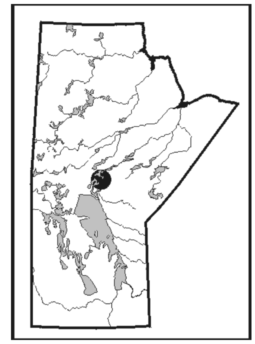
GS-24 NEW INSIGHTS INTO THE PETROGENESIS OF THE PIPESTONE LAKE ANORTHOSITE COMPLEX AND ITS TI-V-FE OXIDE DEPOSITS (PARTS OF NTS 63I/5 AND I/12)

by D.C. Peck, C. Messing[1], N.M. Halden[1] and C. Chandler[2]



Peck, D.C., Messing, C., Halden, N.M. and Chandler, C, 1998: New insights into the petrogenesis of the Pipestone Lake anorthosite complex and its Ti-V-Fe oxide deposits (parts of NTS 63I/5 and I/12); **in** Manitoba Energy and Mines, Geological Services, Report of Activities, 1998, p. 127-134.

SUMMARY

New field observations have provided critical constraints on the petrogenesis of the Pipestone Lake anorthosite complex (PLAC). Detailed stratigraphic mapping in the lower and middle parts of the complex revealed the presence of cyclic units that typically consist of a lower gabbroic layer (melagabbro to gabbro; rare pyroxenite), a thicker, central leucogabbro layer, and a discontinuous, upper megacrystic anorthosite layer. Within the cyclic units, individual layers locally display microrhythmic, centimetre-scale modal layers that comprise pyroxenite to anorthosite. In both the cyclic units and the microrhythmic units, there is a consistent stratigraphy that is believed to have developed by *in situ* fractional crystallization of buoyant plagioclase crystals, less buoyant, high-temperature, Al-rich leucogabbroic parental magma, and relatively dense, Fe- and Ti-rich ferrogabbroic residual liquids. The internal arrangement of mafic and feldspathic components is consistent on both scales of layering and is also reflected in the 3 megacyclic units that are developed in the central part of the PLAC.

The new field evidence supports the interpretation of Jobin-Bevans et al. (1997) who predicted that the PLAC was formed by the repeated influx of chemically-similar Al-rich gabbroic magma. The irregular distribution of gabbro in the PLAC is interpreted as the result of lateral and downward movement of dense, Fe-rich residual liquids. Abundant scours and crosscutting relationships in pre-existing leucogabbroic layers and ferrogabbroic layers suggest that residual mafic liquids were quite mobile during the later stages of crystallization of the cyclic units, and typically migrated toward the bottom of these units. The oxide-enriched layers are interpreted to represent cumulates that developed at the base of these ferrogabbroic residual liquids.

In addition to the observed cyclicity of the layering, cryptic chemical variations were recently reported from plagioclase and oxide compositions, and involve a progressive upward decrease in both Ca:Na ratios in plagioclase and Fe:Ti ratios in the oxide mineral assemblages. Results from the current study suggest that these cryptic trends transcend both the cyclic and megacyclic unit boundaries. Geochemical data (ongoing study) are required to improve the interpretation of these trends and will provide additional constraints on the petrogenesis of the PLAC and its Ti-V-Fe oxide deposits.

INTRODUCTION

The Pipestone Lake anorthosite complex (PLAC) is an ca. 1 km thick x 17 km long layered anorthosite to gabbro sill that occurs in the central part of the Cross Lake greenstone belt (Fig. GS-24-1). The

[1]Department of Geological Sciences, University of Manitoba, 125 Dysart Road, Winnipeg, Manitoba R3T 2N2
[2]Department of Geology, Brandon University, 270 - 18th Street, Brandon, Manitoba R7A 6A9

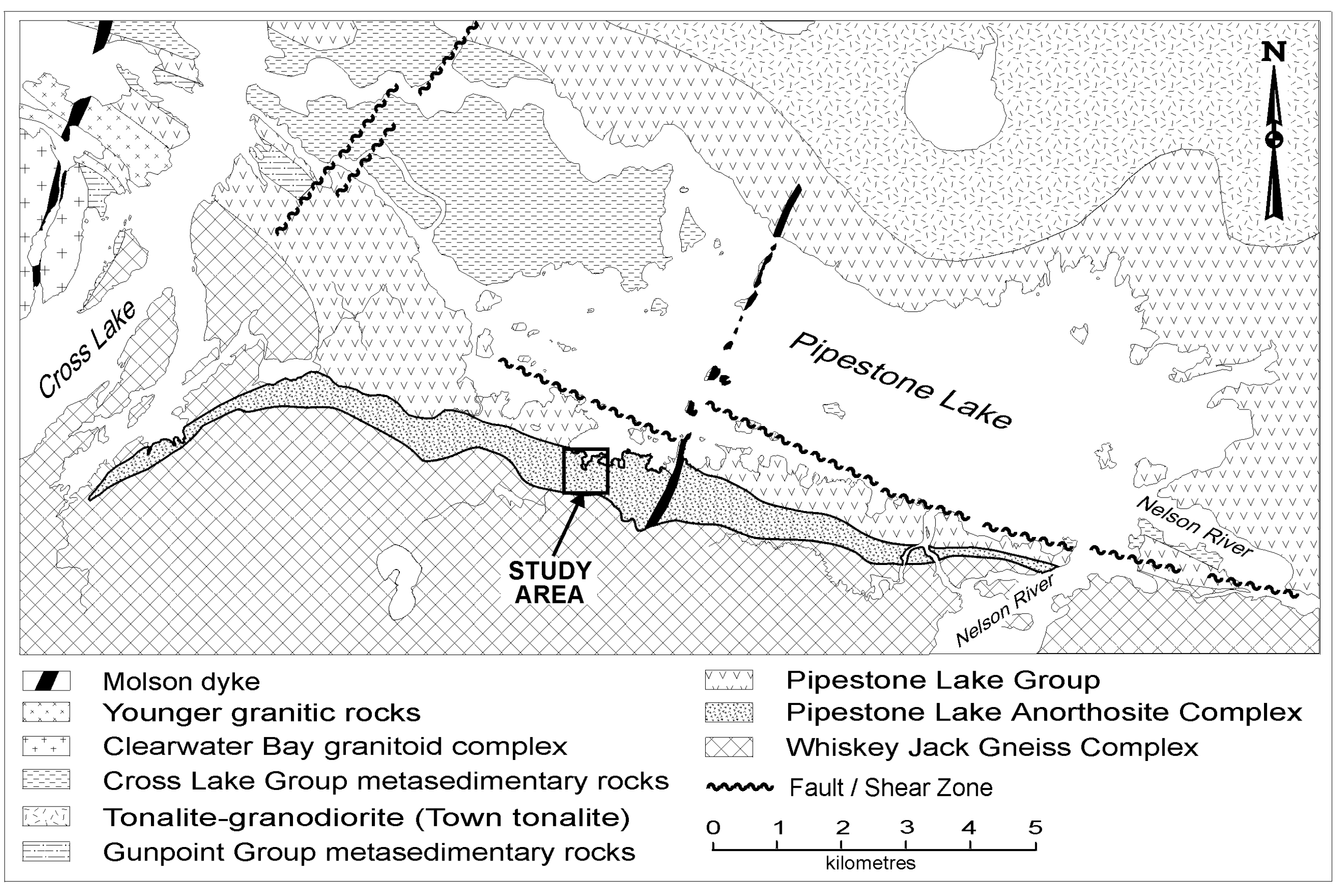


Figure GS-24-1: Geology of the Cross Lake area and location of the Pipestone Lake anorthosite complex (after Corkery et al., 1992). The box indicates the area mapped in detail (Fig. GS-24-2) during the current study.

regional geology is described by Bell (1962) and Corkery et al. (1992). The PLAC is part of a suite of anorthositic to gabbroic intrusions in the Cross Lake area. Collectively, these intrusions have been referred to as the Nelson River anorthosite complex (Bell, 1962). The PLAC is interpreted to be north facing and its igneous layers strike east-southeasterly and have near vertical dips. Corkery et al. (1992) reported a U-Pb zircon age of 2758 ± 3 Ma for the PLAC. Metamorphism (amphibolite facies) resulted in the complete replacement of pyroxene by amphibole and has modified the textures of ilmenite and magnetite (Jobin-Bevans, 1997). In keeping with previous petrological interpretations for the PLAC (e.g., Jobin-Bevans, 1997) we have adopted primary igneous nomenclature such that amphibole pseudomorphs of original pyroxene grains are referred to as pyroxene in the accompanying descriptions. Plagioclase commonly preserves its primary, magmatic composition and the megascopic igneous textures of the rocks are typically preserved.

Over the past 4 years, a collaborative geological investigation of the geology, metallogeny and petrogenesis of the Pipestone Lake anorthosite complex was undertaken. The work supports exploration of several stratiform oxide layers that occur in the PLAC (Gossan Resources Ltd. and Cross Lake Mineral Exploration Inc.) and focuses on improving the stratigraphic interpretations for the PLAC and characterizing the chemistry of the oxide layers (Jobin-Bevans et al., 1997). To date, exploration has focused on two oxide-enriched units, *viz.*, the Main Central and North Disseminated subzones (Fig. GS-24-2). The two zones are contiguous, and are reported to contain a drill-inferred resource of ca. 685 million tonnes that contains ca. 8.4% ilmenite, 0.2% V_2O_5 and 18% magnetite (Gossan Resources Ltd., News Release, September, 1998). Whereas the Main Central subzone contains multiple, <10 cm to 3 m thick magnetite + ilmenite layers, the remaining oxide units (South, Disseminated and North Contact subzones, Fig. GS-24-2; Jobin-Bevans et al., 1997) consist of disseminated ilmenite ± magnetite.

This paper presents results obtained from detailed mapping (1:1000 to 1:100 scale) in the central part of the PLAC (western section, Fig. GS-24-2). This area contains nearly continuous exposure of the L1 and M1 zones and provides an ideal opportunity to carefully document their lithostratigraphy. A second detailed mapping program (eastern section, Fig. GS-24-2) was initiated ca. 1 km to the west. Concurrent with the mapping, ca. 50 samples were collected from all of the major lithologic types encountered in the field studies. Additional sampling was carried out on drill core provided by Gossan Resources Ltd. and Cross Lake Mineral Explorations Inc. These samples will be used in an ongoing mineralogical and whole-rock geochemical study of the PLAC (D. Peck, C. Messing and N. Halden). The field observations described herein, in addition to related geochemical investigations, are part of an Honour's B.Sc. thesis being carried out at the University of Manitoba (C. Messing).

In addition to the stratigraphic mapping in the L1 and M1 zones (Fig. GS-24-2), the external contacts of the PLAC were re-examined in order to better establish the relative ages of the PLAC and adjacent supracrustal rocks and granitic gneisses. Footwall orthogneisses and hanging wall metasedimentary rocks are currently believed to be older than the PLAC, on the basis of geochronological data and field observations (Corkery et al., 1992). However, recent field studies (Peck et al., 1994a, b; Jobin-Bevans, 1997) have cast doubt on this interpretation and we provide new evidence that suggests the PLAC was emplaced along the contact between the WJGC and the Pipestone Lake group.

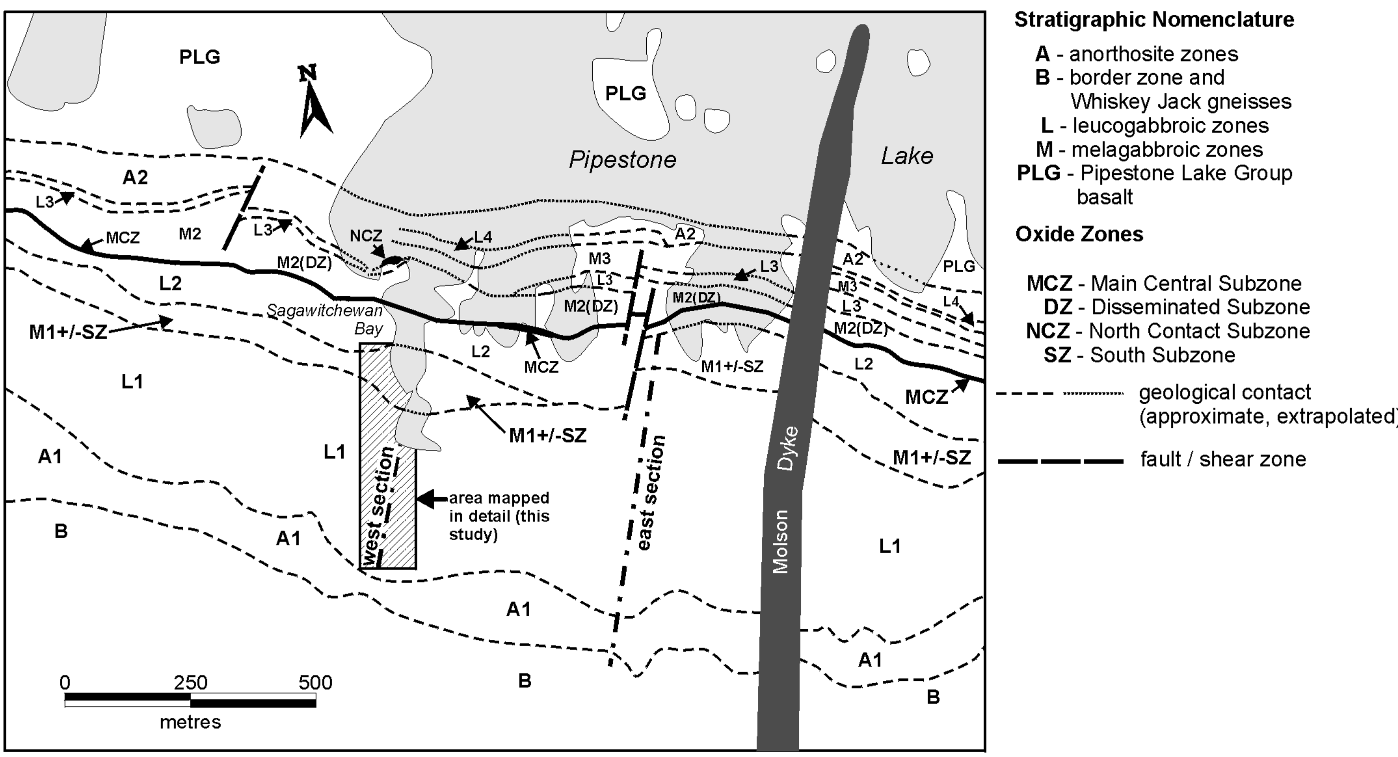


Figure GS-24-2: Geology of the Sagawitchewan Bay area, central part of the Pipestone Lake anorthosite complex (modified from Jobin-Bevans et al., 1997). Box indicates the area mapped in detail. Mapping along the west section line was used to prepare the L1 zone "type section" (Fig. GS-24-4).

GEOLOGY AND STRATIGRAPHY OF THE L1 ZONE

General geology

The PLAC has been subdivided into predominantly leucogabbroic units (L1 to L4 zones), predominantly melagabbroic units (M1 to M3 zones) and generally anorthositic units (A1 and A2 zones) (Peck et al., 1994a, b; Jobin-Bevans et al., 1997; Fig. GS-24-2). A 200 m by 120 m area, covering the L1 zone, was mapped at a scale of 1:1000 (Fig. GS-24-3). Selected subareas were mapped at a scale of 1:100. The area mapped occurs in the central part of the PLAC, where the stratigraphy reaches its maximum known thickness of ca. 900 m. The A1-L1 contact was not observed in this area. The study area is very well exposed and provides more or less continuous outcrop for the L1 and M1 zones. A 10 x 10 m grid was established for control, adjoining an area mapped in detail by Jobin-Bevans (1997) that includes the L2, M2, L3 and M3 zones, along the northeastern shoreline of Sagawitchewan Bay (Fig. GS-24-2). A type stratigraphic section for the L1 zone in the map area is given in Figure GS-24-4.

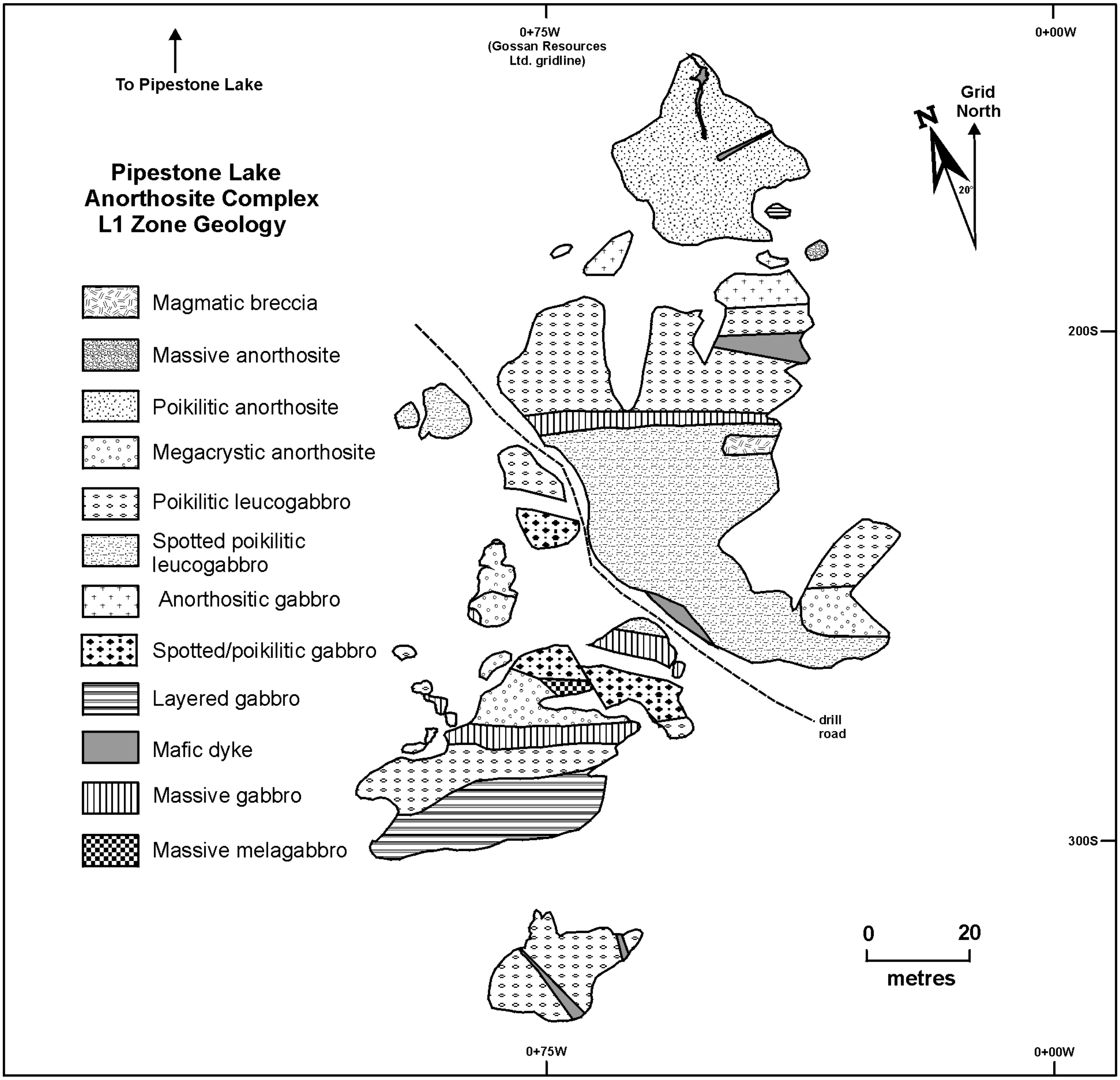


Figure GS-24-3: Geology of the L1 zone, central part of the Pipestone Lake anorthosite complex. See Figure GS-24-2 (west section line) for location of the detailed map area.

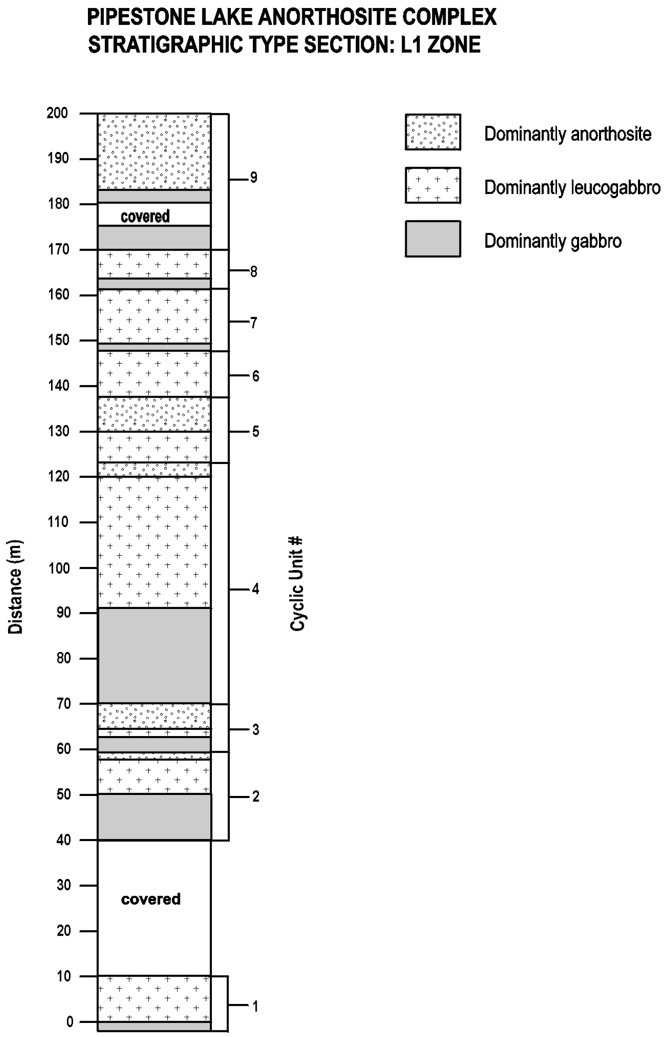


Figure GS-24-4: Type stratigraphic section for the L1 zone, based on mapping in the central part of the Pipestone Lake anorthosite complex (west section, Fig. GS-24-2, 3).

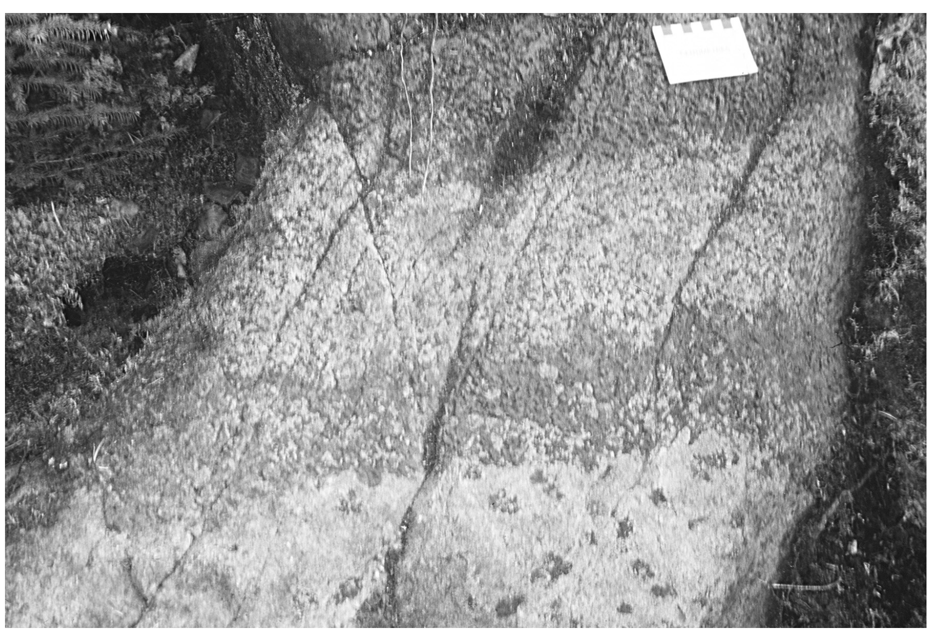
Originally, the L1 zone was thought to be a relatively massive layer of leucogabbro, but detailed mapping revealed a series of metre and decimetre-scale modal layers (Fig. GS-24-5). These layers consist of melagabbro, gabbro, leucogabbro, and anorthosite. The subdivision of the L1 zone into different layers and layered units (see below) was based upon the dominant rock type.

Within the study area, the L1 zone comprises 9 decametre-thick cyclic units (Figs. GS-24-3, 4). A typical unit in this area comprises a melagabbro base that has a sharp and commonly irregular contact with the top of the underlying layered unit (typically megacrystic anorthosite). The melagabbro commonly grades upward into a thicker gabbro layer and in turn is succeeded by an even thicker leucogabbro layer. The contact between the gabbro and leucogabbro can be abrupt or gradational, planar or irregular. The typical cyclic unit in the L1 zone (also, in the overlying L2 zone) has an uppermost megacrystic anorthosite layer that is underlain by megacryst-bearing poikilitic anorthosite or leucogabbro (Fig. GS-24-6).

The textures of the rocks in the L1 zone are highly variable, despite the fact that the modal variations through this zone are systematic (i.e., an upward increase in plagioclase relative to pyroxene). Commonly observed textures in the L1 zone include: (1) polymodal or seriate textures, in which plagioclase phenocrysts range from medium grained to megacrystic (>2 cm to 30 cm); (2) poikilitic textures, in which pyroxene forms medium-grained to very coarse-grained oikocrysts; (3) sub-ophitic textures, developed in fine-grained to medium-grained gabbro and melagabbro layers; (4) size grading, most commonly developed in megacrystic anorthosite layers; (5) "spotted" texture in which pyroxene forms equant crystals that are more resistant to weathering than the plagioclase and, consequently, appear as "spots"; and (6) variable texture (e.g., vari-textured gabbro) evidenced by erratic and major changes in grain size (fine to coarse to pegmatitic) in gabbro bands, pods and veins.

Plagioclase displays a large and continuous range in grain size within the L1 zone, from <2 mm to >30 cm. Most of the smaller crystals are primocrysts that reflect the well established crystallization order for the PLAC: plagioclase > early formed pyroxene + magnetite and/or ilmenite + later-formed pyroxene > granophyre. Plagioclase megacrysts occur throughout the L1 zone and in every major rock type, but are concentrated in the upper, anorthositic parts of the cyclic units (Fig. GS-24-4). The megacrysts are commonly embayed by the surrounding matrix (gabbroic to leucogabbroic), and appear to have been partially resorbed during the crystallization of the L1 zone. The lack of equilibrium textures between plagioclase megacrysts and any of the rocks in which they occur suggests that they are xenocrysts, possibly carried into the PLAC from a deeper sourced magma chamber (see Ashwal, 1993).

Figure GS-24-5: Centimetre-scale modal layering of (base to top of photograph) coarse-grained poikilitic anorthosite, poikilitic to equigranular gabbro, poikilitic leucogabbro and equigranular melagabbro. Base of the L1 zone, central part of the Pipestone Lake anorthosite complex.



Local centimetre-wide, easterly-trending shear zones have modified the primary megascopic textures of the L1 zone units. For example, within sheared poikilitic rock types, the oikocrysts are transformed from original circular to oval forms into elliptical and schlieren-like grains having large aspect ratios (up to 25:1).

Mafic dykes occur throughout the map area and comprise fine-grained amphibole (formerly pyroxene ?) and minor plagioclase. These dykes are consistently north trending and have widths that range from a few centimetres to a few metres. Dyke margins commonly develop flame structures that penetrate a few centimetres into the host rocks (Fig. GS-24-7). In some instances, the dykes have sharp planar contacts with the L1 zone rocks and the largest dykes have chilled margins. In total, dykes are estimated to underlie <5% of the area mapped.

Petrology

Melagabbro forms the thinnest and least abundant layers (<<10%) in the L1 zone. It is present in centimetre-thick units. Locally, the melagabbro layers contain a basal magnetite ± ilmenite layer. Melagabbro is typically medium- to coarse-grained and contains 65 to 90% pyroxene and subordinate plagioclase; it locally grades to pyroxenite. The melagabbro layers are commonly undulose and discontinuous. Near the top of the L1 zone, melagabbro typically occurs as irregular, decametre-size pods within other rock types.

Gabbro is the second most abundant rock type in the L1 zone (ca. 20% of the zone). It occurs as centimetre- to metre-scale layers that appear to become thinner towards the upper part of the L1 zone. The gabbro is typically medium- to coarse-grained and equigranular, but can display several different textures, viz. megacryst-bearing, equigranular-aphyric, "spotted" and poikilitic. Locally, gabbroic units consist of alternating centimetre-size layers of melagabbro and gabbro and, in some cases, the layer contacts are modally graded such that plagioclase abundance increases to the north.

An unusual feature in one of the gabbroic units is the presence of relict pyroxene megacrysts, partially to completely replaced by feldspar and amphibole (Fig. GS-24-8). These megacrysts were originally six- or eight-sided, idiomorphic crystals up to 15 cm long. Matrix pyroxenes in the gabbroic layers of the L1 zone display a textural continuum from equant, idiomorphic primocrysts to (more typical) oikocrysts, <1 cm to 15 cm in diameter. Plagioclase in the gabbroic units is typically medium grained and lath like, although coarser-grained plagioclase phenocrysts and rare plagioclase megacrysts also occur. Pyroxene megacrysts with high Al contents are known to occur in massif-type anorthosites and are believed to represent high-pressure xenocrysts that were entrained in ascending, Al-rich basaltic magmas (Ashwal, 1993).

Figure GS-24-6: Contact between megacryst-bearing leucogabbro to anorthosite layer and overlying (base of photo) megacrystic anorthosite layer, L2 zone, central part of the PLAC. Similar layering is observed in the upper parts of the cyclic units contained within the L1 zone.

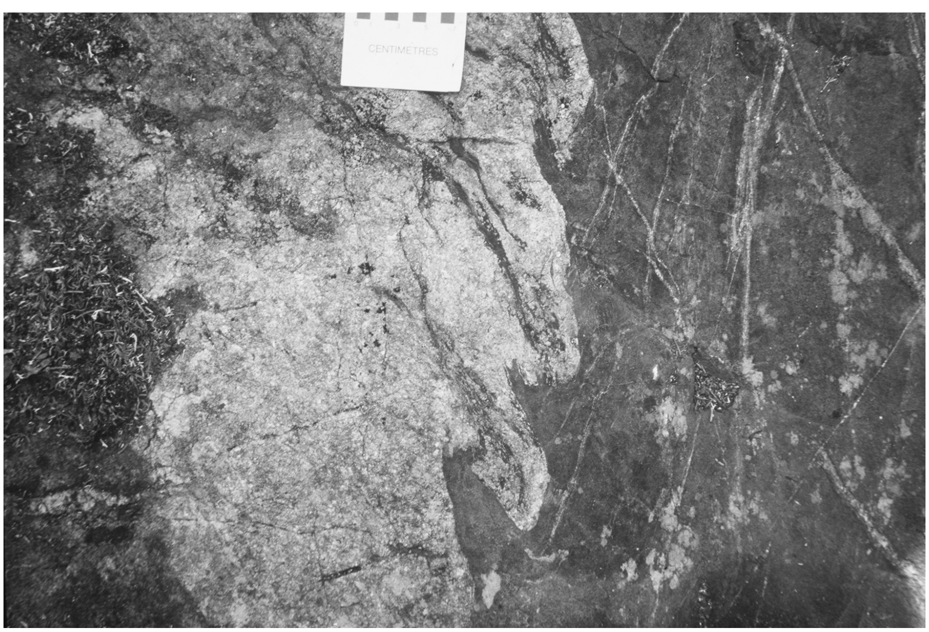


Figure GS-24-7: Flame structures developed at the margins of a gabbroic dyke that intruded anorthosite within the upper parts of the L1 zone (central part of the Pipestone Lake anorthosite complex). North is towards the base of the photograph.

Figure GS-24-8: Relict pyroxene megacrysts in gabbro layer near the base of the L1 zone, central part of the Pipestone Lake anorthosite complex.

Leucogabbro is the most abundant rock type in the L1 zone (underlying ca. 60% of the area mapped). It forms metre-scale layers that become progressively thicker from the south end of the map area to the north (Figs. GS-24-3, 4). The leucogabbro is medium to coarse grained, typically poikilitic and contains pyroxene oikocrysts <2 cm to 20 cm long.

Anorthosite forms distinctive layers, <5 to 20 m thick, in the northernmost part of the L1 zone. Anorthosite is less abundant in the lower parts of the L1 zone, where it forms layers <8 m thick at the interpreted tops of individual layered units. Most of the anorthosite layers are megacrystic and comprises 50 to >90% plagioclase megacrysts that range from ~3 to 20 cm in diameter and displaying oval, rectangular or hexagonal crystal shapes. The megacrysts are commonly compositionally zoned and, locally, display oscillatory zoning. The relative proportions of matrix and megacrysts is highly variable, and individual megacrysts are difficult to recognize within the most plagioclase-rich anorthosite layers. The matrix composition in the anorthosite layers varies from gabbro (sometimes poikilitic) to melagabbro. Large pyroxene oikocrysts, up to several tens of centimetres in maximum dimension, are commonly developed in the megacrystic anorthosite layers.

Stratigraphic interpretation and oxide mineralization

The stratigraphy of the L1 zone in the central part of the PLAC is expressed in a 200 m "type section" (Fig. GS-24-4) that synthesizes the field observations described above. Detailed petrological descriptions for the M1 zone will be reported elsewhere.

The L1 zone has been subdivided into 8 cyclic units (see above). Superimposed on this cyclic, metre- to decametre-scale layering is an upward increase in the abundance of plagioclase at the expense of pyroxene, and a corresponding increase in the thickness of individual leucogabbro and anorthosite layers. The top of the L1 zone is in abrupt contact with the base of the M1 zone. The uppermost 3 m of the L1 zone comprises a to fine- to medium-grained gabbro (grading to leucogabbro) that contains 5 to 10% disseminated magnetite, abundant, irregular granophyre, quartz-feldspar pegmatite pods and veins, and irregular tremolite-filled cavities.

The base of the M1 zone is a thin (<20 cm) chlorite-amphibole-magnetite schist within which occurs a thin (<5 cm) coarse-grained ilmenite band. The ultramafic schist is succeeded to the north by a medium- to coarse-grained pyroxenite that grades northward into a modally-graded, oxide-bearing melagabbro-gabbro layer. The remainder of the M1 zone includes a 15 to 20 m thick oxide-rich melagabbro-gabbro layer (South subzone; Jobin-Bevans et al., 1997) that is overlain by relatively massive gabbro and leucogabbro. The South subzone is the only major oxide-enriched unit in the lower parts of the PLAC. It locally contains up to 7.6 % TiO_2 (Cameron, 1992), but typically consists of <5 % TiO_2 associated with 20 to 40% disseminated ilmenite + magnetite. Gossan Resources has several diamond-drill holes in the South subzone that confirm the V-rich nature of the disseminated oxide mineralization.

Relationships between the L1 and M1 zones and adjacent units

Mapping and geochemical sampling extended through the M1-L2 contact into the area mapped in detail by Jobin-Bevans et al. (1997) on the west shoreline of Sagawitchewan Bay (Fig. GS-24-2, 3). An ongoing chemostratigraphic study of the PLAC (D. Peck, C. Messing and N. Halden) will incorporate Jobin-Bevans' results into a composite type section for the central PLAC focused along or adjacent to Gossan's 0+75 m west gridline. The M1 zone is succeeded by a thin (<50 m) leucogabbroic unit (L2 zone) that has an abrupt contact with the overlying Main Central subzone (base of M2 zone). The geology of upper parts of the M2 zone (Disseminated subzone) and the overlying L3-M3-L4-A2 units are described by Jobin-Bevans et al. (1997).

As noted by these authors, there is significant disruption of layering in the Sagawitchewan Bay region. Trough structures, scours, and truncated and scalloped layer contacts are commonly observed. A critical observation, relevant to the genesis of the oxide mineralization, is the down-cutting relationship between the M3 layer and the underlying L3 leucogabbroic unit (Fig. GS-24-9). We interpret these observations, in light of the field observations for the L1 and M1 zones, as indicating late crystallization of dense, ferrogabbroic magmas. Near the western shoreline of Sagawitchewan Bay, magnetite is concentrated along the base a discontinuous, <1 m wide, melagabbro layer (M2 zone). The oxide mineralization and the melagabbro cut stratigraphically downward into the underlying leucogabbro layer (L2 zone), and are interpreted to represent a large-scale scour and fill structure. In the PLAC, magmatic erosional features are most abundant in the central part of the intrusion, where the largest magma throughput and, consequently, the greatest amount of disruption likely occurred.

The A1 zone underlies the L1 zone along the entire length of the PLAC. In the area investigated (central PLAC), the A1 zone is both thicker and more mafic than at any other locality. The lowermost part of the A1 zone comprises megacryst-bearing pyroxenite (Fig. GS-24-10), melagabbro and gabbro. The upper part of the A1 zone comprises megacrystic leucogabbro and anorthosite. The observed petrological variation is consistent with the proposed *in situ* fractional crystallization model for the PLAC that involves the migration of dense, mafic residual magma towards the bottom parts of cyclic and megacyclic units and, concurrently, the upward movement (displacement?) of plagioclase megacrysts and more Al-rich (less differentiated) magmas.

Figure GS-24-9: Crosscutting relationship between late-stage melagabbro layer (base of M3 zone) and leucogabbro layer (top of L2 zone) near the northwestern end of Sagawitchewan Bay (see Fig. GS-24-2).

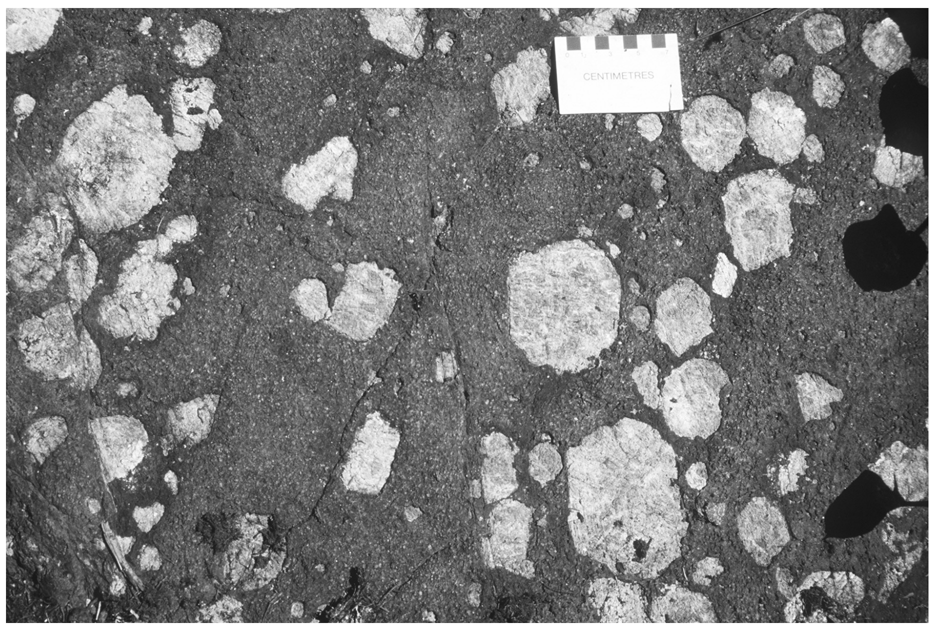


Figure GS-24-10: Plagioclase megacrysts in pyroxenite from the base of the A1 zone in the central part of the Pipestone Lake anorthosite complex.

RELATIONSHIPS BETWEEN THE PLAC AND THE COUNTRY ROCK

In the western part of the PLAC a petrologically complex marginal unit - the Transition zone (Peck et al., 1994a, b), separates the upper part of the A2 zone from overlying basalt and clastic sedimentary rocks. The Transition zone, in the area investigated, comprises a fine- to medium-grained gabbro that intrudes megacrystic anorthosite and leucogabbro that belongs to the A2 zone. The gabbro bodies are irregular in form and appear to constitute an upper chilled margin facies. They are observed to intrude, commonly along bedding planes, the overlying sequence of clastic metasedimentary rocks, including thinly bedded sandstone, arkose and siltstone, which may represent turbidites. The sandstones locally contain detrital magnetite grains up to 5 mm in diameter, and up to 20% red garnet porphyroblasts. The sedimentary rocks appear to be thermally modified (e.g., they become hornfelsic) adjacent to the PLAC and, locally, record the effects of contact metasomatism.

The basal contact of the PLAC was examined in the central part of the intrusion, ca. 400 m south of Sagawitchewan Bay (Figs. GS-24-1, 2). Here, the base of the PLAC is an incipient breccia (B zone; Peck et al., 1994a, b) defined by a network of granitic and gabbroic veins cutting the aforementioned A1 zone megacrystic units. Detailed inspection of this breccia indicates that both the gabbro veins and the granitic veins (tonalite, granodiorite, trondhjemite and aplite) display both irregular and planar contacts with the megacrystic units. In one area, the granitic veins appear to be cut by gabbro veins. The granitic veins emanate from, and intrude, the most mafic (restite?) parts of the Whiskey Jack Gneiss Complex (WJGC) for which limited U-Pb zircon age determinations (Corkery et al., 1992) suggest a post-PLAC origin. The age constraints do not agree with field observations made from the B zone that suggest that heating of the WJGC occurred adjacent to the PLAC and may have caused partial melting of the gneisses. We contend that WJGC-derived partial melts ascended into the consolidated basal parts of the PLAC and formed irregular to planar granitic veins in the B zone. Veining was associated with disaggregation of the partially to completely consolidated megacrystic units and caused K- and Na- metasomatism in anorthositic rocks, evidenced by the development of sericite and granophyre alteration zones. Two samples of the crosscutting granitic veins have been collected from the B zone, for U-Pb zircon geochronology, in order to clarify the age of the veins in relationship to the crystallization age of the PLAC.

ACKNOWLEDGEMENTS

We acknowledge the financial and technical support provided by Gossan Resources Ltd. and Cross Lake Mineral Exploration Incorporated. Additional funding was provided by NSERC (Collaborative Research and Development Grant awarded to N. Halden). B. Lenton, M. Pacey and S. Jobin-Bevans are thanked for their help in preparing several of the figures.

REFERENCES

Ashwal, L.D.
1993: Anorthosites; Springer-Verlag, New York, 200 p.

Bell, C.K.
1962: Cross Lake map-area 63I; Geological Survey of Canada, Paper 61-22, 22 p.

1978: Geology, Wekusko Lake Map-area, Manitoba; Geological Survey of Canada Memoir 384; 84 p.

Cameron, H.D.M.
1992: Pipestone Lake anorthosite complex: Geology and studies of titanium-vanadium mineralization; Manitoba Energy and Mines, Open File OF92-1, 134 p.

Corkery, M.T., Davis, D.W. and Lenton, P.G.
1992: Geochronological constraints on the development of the Cross Lake supracrustal belt, northwest Superior Province, Manitoba; Canadian Journal of Earth Sciences, v. 29, p. 2172-185.

Jobin-Bevans, L.S.
1997: Geology, mineral chemistry and petrogenesis of the Pipestone Lake anorthosite complex; Unpublished M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba, 269 p.

Jobin-Bevans, L.S., Halden, N.M., Peck, D.C. and Cameron, H.D.M.
1997: Geology and oxide mineralization of the Pipestone Lake anorthosite complex; Exploration and Mining Geology, v. 6, p. 35-61.

Peck, D.C., Cameron, H.D.M., and Corkery, M.T.
1994a: Geological environments and characteristics of Ti-V-Fe oxide mineralization in the western part of the Pipestone Lake anorthosite complex; **in** Manitoba Energy and Mines, Geological Services, Report of Field Activities, 1994, p. 118-129.
1994b: Geology and mineral occurrences of the western part of the Pipestone Lake anorthosite complex. Manitoba Energy and Mines, Preliminary Map 1994K-1, 1:5000.