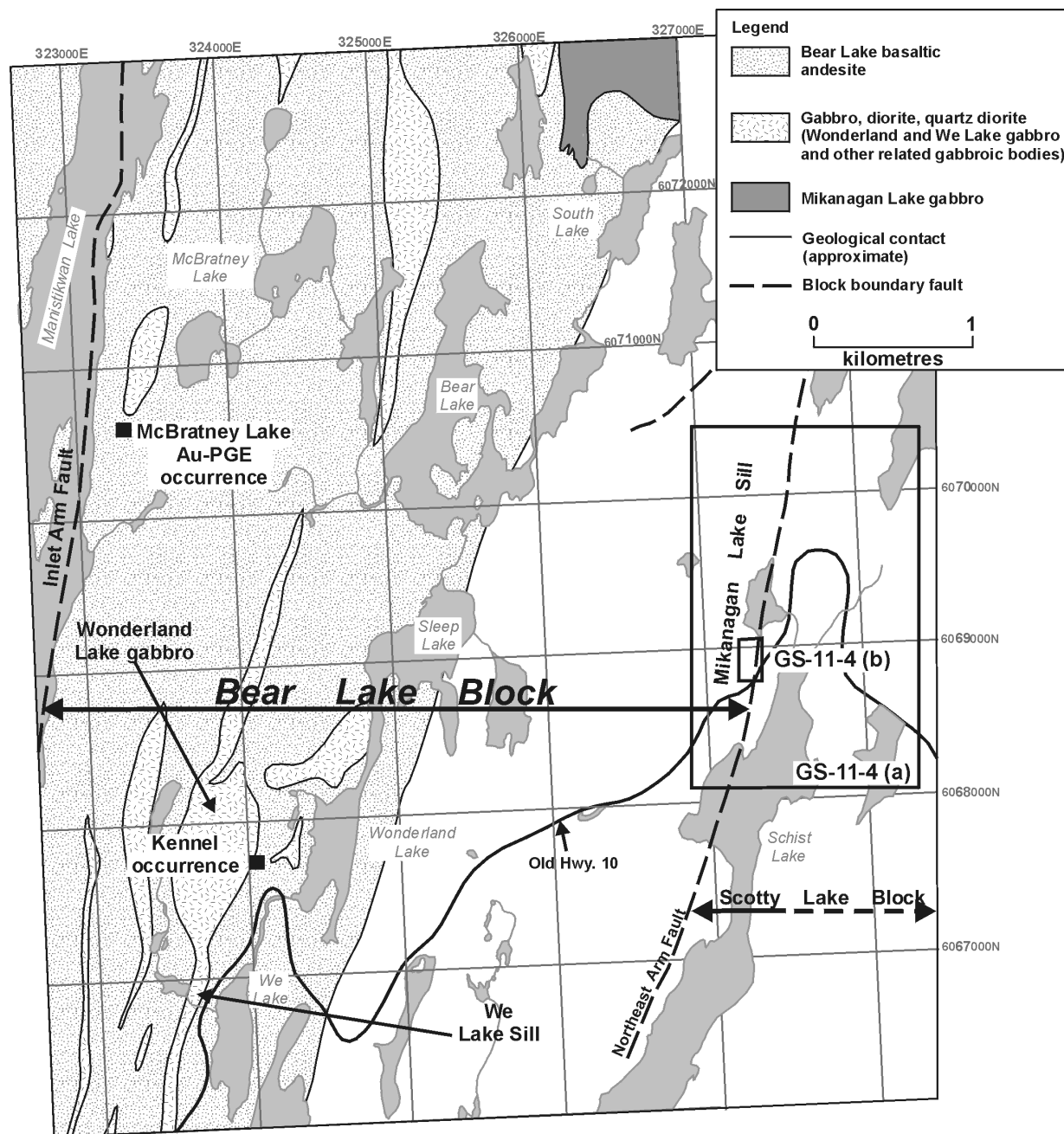


Figure GS-11-1: Flin Flon-White Lake area, showing the location of the Bear and Scotty Lake blocks, bounding faults and study areas (modified after Bailes and Syme, 1989).

western part of the Bear Lake Block and forming its base is the Bear Lake basaltic andesite, comprising a number of volcanic flows that together exceed 3.3 km thickness. Intermediate to felsic volcanoclastic units overlie the basaltic andesite sequence.

### GEOLOGY IN THE VICINITY OF THE MCBRATNEY LAKE PGE-AU OCCURRENCE

This section deals with the geological setting of the McBratney Lake PGE-Au mineralization, as determined through examination of abundant and clean outcrops, especially in the northern and eastern parts of the now-flooded pit that exposed the mineralization (Fig. GS-11-2). The petrography and mineralogy of this occurrence is the subject of a separate study initiated in collaboration with Queens University (Olivo et al., GS-12, this volume). That study highlights the significance of hydrothermal mineralization and/or remobilization and PGE redistribution in the origin

of the McBratney Lake PGE-Au mineralization. A description of the geological units in the vicinity of the occurrence is given below. The unit numbers correspond to those on Figure GS-11-2.

### Bear Lake basaltic andesite (unit 1)

Well-preserved pillowed flows of the Bear Lake basaltic andesite suite are exposed east of Manistikwan (Big Island) Lake. Pillows range in length from 1 to 3 m, with selvages ranging from 5 to more than 30 mm in thickness. Interpillow material, consisting mainly of selvage fragments and hyaloclastite, can attain a thickness of more than 10 cm.

Traverses from Manistikwan Lake to the area of the McBratney Lake PGE-Au occurrence showed a distinct increase in the amount of both epidotization and deformation in an easterly direction. Adjacent to the shore of Manistikwan Lake, pillows showing little deformation are characterized by negligible epidotization that affects mainly their central zones. However, gradual but dramatic increases in both the degree of deformation (flattening and stretching) of the pillows and the intensity of epidotization was observed approximately 150 m east of Manistikwan Lake. At this location, pillows measuring 0.5 to 1 m in width attain lengths of several metres and contain massive, oval to subrounded, decimetre-size epidosite (epidote+quartz) domains. An even greater intensity of deformation and

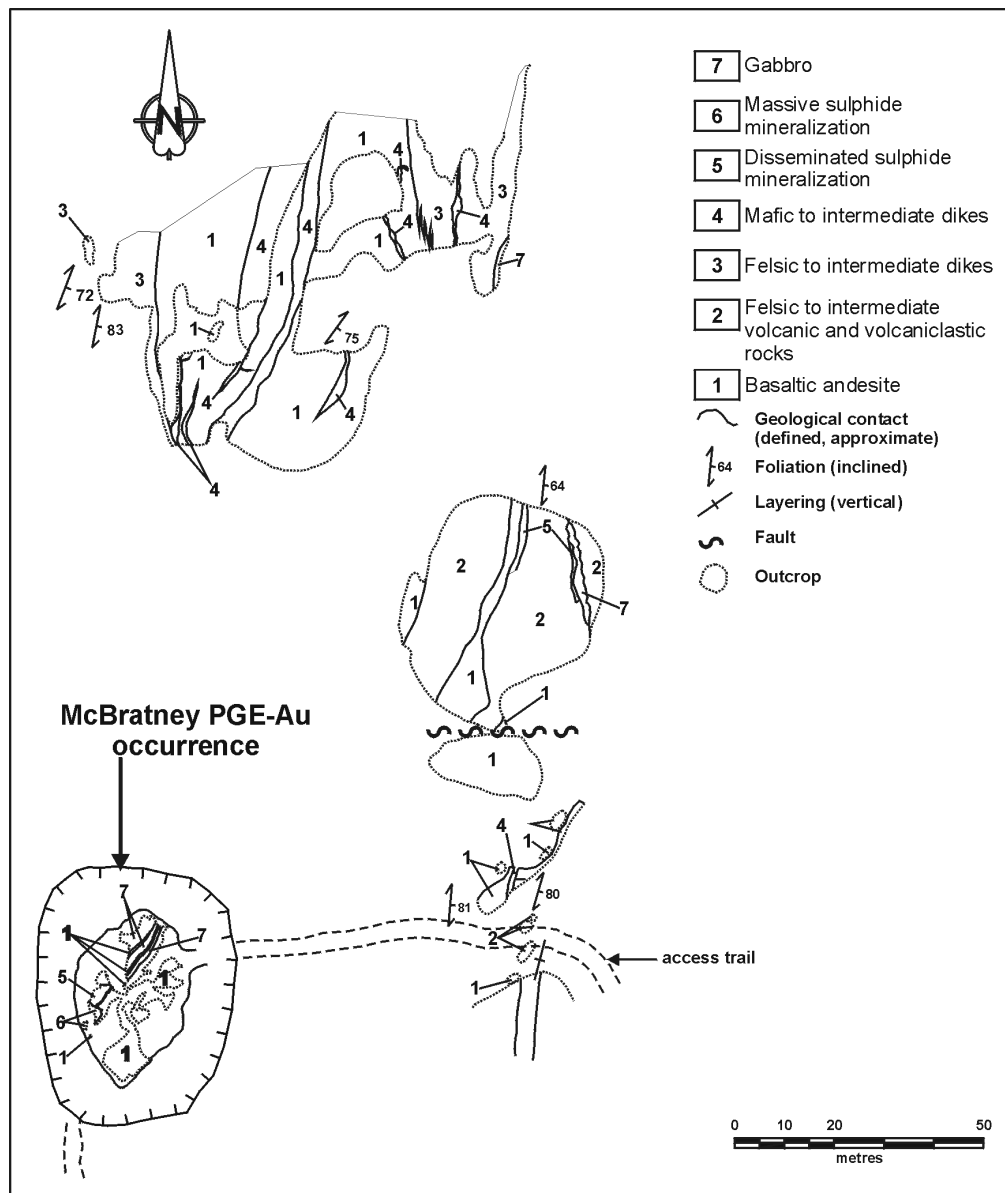


Figure GS-11-2: Geological map of the vicinity of the McBratney Lake PGE-Au occurrence.

epidote alteration was observed in outcrops directly north of the McBratney Lake PGE-Au occurrence. In these exposures, the pillowed basalt consists of a contorted mass of lensoid epidosite and quartz domains (Fig. GS-11-3).

Bailes and Syme (1989) observed a positive correlation between the intensities of deformation and epidotization. Galley and Bailes (2001) are investigating the correlation of epidotization and high-temperature hydrothermal seafloor alteration, which may be associated with the mobilization of large quantities of metals.

### **Felsic to intermediate volcanic and volcanoclastic rocks (unit 2)**

Extensive outcrops of felsic to intermediate volcanic rocks, which weather beige to grey-green, occur northeast of the McBratney Lake PGE-Au exploration pit. This unit is composed of several subunits, each up to a metre thick, that can be distinguished based on subtle compositional and colour variations. Many of the rocks are porphyritic, composed of a fine-grained quartz and plagioclase groundmass hosting approximately 5% millimetre-size, euhedral plagioclase and minor, equally large, strained, mosaic quartz crystals. A north-striking layer, approximately 2 cm thick and characterized by well-rounded carbonate grains ranging from 1 to 2 mm in diameter, is tentatively interpreted as a tuff.

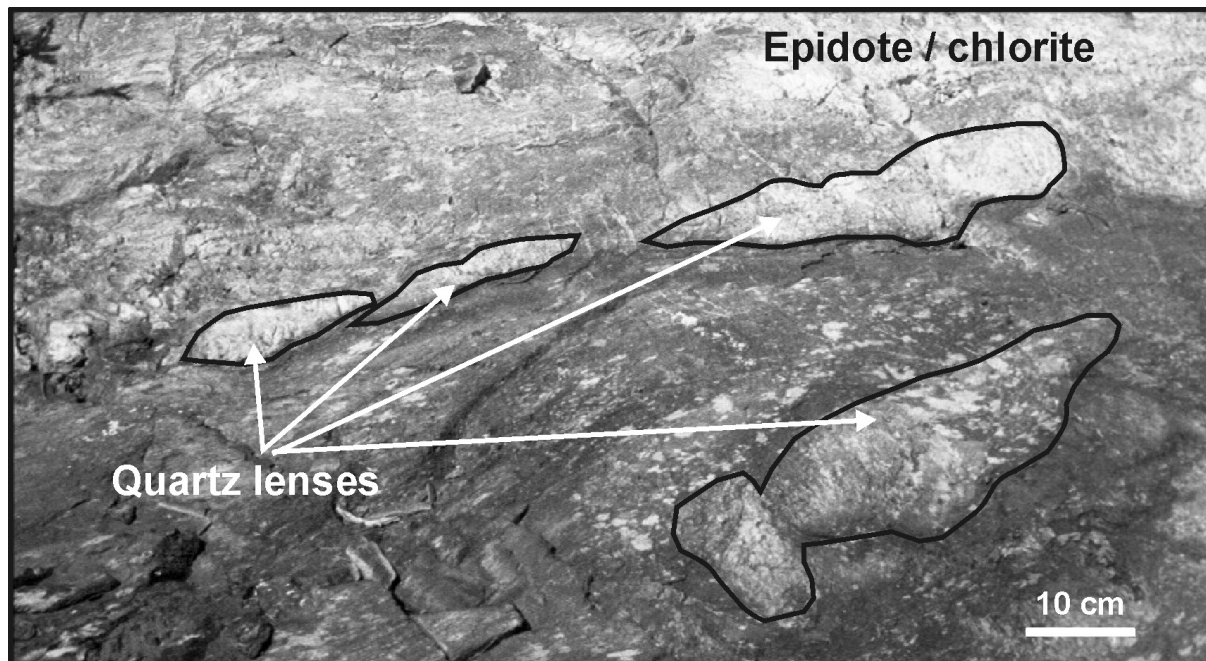
Several outcrops of a greenish grey siliceous rock underlie the eastern access trail to the McBratney pit. These are interpreted as rhyolite.

### **Felsic to intermediate dikes (unit 3)**

Coarse-grained, chloritized and epidotized rock, in places containing abundant pyrite cubes, up to a centimetre in size, constitute some of the outcrops north of the pit. Thin sections show that the rock is composed mainly of coarse epidote, minor quartz, plagioclase and chlorite.

### **Mafic to intermediate dikes (unit 4)**

These are foliated, fine-grained rocks characterized by smooth-weathering, grey surfaces. These rocks occur as concordant units, ranging from a centimetre to a metre in thickness and up to 20 m long, with sharp, well-defined, abrupt contacts. They are uniformly fine grained, both along and across strike, and there is no evidence of chilled margins. The rock is composed of approximately 50% epidote, 20% chlorite, 20% amphibole, 10% quartz and accessory opaque minerals. They are tentatively interpreted as selectively epidotized dikes; however, they may also be of sedimentary origin, as they are subparallel to stratigraphy.



*Figure GS-11-3: Deformed and contorted epidosite, quartz and schist. The rock is a pillowed basalt in a zone of intense deformation in the immediate vicinity of the McBratney Lake PGE-Au occurrence.*

### Disseminated sulphide mineralization (unit 5)

Disseminated sulphide mineralization, hosted by bleached, altered rocks, consistently occurs with felsic rock units. The sulphide minerals occur as disseminated to centimetre-thick layers of pyrrhotite and minor pyrite. Most of the sulphide layers are deeply weathered, with bright red to yellow limonitic crusts. The persistent and repeated association of sulphide units and felsic volcanic rocks has been identified in a preliminary way over a distance of several hundreds of metres north and east of the McBratney pit.

### Massive sulphide mineralization (unit 6)

Massive sulphide mineralization occurs in a lens that was exposed in the McBratney test pit in 2001 (Theyer, 2001). The sulphide mineralization underlying the pit comprises an assemblage of pentlandite, Ni-bearing pyrrhotite, pyrite, bravoite, marcasite, chalcopyrite, millerite, sphalerite and galena (Olivo et al., GS-12, this volume).

### Gabbro (unit 7)

Gabbro occurs as thin (a decimetre to several metres thick), deformed, elongated, north-striking lenses. Contacts with adjoining rocks are sheared and disrupted. In places, the margins of the gabbro are characterized by quartz-filled tension gashes. Thin sections show a coarse-grained, altered magmatic unit composed of plagioclase, amphibole and felted sericite and chlorite masses. Quartz occurs as secondary vein fillings.

### MIKANAGAN LAKE SILL

The Mikanagan Lake Sill is one of several large, differentiated, tholeiitic gabbroic intrusions that occur in the Flin Flon greenstone belt. Described by Bailes and Syme (1989), the sill is approximately 15 km long and 1.2 km thick, well differentiated and indicates stratigraphic tops to the east. This intrusion is one of several in the Flin Flon belt that will be investigated for their potential to host PGE mineralization.

### Platinum group element-bearing sulphide zone

Fracture-controlled PGE-bearing sulphide mineralization occurs within the gabbro zone near the southern end of the Mikanagan Lake Sill, in an area measuring approximately 120 by 30 m (Fig GS-11-4). The mineralized zones in

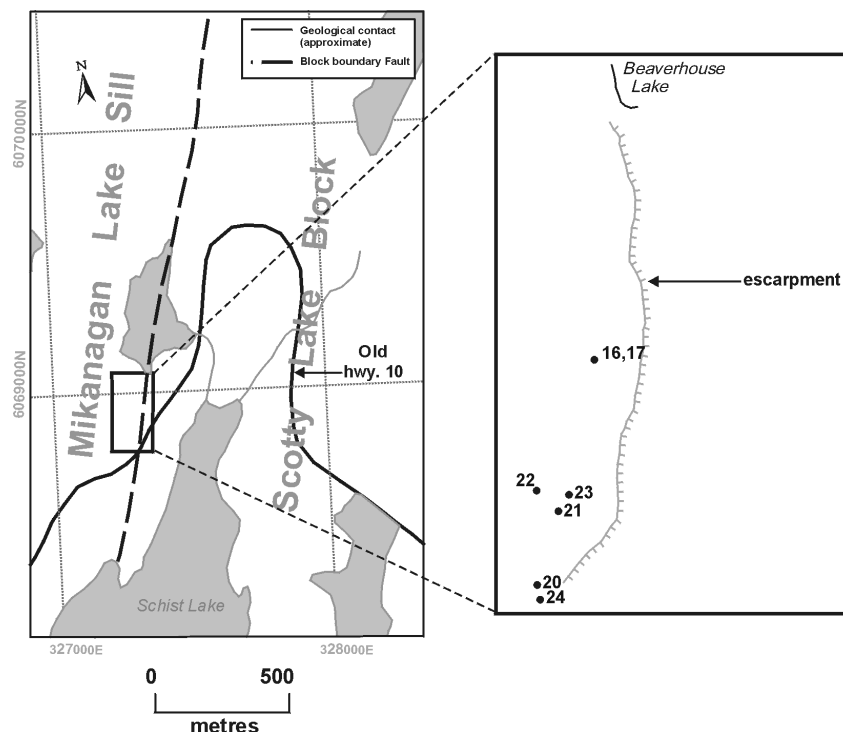


Figure GS-11-4: Geological sketch map showing the location of PGE-bearing sulphide mineralization in the Mikanagan Lake Sill (geology modified after Bailes and Syme, 1989).

this area appear to have a limited distribution, each generally encompassing several square metres. Some of these areas are intensely foliated. The weathered rock surface is grey to green-grey, and the almost complete absence of iron oxide on the surface of sulphide-bearing gabbro makes the recognition of sulphide-bearing zones a challenging task.

Thin sections of several of the mineralized zones show that the hostrock consists of variably altered gabbro. Bailes and Syme (1989) described the alteration sequence of the various parts of the Mikanagan Lake Sill in detail. Thin-section descriptions will thus be kept brief. Coarse-grained, amphibolitized pyroxene is partially altered to chlorite and tremolite aggregates and overprinted by epidote. Plagioclase is rarely well preserved, and is generally completely sericitized and epidotized. Several sections contain up to 5% strained quartz. Opaque subhedral minerals are rare.

Mineralized rocks are characterized by a variety of alteration types, including chloritization, carbonatization and epidotization. Each of these alteration types may occur by itself or in conjunction with the others. The alteration can completely obliterate the original textures, resulting in a chlorite-carbonate-epidote rock.

Pyrrhotite is the dominant sulphide mineral, generally as fine-grained disseminations, and attains concentrations of up to 10%. Pyrite is a minor constituent, rarely exceeding 1%. Minor chalcopyrite is also present.

Table GS-11-1 includes some of the rock sample locations (UTM co-ordinates given), the sample numbers and the results of selected Pt, Pd and Au analyses. The analyses were performed by XRAL Laboratories, using a fire-assay preconcentration step, with PbO as a collector, and analysis by mass spectrometry (FAMS 30 analytical procedure). Lower detection limits of this method are 1 ppb Au, 1 ppb Pd and 0.5 ppb Pt.

*Table GS-11-1: Gold, platinum and palladium concentrations in gabbro samples from the Mikanagan Lake Sill. Detection limits: 1 ppb Au, 1 ppb Pd, 0.5 ppb Pt.*

Sample No.	UTM co-ordinates <sup>1</sup>		Au (ppb)	Pd (ppb)	Pt (ppb)
	Easting	Northing			
16	327283	6069147	<1	3	2.5
17	327283	6069147	2	5	6.4
20	327253	6069025	2	40	9.4
21	327264	6069065	51	461	108
22	327264	6069074	7	352	56.5
23	327269	6069073	5	109	49.9
24	327254	6069018	4	152	69.1

## Discussion

Of the eight rock samples collected from gabbro of the Mikanagan Lake Sill that were analyzed, four contain anomalous Pt+Pd concentrations (Table GS-11-1; Pt+Pd > 100 ppb is defined as anomalous).

Three samples (samples 21, 22 and 23) cluster in an area measuring approximately 40 m<sup>2</sup>. The fourth anomalous sample (sample 24) was collected approximately 50 m south of the aforementioned cluster.

The rock sample with the highest Pt+Pd concentration (sample 21) was collected from a medium-grained, grey-weathering gabbro with minor rusty patches. It is characterized by abundant fractures and shear zones. In an area measuring 2 by 1.5 m, up to 5% pyrrhotite and minor chalcopyrite occur as irregular masses and disseminations. Sample 22 was collected from a small (<1 m<sup>2</sup>) outcrop of strongly carbonatized and epidotized, medium-grained gabbro containing patches of up to 5% pyrrhotite and traces of chalcopyrite. Sample 23 is from epidotized and carbonatized gabbro containing up to 10% pyrrhotite masses with minor chalcopyrite.

Sample 24 was collected from a fresh-looking, medium-grained gabbro with a grey to black mottled appearance caused by fresh amphibole intergrowths with plagioclase. The relatively high Pt+Pd concentration in this sample is remarkable, considering that it contains only traces of pyrrhotite.

The occurrence of anomalous Pt+Pd concentrations in gabbro of the Mikanagan Lake Sill indicates that this intrusion has the potential to contain economic quantities of PGEs. Follow-up work on the presently recognized mineralized zones will include detailed studies of their lithology and geochemistry. Additional studies of the igneous complex will include identification of sulphide-bearing areas.

## WONDERLAND LAKE GABBRO

The discovery of PGE-bearing sulphide mineralization at the eastern contact of the Wonderland Lake gabbro with the Bear Lake basaltic andesite, and at the contact between the basaltic andesite and another gabbro body at the McBratney mineral occurrence, indicates that the contact between the basalt units and gabbro bodies may be significant for the occurrence of PGE mineralization (Theyer, 2001). Current studies of the McBratney PGE-Au mineral occurrence, based on investigations of drill core and sulphide mineralization samples, show that the occurrence is of hydrothermal origin and that the sulphide minerals intersected by exploratory drilling are hosted by basaltic andesite (Olivo et al., GS-12, this volume).

Several traverses across the Wonderland Lake gabbro were undertaken in 2002 to collect rock samples for geochemical and lithological investigations. A large rock sample intended for age determination was also collected

from a pegmatitic phase of the gabbro.

Field evidence indicates that the Wonderland Lake gabbro is a geologically inhomogeneous body comprising a variety of rock types, including granite, diorite and gabbro. A crude lithological zonation, based on a relative increase of felsic rocks in an easterly direction, is recognizable. However, magma mixing that resulted in large, randomly located areas of hybrid granitic to dioritic rocks, characterized by melanocratic inclusions, schlieren and bands contained in a more felsic matrix, is common and weakens the notion of an orderly zonation. Moreover, east-striking, modally layered leuco- and melagabbro indicate further inhomogeneities. Discrete, sharply defined sulphide-bearing zones, up to several metres in size and containing up to 10% coarse-grained, recrystallized pyrite, occur in the central part of the Wonderland Lake gabbro. The composition of these zones and the amount and type of alteration are comparable to those of the gabbroic hostrock. They can, however, be differentiated based on their distinctly finer grain sizes and their ubiquitous sulphide content, which results in red and brown limonitic oxidation on weathered surfaces.

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