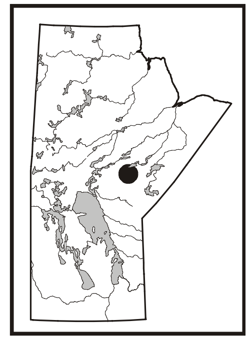
SOUTHEAST MAX LAKE AREA (PARTS OF NTS 53L/5N, /6NW, /12SW)

by H.P. Gilbert



Gilbert, H.P. 2000: Southeast Max Lake area (parts of NTS 53L/5N, /6NW, /12SW); *in* Report of Activities 2000, Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 137-149.

SUMMARY

- The Ralph Anderson Lake greenstone belt is a branch of the Archean 'Max Lake belt', and extends from Logan Lake in the west to Aswapiswanan Lake in the east, a distance of approximately 50 km. The greenstone belt is essentially monoclinal, and consists mainly of arc-type mafic volcanic rocks, with subordinate felsic volcanic and sedimentary units. An early synclinal fold is located close to the north margin of the west part of the belt.
- The lower (southern) part of the Ralph Anderson Lake belt is intruded by an approximately 1.2 km thick gabbro sill. A series of skialithic enclaves in the gabbro, which constitute the lower part of the supracrustal sequence, consist of basalt, heterolithic debris flows and turbidite, and rhyolitic rocks. The overlying main basaltic sequence that constitutes the major part of the belt is divided into geochemically distinct, southern and northern volcanic suites by a conspicuous gabbro (Lavigne Lake gabbro), which extends for more than 24 km through the central part of the belt. A felsic volcanic-sedimentary formation (together with an associated subvolcanic porphyry sill) occurs close to the north (upper) margin of the belt.
- The mafic volcanic rocks, consisting mainly of pillowed aphyric basalt, are characterized by widespread sea-floor–type hydrothermal alteration. A prominent, garnetiferous, silicic alteration zone in the northwest part of the map area is coincident with an oxide-facies iron-formation, and is interpreted as a site of early hydrothermal alteration. Alteration associated with later deformation is also widespread in the map area, and is especially conspicuous at the south margin of the main basaltic sequence.
- Pyritic mineralization occurs in various stratigraphic and structural settings. The best prospects for base-metal exploration appear to be the garnetiferous alteration zone in the northwest part of the map area, and stratabound mineralization associated with chert-siltstone units at various stratigraphic levels within both the southern and northern volcanic suites. Sulphide mineralization is also common in magnetiferous iron-formation, which offers potential base-metal and precious-metal exploration targets. The contact between the volcanic terrane and gabbro at the south margin of the greenstone belt contains sporadic pyritic zones that may represent prospects for economic mineralization. Lastly, a gabbro-pyroxenite intrusion that extends through the central part of the Ralph Anderson Lake belt is currently being tested for possible platinum-group element (PGE) mineralization.

INTRODUCTION

The southeast Max Lake area is located 120 km east-northeast of Norway House, at the junction of the Archean Gods Lake and Molson Lake domains (Manitoba Energy and Mines, 1987). The map area is centred on a series of small lakes immediately southeast of Max Lake, and encompasses part of an approximately 3 km wide supracrustal belt (Ralph Anderson Lake belt) that extends from Logan Lake in the west to Aswapiswanan Lake in the east, a strike length of approximately 50 km (Fig. GS-23-1). This belt merges with the northeast-trending Max Lake belt in the west (Hubregtse, 1974); to the east, the belt is on strike (across a drift-covered area) with supracrustal rocks in the Goose Lake–Beaver Hill Lake area (Elbers and Marten, 1973), which are inferred to be laterally continuous with the Ralph Anderson Lake belt.

A two-year mapping program was initiated in 1999 to upgrade

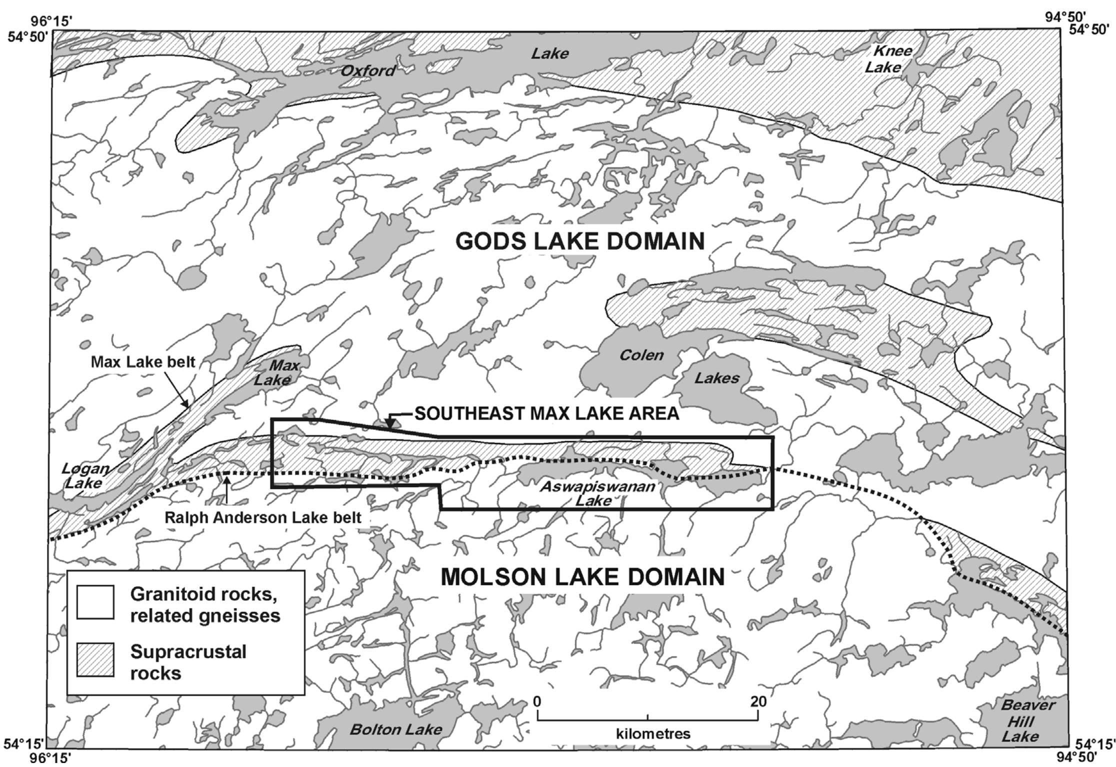


Figure GS-23-1: Regional geological map showing the location of the project area at the junction of the Gods Lake and Molson Lake domains.

previous 1:250 000 scale maps (Currie, 1961; Manitoba Energy and Mines, 1987) and to provide a detailed map as a base for possible further geological studies. Previous geological maps in the southeast Max Lake area show only rudimentary stratigraphic and structural information (Currie, 1961; Elbers, 1973a, b; Schledewitz, 1980). Forest fires in 1989 throughout most of the map area resulted in a significant increase in the amount and quality of bedrock exposure, and thus increased the scope for detailed mapping. In 1999, 1:20 000 scale mapping in the MacVicar Lake–Ralph Anderson Lake area focused on stratigraphy, structure and the geochemistry and alteration of volcanic rocks; a conspicuous 36 m wide, garnetiferous, silicified zone in the northwest part of the map area was the subject of particular attention (Gilbert, 1999a). Field mapping in the 2000 season extended the 1999 map area east to the Franklin Murray Lake–Aswapiswanan Lake area, and also farther west in the MacVicar Lake area.

The Ralph Anderson Lake belt consists mainly of basaltic pillow lavas with subordinate felsic volcanic rocks, heterolithic breccia and epiclastic deposits, flanked by granitoid rocks to the north and a 1.2 km wide gabbroic intrusion (McLeod Narrows gabbro) to the south (Fig. GS-23-2, -3; Table GS-23-1). The supracrustal rocks are provisionally equated with the volcanosedimentary 'Hayes River Group' in the Oxford Lake–Knee Lake–Gods Lake area northeast of Max Lake (Hubregtse, 1985a and references therein). The margins of the Ralph Anderson Lake belt are characterized by contact zones in which the supracrustal rocks are intruded by conformable units derived from the flanking plutonic terranes. The granitoid terrane north of the Ralph Anderson Lake belt consists of tonalitic to granodioritic intrusions and related gneissic units (Hubregtse, 1985b). The McLeod Narrows gabbro south of the belt contains volcanic and related sedimentary skialithic enclaves (up to 300 m thick) considered to be part of the supracrustal sequence, which is interpreted as essentially monoclinal. Abundant facing directions, indicated by pillow structure and sporadic top indicators in epiclastic rocks, are almost exclusively to the north. A synclinal fold near the north margin of the belt is indicated by a south-facing turbidite deposit in the west part of the project area. Whereas regional strike-parallel faults have not been identified within the greenstone belt, the effects of possible faulting (i.e. stratigraphic hiatus or repetition) cannot be discounted.

Fifty rock samples from volcanic and related intrusive map units were analyzed for major, trace and rare-earth elements. Mafic to felsic volcanic and associated intrusive rocks are geochemically akin to modern arc tholeiite. They display marked negative Nb anomalies and flat to negatively sloping rare-earth element (REE) profiles due to decoupling between large-ion lithophile elements (LILE) and high field-strength elements (HFSE); TiO_2 values are generally less than 1.0%. Interflow gabbroic sills are compositionally similar to mafic volcanic units. The mafic-ultramafic Lavigne Lake gabbro sill in the central part of the belt, which is relatively less fractionated than the synvolcanic gabbro bodies, may be penecontemporaneous with volcanism and represent a more primitive fraction of the source magma for the volcanic rocks.

This report provides a summary of the geology of the Franklin Murray Lake–Aswapiswanan Lake area mapped this year (Fig. GS-23-4), as well as new data in the vicinity of MacVicar Lake (west part of the project area; Fig. GS-23-5), where mapping was initiated in 1999. The reader should refer to Table GS-23-1 for abbreviated descriptions of all subunits discussed in the text. Stratigraphic details in the MacVicar Lake–Ralph Anderson Lake area were published in Gilbert (1999a). An open file report, scheduled for publication in late 2000 or early 2001, will contain a geological description of the entire project area, together with a synthesis of the geochemistry of the volcanic rocks, the tectonic and metamorphic history, and a discussion of the economic potential of the belt.

STRATIGRAPHY OF THE FRANKLIN MURRAY LAKE–ASWAPISWANAN LAKE AREA

The stratigraphic sequence defined in the west part of the Ralph Anderson Lake greenstone belt (Gilbert, 1999a) extends eastward to the vicinity of Franklin Murray Lake. Farther to the east, in the Aswapiswanan Lake area, stratigraphic details are incomplete due to more intense deformation and metamorphism, the occurrence of pervasive intrusive rocks and an extensive cover of glacial drift. All volcanic supracrustal rocks in the Aswapiswanan Lake area occur south of an east-trending gabbro/pyroxenite sill that is interpreted as the on-strike equivalent of the Lavigne Lake gabbro, and thus constitute the 'south part' of the volcanic section (Gilbert, 1999a). Details of the 'north part' of the sequence (Gilbert, 1999a) are not known due to lack of exposure; supracrustal rocks in that area have either been covered by glacial drift and swamp, or they have been removed due to assimilation by granitoid intrusions that are part of an extensive plutonic terrane to the north of the greenstone belt. The greenstone belt is increasingly more attenuated and disrupted by granitoid rocks toward the east, in the Franklin Murray Lake–Aswapiswanan Lake area. At the south margin of the belt, strongly deformed basalt and laminated amphibolite have been folded and subsequently incorporated within granitic to quartz dioritic rocks. In that locality, a distinctive, plagioclase-phyric tonalite is interlayered with basalt-derived amphibolite and granitoid rocks in a gneissic zone (0.5–1.0 km wide) between the greenstone belt to the north and granodioritic rocks to the south.

The following section describes the main stratigraphic components of the Franklin Murray Lake–Aswapiswanan Lake area; equivalent rock units in the MacVicar Lake–Ralph Anderson Lake area to the west, which are relatively less deformed and better preserved, are described in Gilbert (1999a).

Basalt, Related Fragmental and Intrusive Rocks; Derived Laminated Amphibolite, Schist and Gneiss (Unit 1)

Aphyric basalt (subunit 1a) is the principal rock type in the Ralph Anderson Lake greenstone belt at the west end of Aswapiswanan Lake, where mafic flows are intercalated with gabbro and laminated amphibolite in a section up to 1.4 km wide. North-facing pillows were observed at one locality within this section, but the mafic volcanic rocks are generally too deformed for tops to be determined; pillow elongations are typically 8:1 to 15:1. Amygdaloidal zones occur sporadically (plagioclase±quartz, or carbonate amygdales); epidote alteration is common, either in the cores or toward the margins of pillows; silicic alteration at pillow rims is subordinate. Basalt in the Franklin Murray Lake–Aswapiswanan Lake area is intimately intercalated with subordinate synvolcanic gabbro units up to 20 m thick (subunit 1c). The mafic sills are largely massive and equigranular, but a plagioclase-megaphyric phase (subunit 1d), with equant feldspars up to 2.5 cm across, occurs at the west extremity of Aswapiswanan Lake.

In strongly deformed zones, basalt is locally altered to gneiss (subunit 1e) with fine (1–15 mm) laminae that are variously hornblendic (±chlorite), epidotic or quartzofeldspathic. The tectonometamorphic lamination is due to the attenuation of previous epidotic or silicic alteration domains and chloritic selvages in the pillowed flows. Stringers and aggregates of epidote (±quartz±carbonate±garnet) postdate the lamination. Elsewhere, where metamorphism was not accompanied by strong deformation, mafic volcanic rocks locally contain diffuse, recrystallized domains of fine- to medium-grained plagioclase+hornblende.

Narrow (10–40 cm thick) alteration zones with surficial iron staining and silicification (±garnet porphyroblastesis) occur in several mafic flow units. Similar gossan zones occur sporadically within or at the margins of synvolcanic gabbro sills (subunit 1c). These zones contain disseminated pyrite and pyritic stringers and local trace to minor concentrations of Cu, Zn, Ni, Cr and, at one locality, Au (*see* 'Economic Geology' section).

In the central and east parts of Aswapiswanan Lake, bedrock exposure is generally poor, except for a basaltic section, more than 1.2 km wide, that extends north from the eastern lobe of the lake. Scattered outcrops along the south shore of the lake display sporadic blocks or

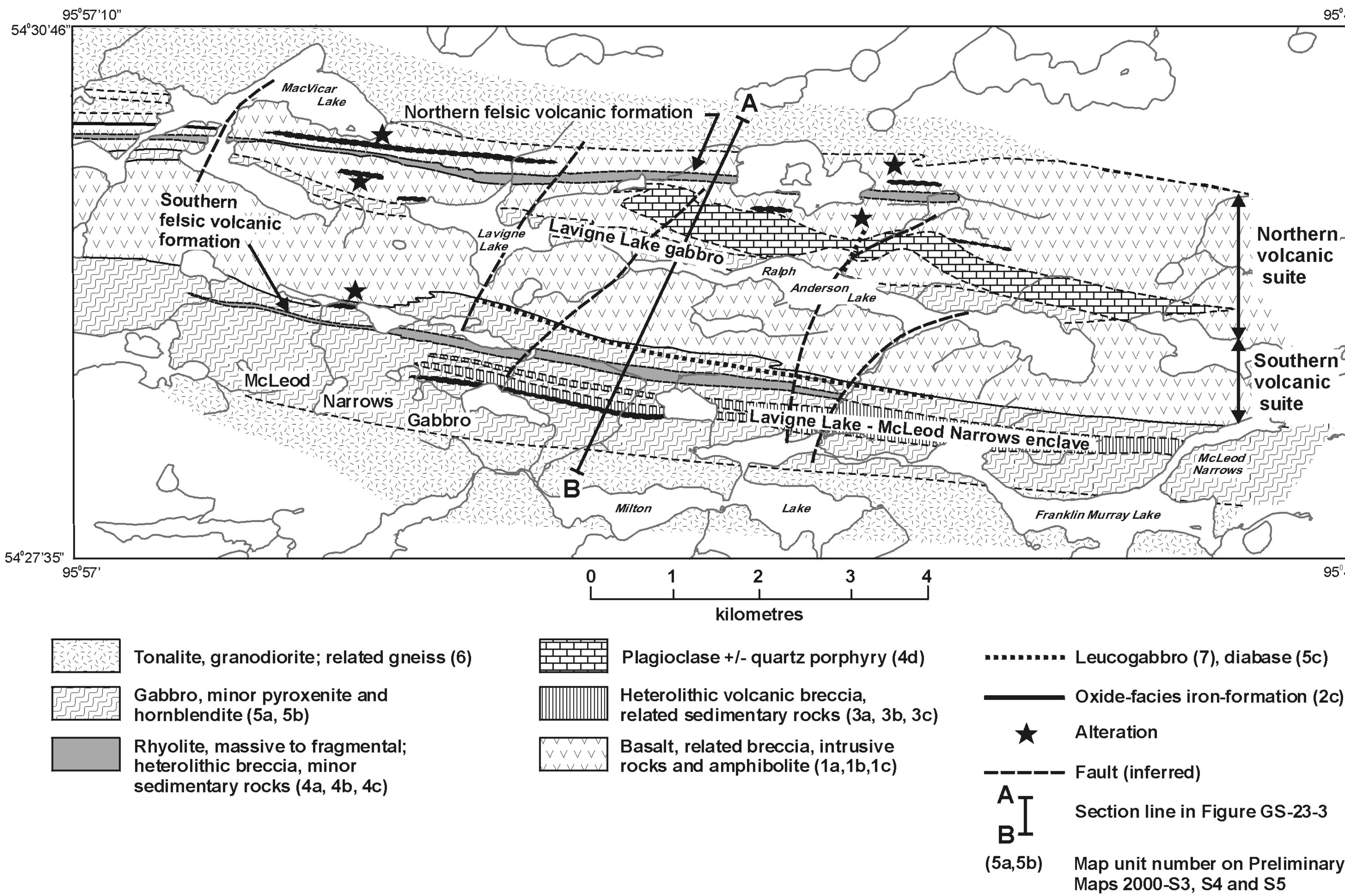


Figure GS-23-2: Simplified geological map of the MacVicar Lake–Ralph Anderson Lake area.

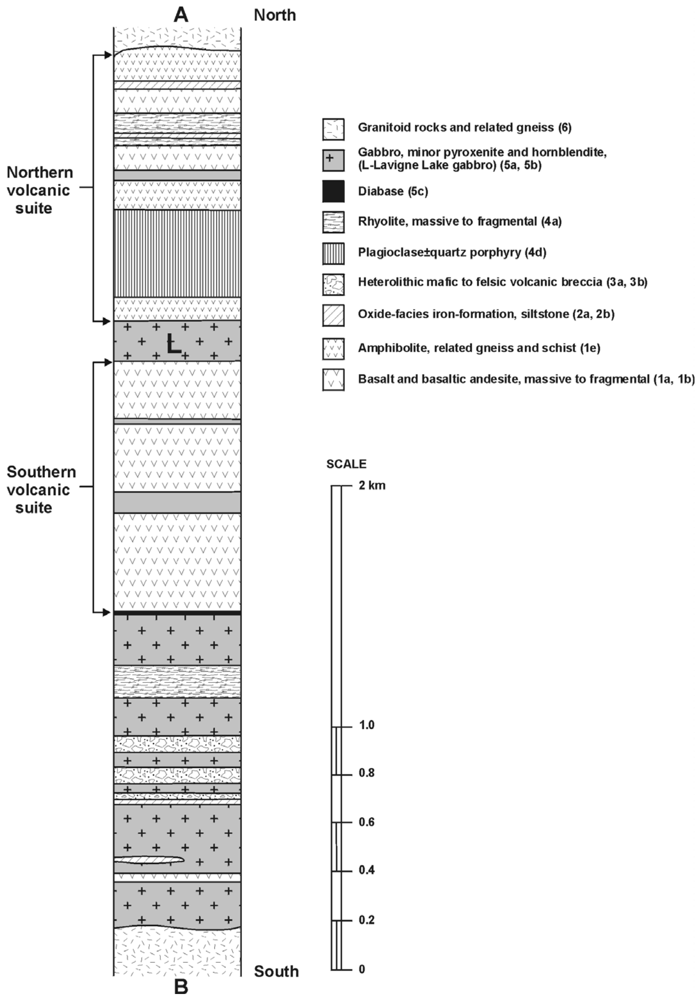


Figure GS-23-3: Transverse cross-section, oriented NNE-SSW through the Ralph Anderson Lake belt (marked as A-B on Fig. GS-23-2).

skialithic enclaves of basalt (up to 20 m wide) within granitoid rocks and associated gneiss. Pillow structure is preserved at one locality, but primary features are generally absent.

Heterolithic Volcanic Breccia and Associated Tuff; Related Sedimentary Rocks (Unit 3)

A unique occurrence of intermediate volcanic breccia (subunit 3b) on the south shore of central Aswapiswanan Lake contains attenuated felsic fragments (up to 25 by 2 cm) within an intermediate, tuffaceous matrix. The unit, more than 8 m in thickness, is assumed to be affiliated with volcanic breccia of inferred debris-flow origin, which is common within the greenstone belt farther to the west (Gilbert, 1999b).

INTRUSIVE ROCKS

Gabbroic units that are intimately interlayered with mafic volcanic flows in the MacVicar Lake–Ralph Anderson Lake area (subunits 1c, 1d) have been identified as synvolcanic on the basis of their field setting and geochemical signature (*see* 'Geochemistry' section). Major gabbroic intrusions (unit 5) in the same area have been interpreted as postvolcanic due, in part, to their typically massive texture, in contrast to the highly attenuated state of incorporated supracrustal enclaves, even though the mafic intrusions are locally foliated and sheared at the margins (Gilbert, 1999a). An alternative interpretation is that the gabbro intrusions (unit 5) are penecontemporaneous with mafic volcanism; according to this view, tectonic strain due to early, regional deformation (D_1) within the mafic sills was confined to incompetent zones (i.e. tabular skialithic enclaves and gabbro margins). The main, nonfoliated

Table GS-23-1: Geological map units in the southeast Max Lake area.

INTRUSIVE ROCKS		
7	Leucogabbro, diabase	
6	Granitoid rocks and related gneisses: tonalite, granodiorite, granite; minor plagioclase porphyry, pegmatite, aplite; hybrid gneiss derived from units 1 and 6	
	(6a)	Granite, massive; related aplite and pegmatite
	(6b)	Granodiorite and granite, massive to gneissoid; minor K-feldspar blastic granodiorite-granite; minor pegmatite
	(6c)	Tonalite and granodiorite, gneissoid
	(6d)	Hornblende quartz diorite to diorite
	(6e)	Tonalite, plagioclase-phyric; minor felsitic *lits*
	(6f)	Hybrid gneiss (derived from units 1 and 6)
5	Gabbro, minor pyroxenite and hornblendite (Lavigne Lake gabbro; McLeod Narrows gabbro); diabase	
	(5a)	Gabbro, mesocratic to melanocratic
	(5b)	Pyroxenite, hornblendite
	(5c)	Diabase
	(5d)	Magnetiferous quartz diorite, diorite
VOLCANIC AND SEDIMENTARY ROCKS		
4	Rhyolite, massive to fragmental; heterolithic breccia, minor related sedimentary rocks; plagioclase±quartz porphyry (subvolcanic sill)	
	(4a)	Rhyolite, massive to fragmental
	(4b)	Heterolithic volcanic breccia and tuff
	(4c)	Volcanic-derived conglomerate, feldspathic greywacke and siltstone
	(4d)	Plagioclase±quartz porphyry
3	Heterolithic volcanic breccia and associated tuff; related sedimentary rocks	
	(3a)	Heterolithic volcanic breccia and tuff, mafic to felsic fragments
	(3b)	Heterolithic volcanic breccia and tuff, felsic and minor intermediate fragments
	(3c)	Volcanic-derived conglomerate, greywacke and siltstone
2	Sedimentary rocks; altered supracrustal rocks	
	(2a)	Oxide-facies iron-formation
	(2b)	Siltstone, feldspathic greywacke, minor chert
	(2c)	Altered garnetiferous supracrustal rocks
1	Basalt, related fragmental and intrusive rocks; derived laminated amphibolite, schist and gneiss	
	(1a)	Aphyric basalt; minor plagioclase-phyric basalt and related gabbro
	(1b)	Basalt pillow-fragment breccia, flow-top breccia
	(1c)	Gabbro, minor hornblendite
	(1d)	Gabbro, megaphyric to glomeroporphyritic
	(1e)	Amphibolite, related gneiss and schist
	(1f)	Spherulitic pillowed basalt

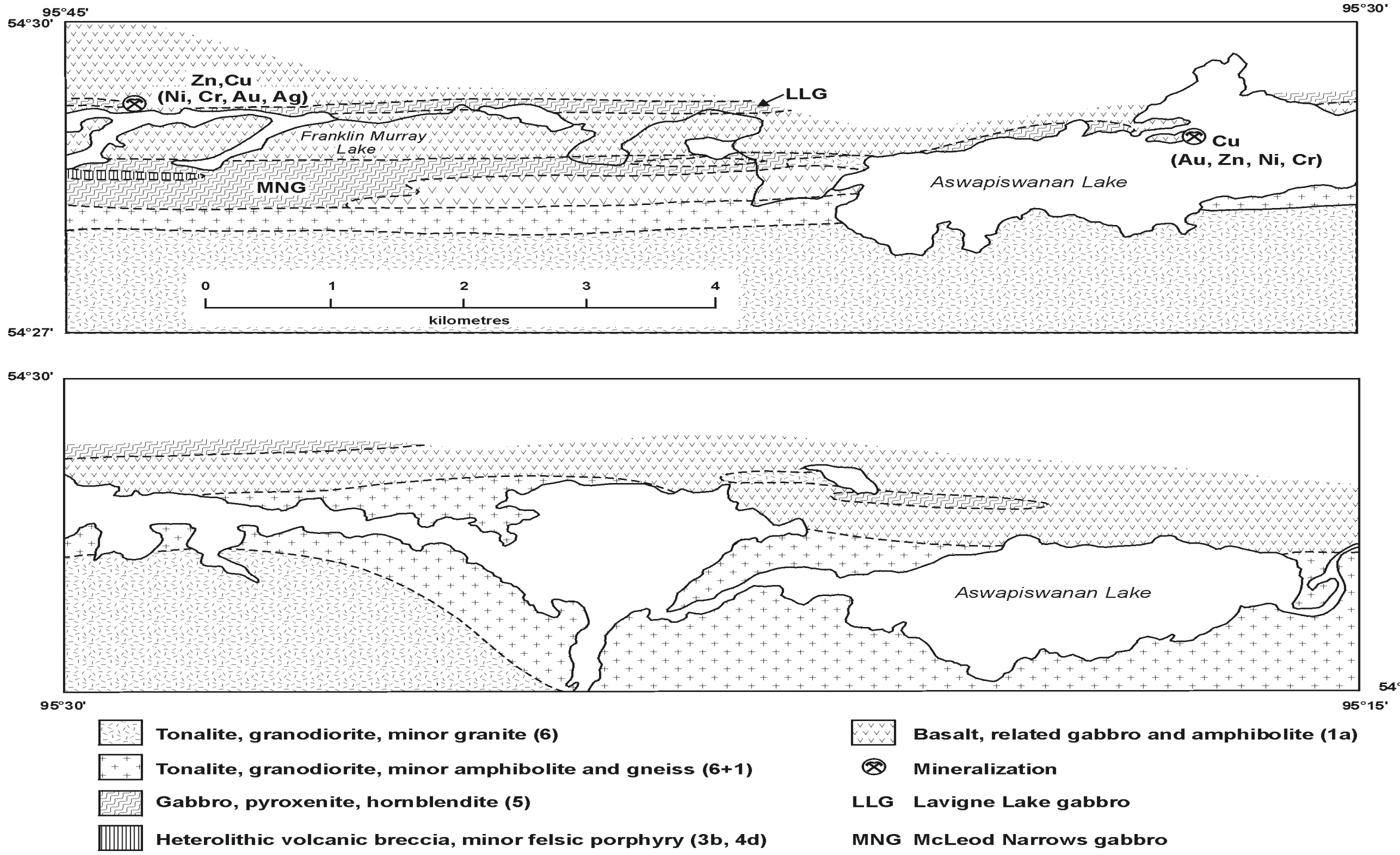


Figure GS-23-4: Simplified geological map of the Franklin Murray Lake–Aswapiswanan Lake area.

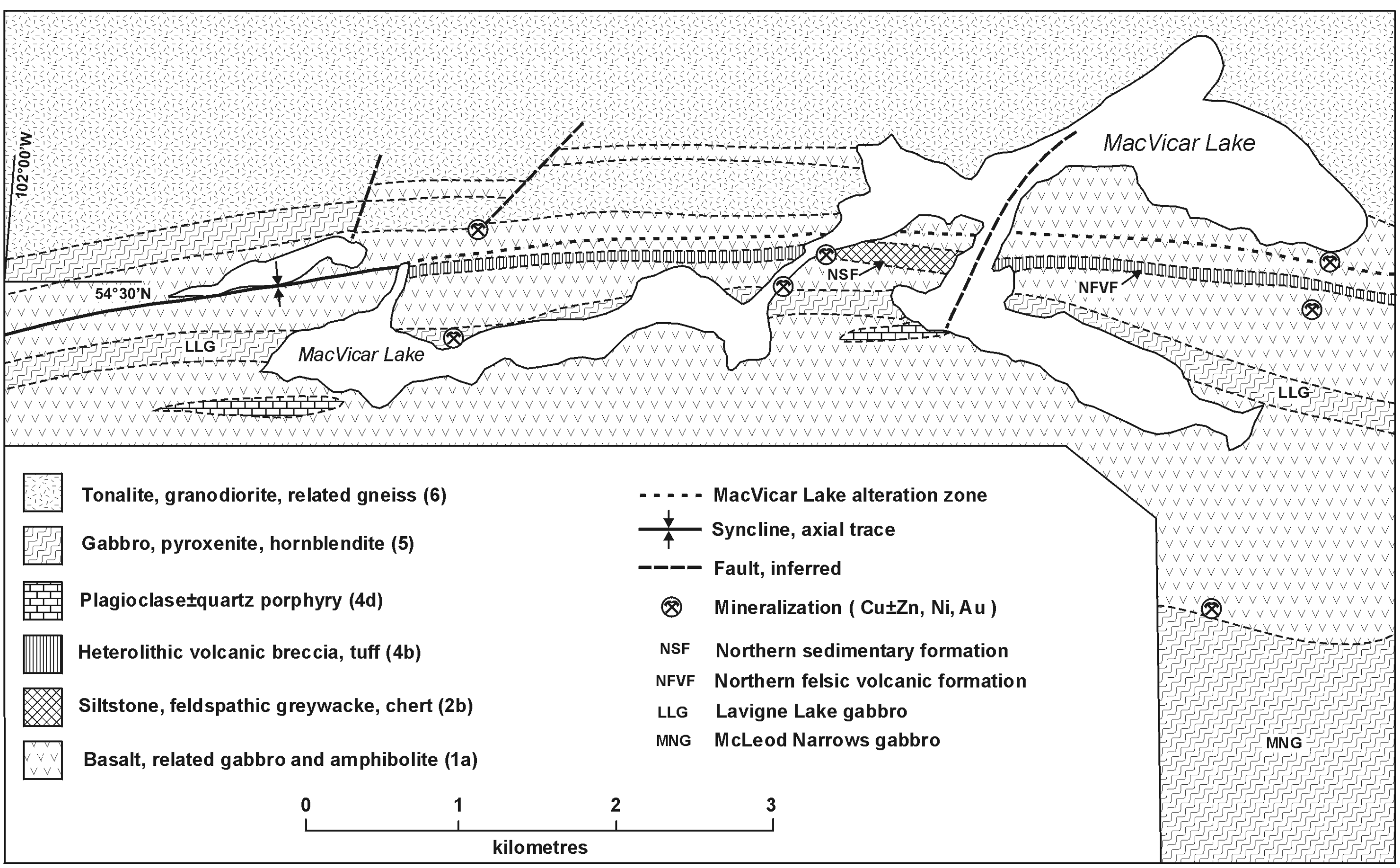


Figure GS-23-5: Map showing stratigraphic and structural details in the vicinity of MacVicar Lake in the northwest part of the project area.

cores of the mafic sills would thus be recrystallized but retain a massive fabric due to lack of strain within the central part of the intrusions. In support of this interpretation, the geochemical signatures of both the McLeod Narrows and Lavigne Lake gabbro intrusions (subunits 5a, 5b) are consistent with a magmatic affiliation between the gabbro and mafic volcanic rocks (see 'Geochemistry' section). Furthermore, basaltic enclaves (unit 1) within the gabbroic rocks (unit 5) are massive (i.e. there is no evidence that they differ significantly in age from the host rocks). In contrast, mafic volcanic inclusions within granitoid rocks (unit 6) are typically foliated and locally folded, indicating that a phase of metamorphism and deformation occurred prior to their incorporation. In summary, although the age of unit 5 gabbro intrusions cannot be clearly identified, there is some evidence that they are penecontemporaneous with mafic volcanism. Granitoid intrusions (unit 6) are invariably intrusive into gabbro (unit 5) and are therefore younger.

Gabbro, Minor Pyroxenite and Hornblendite; Diabase (Unit 5)

Massive, homogeneous gabbro (subunit 5a) in the Aswapiswanan Lake area occurs within the mafic volcanic section and as sporadic skialithic enclaves within younger granitoid rocks (unit 6) on the north shore of the lake. The mesocratic to melanocratic gabbro contains 40 to 70% (locally up to 90%) prismatic to equant hornblende (after pyroxene); leucocratic domains (<30% hornblende) are rare. One of the larger sills (>150 m thick) within the basaltic section on western Aswapiswanan Lake locally displays diffuse igneous layering (2–12 cm scale) defined by variable hornblende and plagioclase content. The gabbro is typically medium grained and massive to slightly foliated; sporadic minor shear zones, veined by quartz, are attributed to late brittle deformation.

Altered, olivine-bearing pyroxenite (subunit 5b), more than 120 m thick, occurs within mafic volcanic flows immediately north of the creek between Franklin Murray and Aswapiswanan lakes; the ultramafic rock extends laterally from the east end of Franklin Murray Lake for more than 1 km to the east. The unit is massive and homogeneous, except for minor brecciated zones (up to 1 by 5 m) that are characterized by ankeritic alteration. The brecciated zones appear to be the result of brittle fracturing, possibly penecontemporaneous with emplacement of the intrusion. Gabbro and hornblendite occur directly to the east, on strike with the pyroxenite. The ultramafic and gabbroic rocks at this locality are interpreted as part of the approximately 0.25 km thick Lavigne Lake intrusion (Gilbert, 1999a), which extends through the central part of the greenstone belt for a distance of more than 24 km, from MacVicar Lake in the west to central Aswapiswanan Lake in the east.

Granitoid and Related Gneissic Rocks: Tonalite, Granodiorite, Granite; Minor Plagioclase Porphyry, Pegmatite, Aplite; Hybrid Gneiss Derived from Units 1 and 6 (Unit 6)

Granitoid rocks of quartz dioritic to granitic composition extend along the south shore and part of the north shore of Aswapiswanan Lake, and occur as scattered minor intrusions within the predominantly mafic volcanic section that extends through the main part of the lake. The granitoid terrane south of the lake appears to be mainly granodioritic to granitic (subunit 6b). Along the south shore of Aswapiswanan Lake, a tonalitic to granodioritic zone, with localized gneiss and migmatite, extends between the mafic volcanic section to the north and the granodioritic-granitic terrane south of the lake. Within this 0.5 to 1.0 km wide zone, strongly foliated biotite tonalite with conspicuous subhedral plagioclase phenocrysts (up to 1 cm; 25% of the rock) extends intermittently along the entire south shore of the lake. The porphyritic tonalite (subunit 6e) occurs both as discrete concordant intrusions (approx. 1–10 m thick) and as a component of layered gneiss (subunit 6f) that contains diverse mafic to felsic *lits*. Gneissic layers (2–25 cm wide), which are interpreted as a product of the earliest tectonometamorphic event (F_1/M_1), are locally deformed by F_2 folds. The folds are truncated by younger granodiorite to granite (subunit 6b), which is massive to moderately foliated; this foliation, together with boudinage and disruption of granodioritic veins (subunit 6b), is attributed to a third (F_3) event. In southwestern Aswapiswanan Lake, the younger granodiorite is largely homogeneous, apart from localized white to pale pink, diffuse banding of inferred metasomatic origin. Porphyroblasts of K-feldspar locally occur in this unit.

The youngest granitoid phase is undeformed, and consists of massive granitic rocks (subunit 6a) that occur as minor dykes within earlier intrusions. The unit includes medium-grained granite, aplite and pegmatite; these occur both as exclusive rock types in some dykes and as contiguous, gradational phases in other intrusions. Minor mafic *schlieren* occur in the aplite-granite. Pegmatite is characterized by graphic quartz-feldspar intergrowths up to 25 cm across, randomly oriented biotite blades, and sporadic garnet. Rare traces of a surficial yellow bloom may be derived from a uranium mineral in the pegmatite.

Leucogabbro, Diabase (Unit 7)

Minor north-northeast-trending aphyric diabase dykes occur within gneissoid granodiorite (subunit 6b) on southwestern Aswapiswanan Lake. The mafic dykes truncate the granodiorite foliation, and contain an internal northeast-trending foliation that is attributed to local strain. These intrusions are interpreted as being related to north-northeast-trending leucogabbro-diabase dykes (unit 7), on the north shore of Ralph Anderson Lake, which represent the youngest intrusive unit in the map area (Gilbert, 1999a).

STRATIGRAPHY OF THE MACVICAR LAKE–RALPH ANDERSON LAKE AREA

Stratigraphic details of the MacVicar Lake–Ralph Anderson Lake area are the subject of a previous report on the geology of the southeast Max Lake area (Gilbert, 1999a). The following new information on selected stratigraphic units in the northwest part of the project area is complementary to that report.

Sedimentary Rocks: Feldspathic Greywacke, Siltstone; Oxide-Facies Iron-Formation; Altered Supracrustal Rocks (Unit 2)

A diverse assemblage of sedimentary rocks ('northern sedimentary formation') occurs within the northern mafic volcanic sequence in the northwest part of the map area, approximately 0.2 km south of the margin of the greenstone belt (Fig. GS-23-5). The sedimentary rocks wedge out to the west, where they are laterally gradational with felsic fragmental deposits (subunit 4b) of probable mass-flow origin. New structural data indicate that the sedimentary formation is located within a synclinal fold, the hinge line of which is probably coincident with a garnetiferous alteration zone (subunit 2c, Gilbert, 1999a) approximately 75 m north of the sedimentary rocks (*see* 'Structural Geology' section). The northern sedimentary formation is approximately 85 m wide on the peninsula in central MacVicar Lake, but the equivalent section farther west, at the limit of mapping, is only 40 m wide. To the east, the northern sedimentary formation is interpreted as laterally gradational with the northern felsic volcanic formation (Fig. GS-23-2; Gilbert, 1999a), which consists largely of massive to fragmental rhyolite with subordinate sedimentary units; the abrupt thickness change between these two formations at central MacVicar Lake is attributed to faulting.

Siltstone, feldspathic greywacke, minor chert (subunit 2b)

Fine-grained sedimentary rocks within the northern sedimentary formation consist largely of intermediate siltstone and greywacke with minor argillitic siltstone layers (subunit 2b). The rocks are both finely laminated (2–10 mm) and thinly bedded (2–40 cm scale), and are locally garnetiferous and/or characterized by stratabound cordierite and anthophyllite. Ovoid cordierite constitutes up to 65% of porphyroblastic units 10 to 50 cm thick; the blasts (up to 3 by 1 cm) are flattened within S_1 (Fig. GS-23-6) and locally lineated parallel to minor F_1 folds (Fig. GS-23-7). Randomly oriented, euhedral anthophyllite constitutes a later

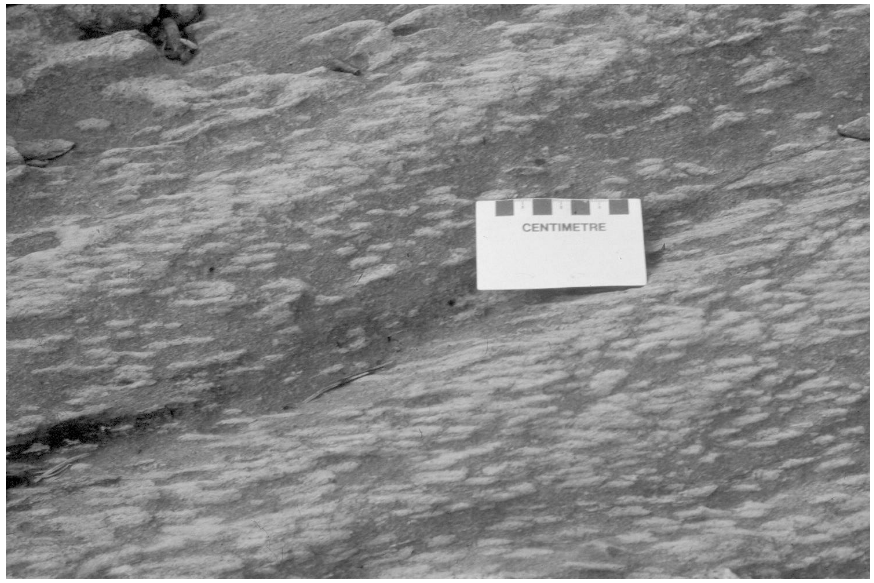


Figure GS-23-6: Stratabound cordierite porphyroblasts parallel to S_1 in the northern sedimentary formation (unit 2).

Figure GS-23-7: Discordance between S_o and S_1 in a cordierite-bearing siltstone-greywacke bed (subunit 2b) within the northern sedimentary formation. Cordierite is lineated parallel to F_1 folds.

metamorphic overprint (M_2). Sporadic argillitic, graphitic siltstone beds, commonly associated with amphibolitic interlayers, are associated with surficial iron staining due to pyrite oxidation.

Laminated chert is intercalated with greywacke and siltstone close to the south margin of the northern sedimentary formation, where chert beds up to 30 cm thick locally display flame structures at the contact with overlying greywacke (Fig. GS-23-8). Garnetiferous siltstone close to the north margin of the formation contains thin laminae of white chert and massive black magnetite (Fig. GS-23-9). Chert is also a subordinate component of garnetiferous mafic gneiss units (subunit 2c), which are located close to both north and south margins of the formation and typically display surficial iron staining.

Chert and related siliceous siltstone, up to 11 m thick, occur on the north shore of Franklin Murray Lake, in the upper part of the southern volcanic section. The south margin of the unit is mineralized where it is in contact with mafic volcanic flows (see 'Economic Geology' section); the north margin is in contact with a plagioclase porphyry sill.

A graded turbidite unit, at least 6 m thick, occurs within laminated amphibolite 60 m south of the contact between mafic volcanic and granitoid rocks in the northwest corner of the map area. Feldspathic greywacke and siltstone display graded A-D Bouma divisions, with well defined, south-facing tops (Fig. GS-23-10). The unit also contains stratabound cordierite, lineated parallel to F_1 minor fold axes.

Altered garnetiferous supracrustal rocks (subunit 2c)

A mineralized alteration zone, within the basaltic section in the vicinity of MacVicar Lake (Gilbert, 1999a), extends west to the limit of mapping in the northwest part of the map area; at that locality, the zone is less than 150 m from the north margin of the greenstone belt, at latitude 54.5ºN (Gilbert, 2000). The lateral extent of the zone, together with stratigraphically equivalent oxide-facies iron-formation to the east, is more than 10 km; the thickness of the zone diminishes from a maximum of 36 m at the northeast corner of MacVicar Lake to 5 m at the west end of the lake. The alteration zone is coincident with a sedimentary unit that may overlie the mafic volcanic sequence in this part of the greenstone belt, based on the limited structural data available. The sedimentary unit consists of siltstone and chert (locally magnetiferous), intercalated with massive to laminated amphibolite. Whereas some amphibolite is interpreted as basalt, finely laminated hornblendic laminae within siltstone units are probably sedimentary in origin. Pervasive garnet blastesis, extensive silicic alteration, and surficial iron staining derived from pyritic zones are characteristic of both the siltstone and amphibolite. The alteration is interpreted to be the result of early hydrothermal activity and associated sulphide mineralization, probably contemporaneous with volcanism and related felsic porphyry intrusions. Porphyroblastic growth and subsequent disruption of the altered rocks due to sinistral strike-slip movement are attributed to later regional metamorphism and deformation. Lithological details of the MacVicar Lake alteration zone are given in Gilbert (1999a); assay data are discussed in the 'Economic Geology' section.

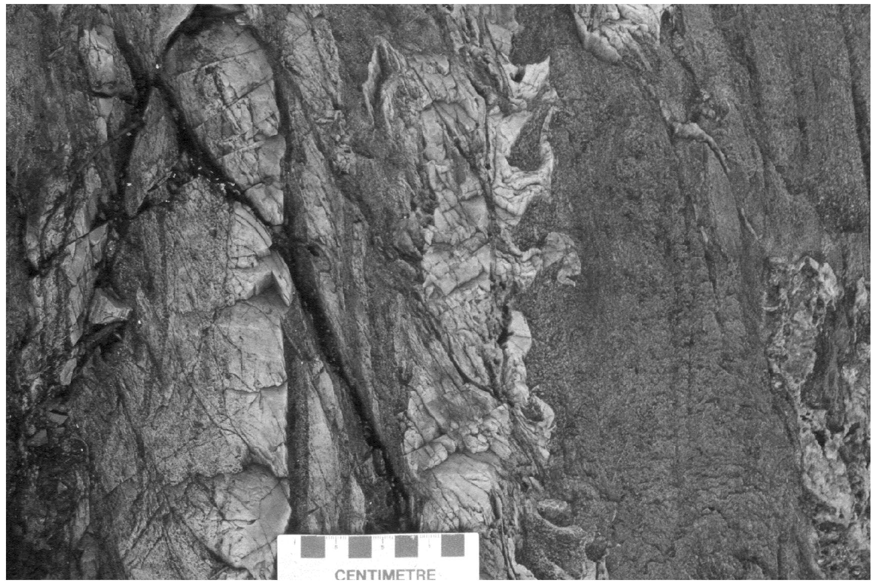


Figure GS-23-8: Flame structure in a chert layer (subunit 2b) within the northern sedimentary formation.

Figure GS-23-9: White chert and black magnetite laminae within intermediate to argillitic, garnetiferous siltstone (subunit 2b), close to the north margin of the northern sedimentary formation.

Figure GS-23-10: Graded turbidite deposit (subunit 2b) close to the margin of the Ralph Anderson Lake belt in the northwest part of the map area.

Layered garnetiferous gneissic zones (subunit 2c), approximately 1 to 4 m wide and similar to the MacVicar Lake alteration zone, occur close to both the north and south margins of the northern sedimentary formation. These zones are strongly deformed and characterized by pervasive metasomatism that resulted in silicic, hornblendic and chloritic alteration, extensive garnet blastesis, and development of massive garnetite. The garnetiferous zones, which display surficial iron staining due to the weathering of disseminated pyrite, appear to be mainly of sedimentary origin; amphibolitic layers may be derived, in part, from mafic extrusive or intrusive rocks.

Rhyolite, Massive to Fragmental; Heterolithic Breccia, Minor Related Sedimentary Rocks; Related Plagioclase±Quartz Porphyry (Unit 4)

A felsic fragmental rock formation, up to 34 m thick, occurs along strike from porphyroblastic siltstone (subunit 2b) of the northern sedimentary formation in the northwest part of the project area (Fig. GS-23-5). The felsic fragmental rocks are interpreted as laterally equivalent to porphyroblastic siltstone at central MacVicar Lake, and thus analogous to the northern felsic volcanic formation along strike to the east, north of Lavigne and Ralph Anderson lakes (Gilbert, 1999b; Fig. GS-23-2, -5). At outcrop scale, the felsic fragmental rocks directly overlie the porphyroblastic siltstone section at several localities in the central part of MacVicar Lake. The siltstone and related sedimentary rocks wedge out to the west, where they are replaced by the felsic fragmental rocks. The latter are interpreted as debris-flow deposits, possibly derived from preexisting volcanic fragmental rocks akin to those in the northern felsic volcanic formation.

Heterolithic volcanic breccia and tuff (subunit 4b)

Heterolithic volcanic breccia in western MacVicar Lake is typically clast supported, with 40 to 75% diverse, felsic fragment types up to 1.2 by 0.3 m in size. The predominant white, rhyolitic clasts vary texturally due to differences in plagioclase phenocryst content (5–40% of clasts). A minority of clasts (<15%) are grey-weathering, intermediate types characterized by aphyric to sparsely plagioclase-phyric texture. The breccia formation is generally devoid of sorting, except for sporadic, diffuse, lapilli-bearing zones and felsic tuff interlayers (0.2–1.5 m thick). Breccia fragments are moderately to strongly flattened, and locally lineated with moderate east-southeast plunge. The shape of the original fragments is not known due to the deformation, but similar fragmental rocks in the northern felsic volcanic formation to the east display traces of original, angular clast shapes (Gilbert, 1999a). Fragmental rocks within the latter formation, which contain graded layers of possible turbidite origin, have been interpreted as subaqueous mass-flow deposits, and a similar mode of origin is inferred for the felsic fragmental rocks in western MacVicar Lake.

GEOCHEMISTRY

Fifty volcanic and related intrusive rocks in the west part of the Ralph Anderson Lake greenstone belt were analyzed for major, trace and rare-earth elements. Analysis of powder rock samples was carried out, using ICP–MS and ICP–OES, by Activation Laboratories, Ancaster, Ontario. The geochemical data are consistent with the field interpretation that the supracrustal assemblage is an arc-type volcanic sequence. A significant geochemical break divides the volcanic section into a lower, southern volcanic suite and upper northern volcanic suite, separated by the Lavigne Lake gabbro sill (Fig. GS-23-2, -3). The southern volcanic suite consists largely of basalt and synvolcanic gabbro that are depleted arc tholeiite. The southern basalt is characterized by LILE enrichment, high Th/Nb ratios and flat, incompatible element profiles with overall REE contents below those of depleted normal mid-ocean ridge basalt (N-MORB; Fig. GS-23-11A); in contrast, the more evolved basalt and

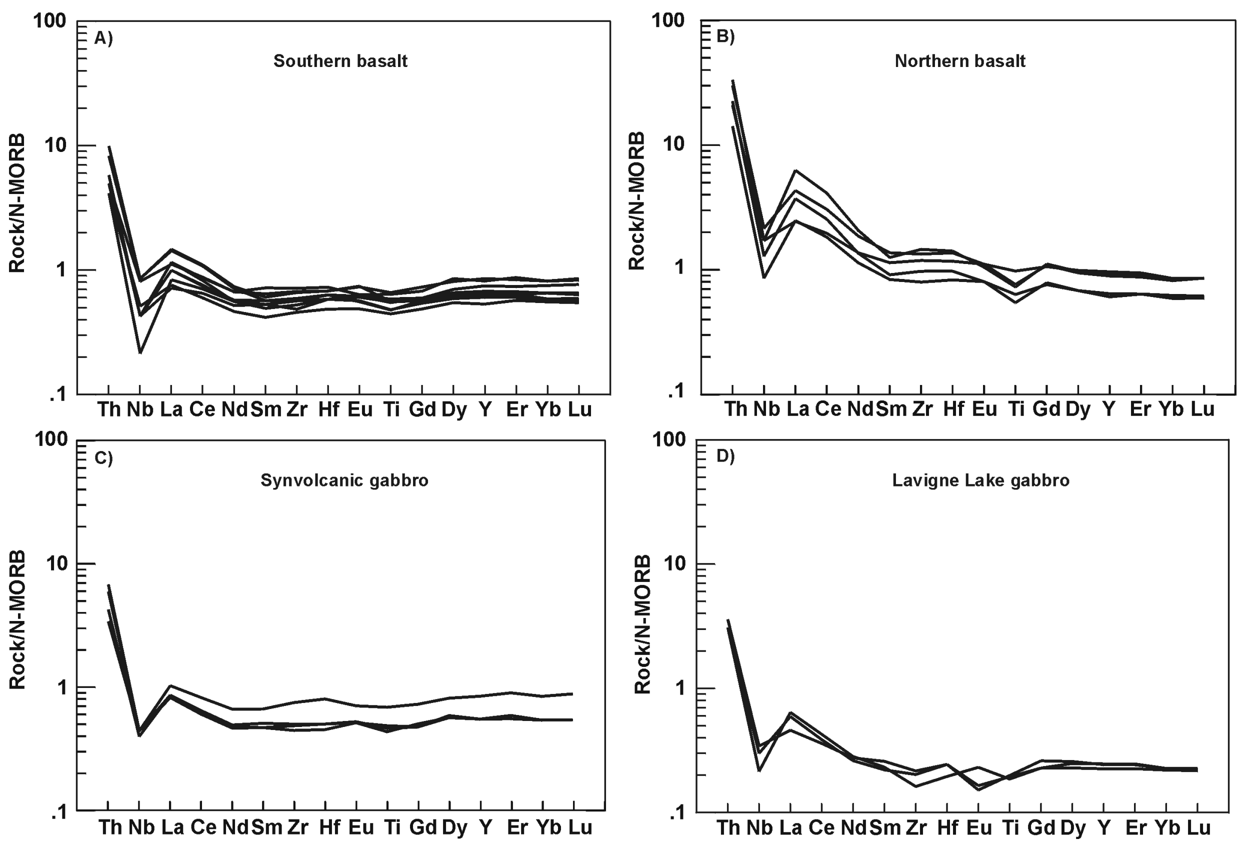


Figure GS-23-11: Extended element plots (N-MORB-normalized) of mafic volcanic and gabbroic rocks in the southeast Max Lake area, showing LREE (light rare-earth element)–depleted to –enriched, arc-type signatures of basalt and synvolcanic gabbro: A) southern basalt suite, B) northern basalt suite, C) synvolcanic gabbro, D) Lavigne Lake gabbro. Normalizing values from Sun and McDonough (1989).

basaltic andesite in the northern suite display moderately negative sloping, incompatible element profiles with more pronounced LILE/HFSE decoupling (Fig. GS-23-11B). These REE profiles and the FeO_{tot}/MgO vs. SiO_2 ratios (Fig. GS-23-12) indicate that the volcanic rocks are a transitional tholeiitic–calc-alkaline, arc-type assemblage. Both equigranular and megaphyric synvolcanic gabbroic units within the southern volcanic suite are compositionally very similar to the associated basalt; in contrast, the Lavigne Lake gabbro in the central part of the belt is relatively more primitive (Fig. GS-23-11C, D). The available geochemical data suggest that both the southern basaltic sequence and the Lavigne Lake gabbro are derived from a common, depleted, arc-tholeiite magma that was also the source for the northern volcanic suite.

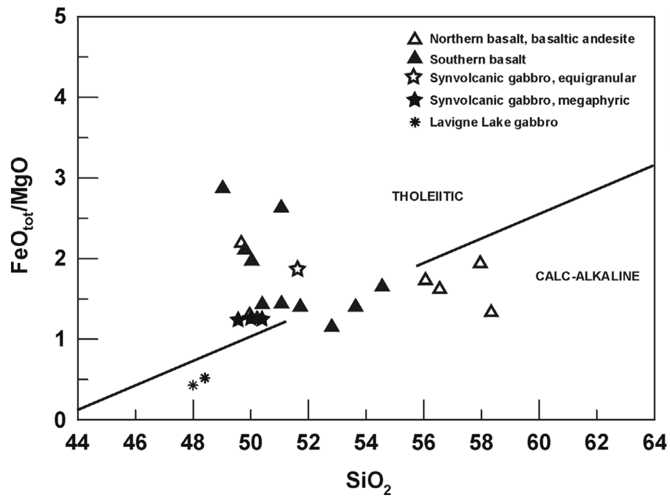


Figure GS-23-12: Plots of FeO_{tot}/MgO vs. SiO_2 for mafic volcanic and gabbroic rocks in the southeast Max Lake area.

Intermediate to felsic rocks in the west part of the Ralph Anderson Lake belt include massive to fragmental, volcanic extrusive types and plagioclase-quartz porphyry intrusions; geochemical data support the field interpretation that the two rock types are genetically related. Based on REE ratios and fractionation patterns, the volcanic extrusive and related intrusive rocks are classified as Archean 'F1 type' (Fig. GS-23-13), according to the scheme of Lesher et al. (1986); these rock types are characteristic of stratigraphic sequences that are devoid of base-metal sulphide mineralization, or barren horizons within mineralized sections (Lesher et al., 1986). Thus, the F1-type felsic volcanic extrusive rocks and most related porphyry dykes do not appear to represent good prospects for base-metal mineralization. Several silica-rich porphyry dykes at the north margin of the belt may be more prospective for economic mineralization, because some degree of crustal modification is indicated by SiO_2 contents that are elevated (>77%) above stoichiometric values. These intrusions are also characterized by strongly depleted TiO_2 (0.02–0.24%) and Nb (2–4 ppm), compared to other felsic porphyry and volcanic extrusive rocks in the map area (average TiO_2 = 0.5%; Nb = 7 ppm).

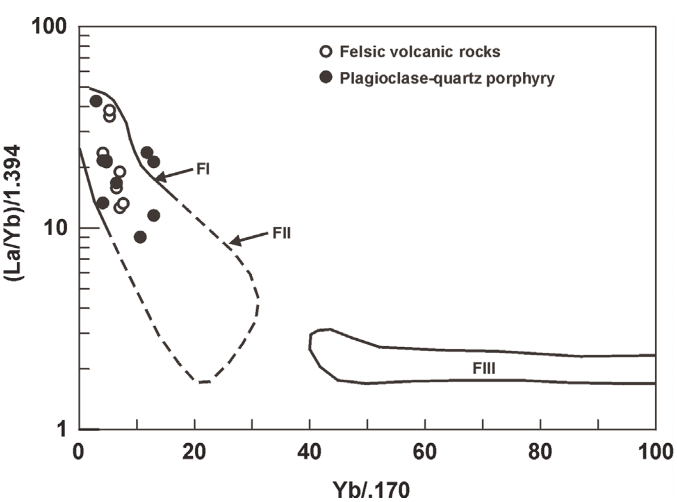


Figure GS-23-13: Plot of $(La/Yb)_N$ vs. Yb_N for felsic volcanic rocks and related plagioclase-quartz porphyry intrusions in the southeast Max Lake area. Fields of Archean felsic volcanic rock types after Lesher et al. (1986). Normalizing values from Sun and McDonough (1989).

STRUCTURAL GEOLOGY AND METAMORPHIC HISTORY

The structural and metamorphic history of the west part of the project area has been previously described (Gilbert, 1999a). The following is a brief summary of that account:

1) Major F_1 folding resulted in the subvertical, east-southeast trend of the volcanosedimentary sequence. Associated F_1 minor folds trend east-southeast with moderate plunge. The deformation was accompanied by regional S_1 foliation and associated planar features, such as clast flattening in fragmental rocks and lamination in amphibolite derived from basaltic rocks. Associated M_1 metamorphism resulted in the alteration of pyroxene to amphibole in mafic volcanic and intrusive rocks, and the development in sedimentary and altered volcanic rocks of various porphyroblasts, including cordierite (lineated parallel to F_1 folds; Fig. GS-23-7), andalusite and garnet (locally in massive garnetite laminae).
2) F_2 folding, localized boudinage of F_1 planar elements and refolding of F_1 folds were associated with regional movement parallel to S_1 (Fig. GS-23-14, -15). The F_2 folds plunge moderately southeast to east-southeast, roughly coincident with minor F_1 folds. The F_2 folding was associated with development of S_2 foliation (sub parallel to S_1), M_2 anthophyllite and cummingtonite porphyroblasts, and rotation and crenulation of M_1 porphyroblasts.

Figure GS-23-14: F_2 folding of S_1 foliation and related lamination in strongly attenuated volcanic rock.

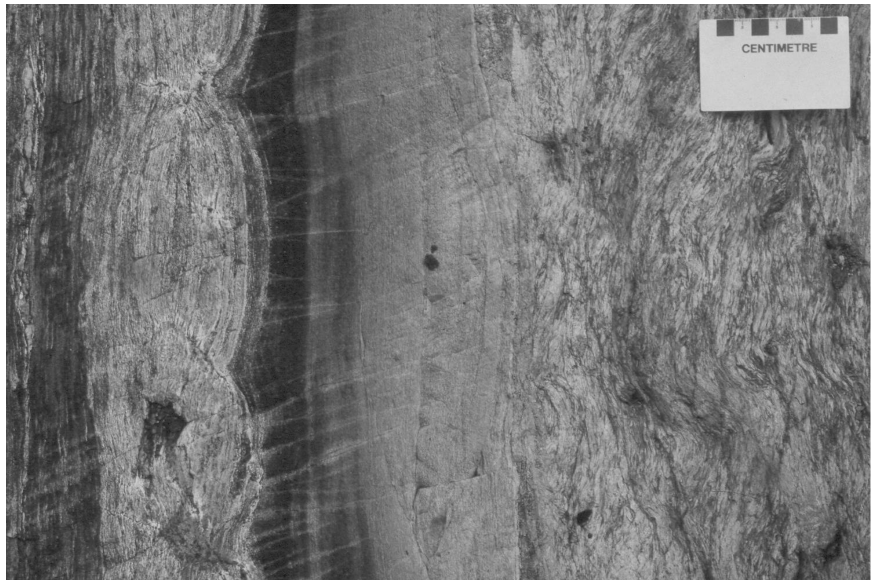


Figure GS-23-15: D_2 boudinage and disruption of S_1 in altered basalt with felsic interlayers.

3) Discrete F_3 shear zones occur sporadically throughout the greenstone belt (locally at incompetent horizons such as brecciated basalt flow contacts, alteration zones or thin sedimentary rock units). The deformation resulted in localized conformable tectonic breccia zones, and mylonitization at the contact between the McLeod Narrows gabbro and mafic volcanic rocks immediately to the north (Fig. GS-23-2). Folding of S_2 foliation is associated with development of S_3 strain-slip cleavage. Associated M_3 metamorphism resulted in greenschist-facies alteration of earlier porphyroblasts, chloritization in shear zones, and localized silicification, carbonatization and epidotization throughout the greenstone belt, especially conspicuous in a zone along the south margin of the southern volcanic section.
4) The F_4 event resulted in north-northeast- to northeast-trending, high-angle faults (displacement on order of tens of metres) that transect the greenstone belt.

Structural data in the MacVicar Lake–Ralph Anderson Lake area indicate that the belt is a north- to north-northeast-facing monocline (Gilbert, 1999a, b). In the Franklin Murray Lake–Aswapiswanan Lake area, rocks of the southern volcanic suite dip moderately to steeply south; F_2 linear elements trend mainly southeast to east-southeast with moderate to steep plunge. New data from 2000 mapping at the west end of MacVicar Lake has identified an east-trending synclinal fold close to the north margin of the greenstone belt. At that locality, a turbidite unit faces south, in opposition to the predominant northward-facing direction throughout in the belt. The available data indicate that the hinge-line of the fold is approximately coincident with the MacVicar Lake alteration zone. Delineation of this structural feature in the area east of MacVicar Lake was not possible due to intense deformation and attenuation along the north flank of the greenstone belt.

ECONOMIC GEOLOGY

Seven mineral occurrence settings (Table GS-23-2) have been identified in the map area:

i) Hydrothermal alteration zone at central MacVicar Lake and associated oxide-facies iron-formations (at or close to the top of the northern volcanic suite)
ii) Stratabound mineralization associated with chert-siltstone units a) in the upper part of the southern volcanic suite; b) at the basalt/gabbro contact at the base of the northern volcanic suite; and c) within the northern sedimentary formation
iii) Felsic porphyry dykes within mafic volcanic rocks
iv) Gabbro-related mineralization, commonly close to margins of intrusions or at gabbro-basalt contacts
v) Sulphide mineralization in mafic volcanic rocks, occurring as irregular zones within pillowed flows, interstitial to pillows or in related breccia units
vi) Along the contact between the McLeod Narrows gabbro and the southern volcanic suite; mineralization is associated variously with siltstone, altered basalt and/or protomylonite in the contact zone
vii) The north margin of the northern volcanic section, at the contact between attenuated basalt and sheared, hybrid gneiss derived from the granitoid terrane to the north.

Details of mineralized localities listed in Table GS-23-2 are as follows:

i) Volcanic rocks in the MacVicar Lake alteration zone contain up to 420 ppm Cu and minor Zn (108 ppm). The mineralized samples are from strongly deformed layers of garnetiferous, silicified basalt with massive garnetite stringers and disrupted quartz veins. Magnetiferous chert beds within and adjacent to the alteration zone contain up to 314 ppb Au and 252 ppm Zn.
ii) Stratabound base-metal sulphide mineralization and gold occur in an approximately 11 m thick cherty siltstone unit close to the top of the southern mafic volcanic suite at Franklin Murray Lake. The mineralization (1700 ppm Zn, 470 ppm Cu, 31 ppb Au and traces of Ag, Ni and Cr) occurs over a 1 m wide section at the south margin of the sedimentary unit, which occurs between pillowed basalt to the south and a plagioclase porphyry sill to the north. At the south margin of the northern volcanic suite, a 2 m laminated chert unit between basalt and the Lavigne Lake gabbro at Ralph Anderson Lake contains 828 ppm Cu and traces of Au and Ag. Chert layers within the northern sedimentary formation at MacVicar Lake contain 293 ppm Cu and 237 ppm Zn.
iii) Between 250 and 400 m south of the MacVicar Lake alteration zone, quartz-plagioclase porphyry dykes within strongly deformed basalt contain up to 478 ppm Zn, 159 ppm Cu and a trace of Au.
iv) At Aswapiswanan Lake, gold and base-metal mineralization occurs at the south margin of a 10 m thick synvolcanic gabbro sill in the upper part of the southern volcanic suite (1373 ppm Cu, 306 ppm Cr, 124 ppb Au, and traces of Ni and Zn). The mineralization occurs in a narrow (30 cm wide) silicified zone in the marginal part of the sill. In the west part of the project area, both the Lavigne Lake and McLeod Narrows gabbro intrusions contain sporadic pyritic zones with Cu (687 ppm) and Zn (206 ppm).
v) Pillowed basalt, 150 m north of the Lavigne Lake gabbro, contains pervasive mineralized zones within and between pillows (up to 248 ppm Cu).
vi) At the south margin of the greenstone belt, a tectonized anthophyllite-chlorite-sericite alteration zone with patchy silicification contains 482 ppm Cu and 859 ppm Ni.
vii) At the north margin of the belt, minor Cu, Zn, Ni and Cr mineralization occurs in a narrow zone at the basalt-granite contact.

Table GS-23-2. Selected geochemical data for mineralized rock samples in the Ralph Anderson Lake greenstone belt.

Sample #	Type	Cu (ppm)	Zn (ppm)	Au (ppb)	Ag (ppm)	Ni (ppm)	Cr (ppm)	Location of mineralized zones	Host rock
32-99-2019-2	(i)	110	108	6	0.3	6	-	MacVicar Lake alteration zone, eastern MacVicar Lake	Quartz felsite vein with chloritic laminae
32-99-2020-1	(i)	424	8	-5	0.4	33	-	MacVicar Lake alteration zone, eastern MacVicar Lake	Silicified, tectonic laminated basalt; garnet-bearing, with mafic remnants and quartz veins
32-99-2020-3	(i)	49	82	-5	-0.2	27	-	MacVicar Lake alteration zone, eastern MacVicar Lake	Silicified, tectonic laminated basalt; garnet-bearing, with mafic remnants and quartz veins
32-99-2020-6	(i)	21	10	-5	0.5	6	-	MacVicar Lake alteration zone, eastern MacVicar Lake	Silicified, tectonic laminated basalt; garnet-bearing, with mafic remnants and quartz veins
32-00-3325-2	(i)	41	145	9	-0.3	13	59	MacVicar Lake alteration zone, central MacVicar Lake	Magnetiferous chert associated with garnetiferous amphibolite
32-00-3281-1	(i)	23	252	314	-0.3	11	12	20 m south of the alteration zone, west MacVicar Lake	Magnetiferous chert component of oxide-facies iron-formation
32-00-3023-2	(ii)	189	95	-2	-0.3	74	55	North shore, Franklin Murray Lake	Cherty siltstone with fine bedding lamination
32-00-3023-3	(ii)	288	1700	29	1.4	50	48	North shore, Franklin Murray Lake	Cherty siltstone with fine bedding lamination
32-00-3025-3	(ii)	178	206	-2	6.0	119	67	North shore, Franklin Murray Lake	Cherty siltstone with fine bedding lamination
32-00-3025-4	(ii)	470	978	6	1.2	78	50	North shore, Franklin Murray Lake	Cherty siltstone with fine bedding lamination
32-00-3025-5	(ii)	211	572	31	0.4	37	103	North shore, Franklin Murray Lake	Cherty siltstone with fine bedding lamination
32-00-3234-3	(ii)	68	237	9	0.4	53	89	Northern sedimentary formation, MacVicar Lake	Chert/cherty siltstone associated with porphyroblastic siltstone
32-00-3235-2	(ii)	293	115	3	-0.3	43	58	Central peninsula, MacVicar Lake	Thin (0.5 m) chert unit within pillowed basalt adjacent to northern sedimentary formation
32-99-2321-4	(ii)	828	64	19	1.6	65	-	North margin of Lavigne Lake gabbro, Ralph Anderson Lake	Chert unit between basalt and gabbro at base of northern volcanic suite
32-99-2024-1	(iii)	99	478	57	0.3	26	-	275 m south of MacVicar Lake alteration zone	Quartz-plagioclase porphyry in laminated amphibolite
32-99-2120-2	(iii)	159	134	-5	0.6	14	-	400 m south of MacVicar Lake alteration zone	Quartz-plagioclase porphyry in partly altered and sheared basalt
32-00-3104-1	(iv)	202	146	-2	0.3	-1	-5	North shore, western Aswapiswanan Lake	Gossan zone within synvolcanic gabbro
32-00-3111-1	(iv)	237	112	-2	-0.3	69	81	North shore, western Aswapiswanan Lake	Gossan zone within synvolcanic gabbro
32-00-3142-5	(iv)	301	145	3	-0.3	6	-5	Island, northwest part of Aswapiswanan Lake	Gossan zone at margin of synvolcanic gabbro
32-00-3143-1	(iv)	1373	76	124	0.5	59	306	Island, northwest part of Aswapiswanan Lake	Gossan zone at margin of synvolcanic gabbro
32-00-3260-1	(iv)	166	119	13	0.4	-1	-5	McLeod Narrows gabbro (western part)	Gossan zone in gabbro adjacent to supracrustal enclave
32-00-3264-1	(iv)	177	206	-2	-0.3	28	26	Lavigne Lake gabbro (western part)	Gossan zone in melanocratic gabbro
32-00-3316-1	(iv)	687	5	9	-0.3	70	-5	McLeod Narrows gabbro (western part)	Silicified, epidotized 12 m alteration zone in gabbro
32-99-2222-1	(v)	248	38	-5	0.4	12	-	150 m north of central Lavigne Lake gabbro	Aphyric, pillowed basalt with epidotic domains and minor silicification
32-99-2041-3	(vi)	482	29	-5	0.6	859	-	South margin of southern basalt suite	Altered amygdaloidal basalt (quartz-anthophyllite-sericite-chlorite-epidote); locally protomylonitic or gneissic
32-00-3291-5	(vii)	66	146	4	-0.3	107	187	North margin of northern basalt suite	0.5 m gossan zone at contact between basalt and granitoid hybrid gneiss

Refer to text for explanation of mineralization types

Exploration Prospects

The numerous sulphide showings and the varied settings in which mineralization occurs in the southeast Max Lake area suggest that the terrane represents a viable exploration prospect for both base metals and gold. Bimodal volcanism, synvolcanic felsic porphyry intrusions, exhalative sedimentary horizons, conformable alteration zones and stratabound mineralization, all present in the southeast Max Lake area, are key features in VMS-hosting terranes of all ages, such as Noranda and Timmins (Gibson et al., 1984), and Flin Flon (Syme and Bailes, 1993). The stratigraphy in the southeast Max Lake area is also similar to that of some gold camps, such as Red Lake, Ontario (Pirie et al., 1982).

The best prospects for base-metal or precious-metal exploration are considered to be the garnetiferous alteration zone (unit 2c) that extends through MacVicar Lake, together with related magnetiferous iron-formation (type i); and stratabound, sediment-hosted mineralization in the central to upper parts of the sequence at MacVicar and Franklin Murray lakes (type ii). Alteration and mineralization in the garnetiferous zone may be a result of hydrothermal activity associated with synvolcanic felsic porphyry intrusions.

Copper-nickel mineralization at the south margin of the Ralph Anderson Lake belt may be related to the emplacement of the contiguous McLeod Narrows gabbro; however, the secondary mineral assemblage associated with this mineralization (anthophyllite-quartz-sericite-chlorite) is more typical of hydrothermal processes. The Cu-Ni mineralization occurs very close to an inferred major fault that could have provided a conduit for the hydrothermal fluids assumed to be the source of sulphide mineralization and alteration.

Lithostratigraphic and geochemical data suggest the southeast Max Lake area offers good potential for economic mineralization. However, this suggestion must necessarily be tempered by consideration of the fact that the geochemical signature of felsic volcanic rocks in the map area (‘type F1’ of Lesher et al., 1986) indicates that they have low potential for economic mineralization.

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