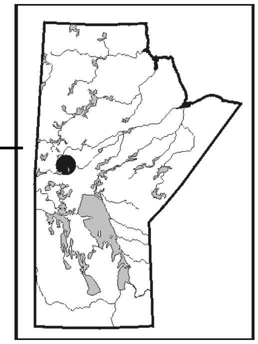
GS-1 GEOLOGY AND GEOCHEMISTRY OF PALEOPROTEROZOIC VOLCANIC ROCKS BETWEEN THE MCLEOD ROAD AND BIRCH LAKE FAULTS, SNOW LAKE AREA, FLIN FLON BELT (PARTS OF NTS 63K/16 AND 63J/13)



by A. H. Bailes and D.C.P. Schledewitz

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SUMMARY

Geological investigation of the poorly documented volcanic rocks between Snow and Birch lakes indicates they comprise a monoclinal, north-facing, subaqueously deposited, bimodal basalt-rhyolite sequence with strong physical and geochemical similarities to the mature arc and arc-rift sequences of the Snow Lake arc assemblage. We interpret them to be a thrust repetition or imbricate of the adjacent VMS-hosting Snow Lake arc assemblage, and to have similar potential for containing VMS deposits.

Lode gold deposits in volcanic rocks north of Snow Lake occur in the hanging wall of, and in proximity to, the basal McLeod Road Fault (thrust). On the basis of the regional distribution of a stratigraphic marker unit (Corley Lake member) in structurally underlying Burntwood Group metapelites, the McLeod Road Fault is suggested to coincide with the southeast shore of Squall Lake and to curve north of the Squall Lake dome.

INTRODUCTION

The Snow Lake area, at the east end of the Paleoproterozoic Flin Flon Belt (Fig. GS-1-1), is an important VMS and lode gold mining area (Fig. GS-1-2, GS-1-3). It contains 10 producing and past producing VMS mines (Fig. GS-1-2, Osborne Mine not shown) with production plus reserves of 25.4 million tonnes (Bailes and Galley, 1996) and the newly reopened New Britannia/Nor Acme lode gold deposit with production plus reserves of 10.1 Mt (TVX staff, 1998). All VMS deposits in the Snow Lake area occur in volcanic rocks that display oceanic arc geochemical characteristics (Syme and Bailes, 1993; Stern et al., 1995a; Bailes and Galley, 1996). The major lode gold deposits at Snow Lake are spatially related to and in the structural hanging wall of the McLeod Road Fault (Galley et al., 1986, 1988).

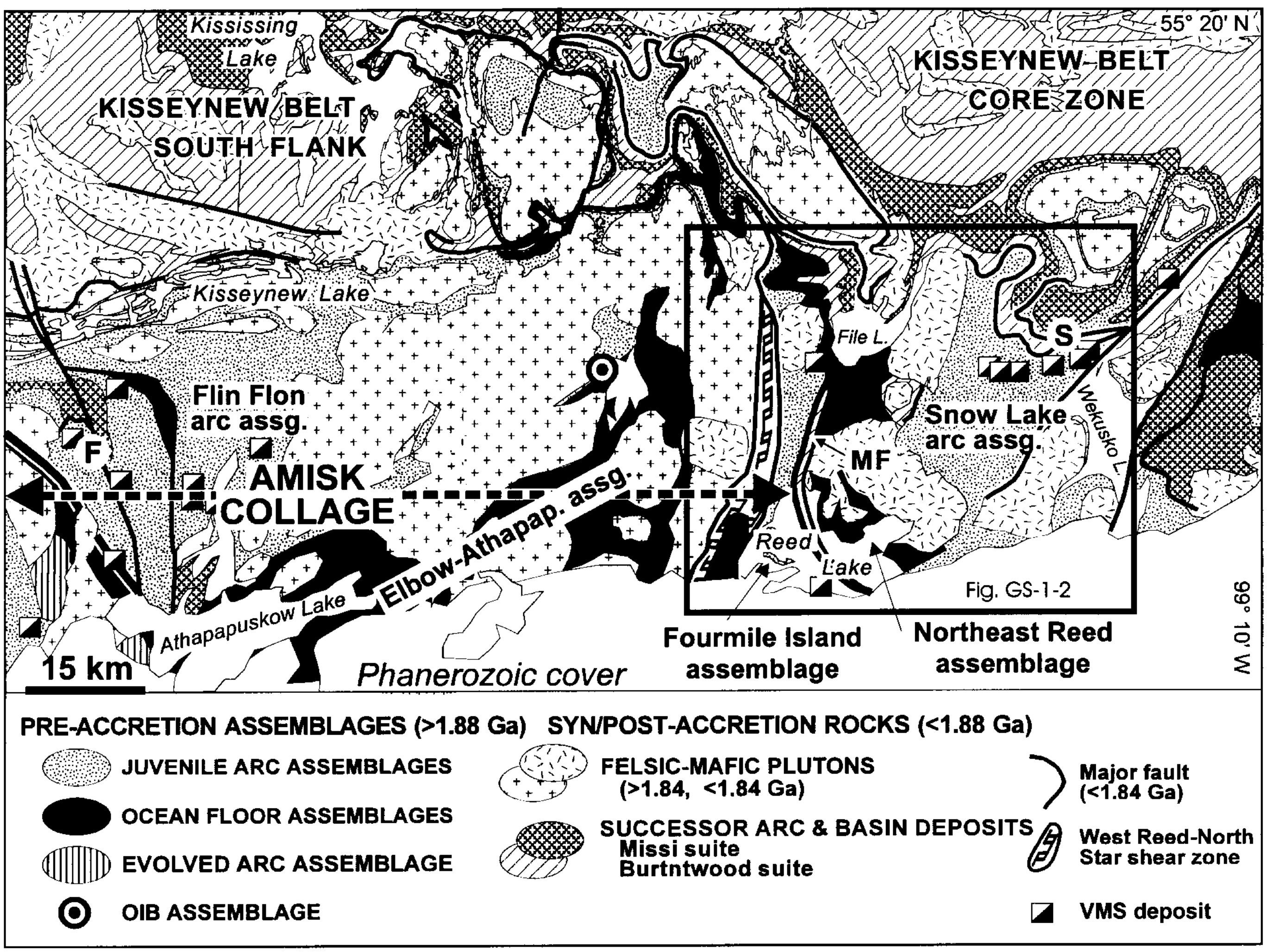

Figure GS-1-1: Simplified geological map of the central and eastern portion of the Flin Flon Belt showing major tectonostratigraphic assemblages and plutons, and locations of mined VMS deposits. F: Flin Flon, S: Snow Lake, ML: Morton Lake faults zone.

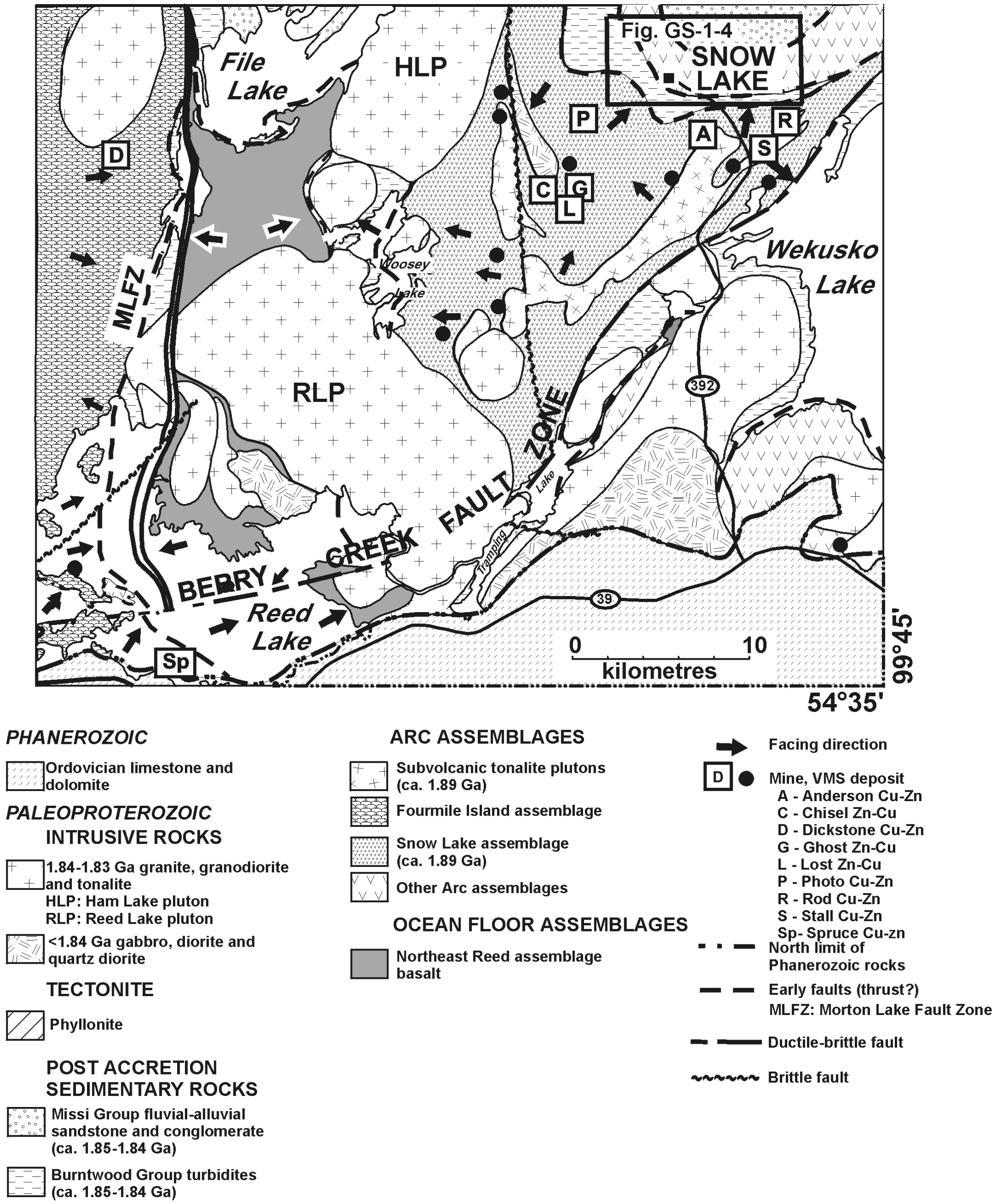

Figure GS-1-2: Generalized geology of the Reed Lake-Snow Lake area, modified from Syme et al. (1995) and Bailes et al. (1994). The Morton Lake fault zone (MLFZ) is interpreted to represent the basal thrust (Syme et al., 1995; Lucas et al., 1996) that separates the Snow Lake area from the central Flin Flon Belt. The Snow Lake area is characterized by a structural style and lithologies that are more comparable to the Kisseynew domain than those observed in the central Flin Flon Belt. The Snow Lake area consist of a series of Kisseynew-type allochthons of 1.89 Ga volcanic and 1.84 Ga sedimentary rocks.

This contribution outlines some of the results of geological investigations and geochemical sampling in hitherto incompletely investigated volcanic rocks contained in a fault slice between the McLeod Road and Birch Lake faults, north of Snow Lake. The objective was to provide basic geological information (facing direction of strata, stratigraphy and geochemistry of volcanic rocks) to assist gold deposit related structural studies being undertaken in these rocks by geologists from both Manitoba Energy and Mines (Gale, 1997) and the University of Manitoba (MSc. students Ian Fieldhouse and Pamela Fulton).

Seven samples of volcanic rocks from the McLeod-Birch fault slice (discussed in a later section) were submitted for trace element and rare earth element analysis by neutron activation and acid digestion ICP-MS analytical procedures. These analyses add to a growing geochemical database that is being used to identify the paleotectonic environment of volcanism and to aid correlation of volcanic sequences from one domain to another in this structurally complex area.

REGIONAL AND LOCAL SETTING

The Flin Flon Belt (Fig. GS-1-1) is a collage of 1.92-1.88 Ga tectonostratigraphic assemblages that were juxtaposed during a period of 1.88-1.87 Ga intra-oceanic accretion and subsequent 1.84-1.78 Ga terminal collision with the bounding Archean cratons (Lucas et al., 1996). The volcanic rocks include oceanic arc, ocean floor (back arc), oceanic island, oceanic plateau and older crustal assemblages (Syme and Bailes, 1993; Stern et al., 1995a, 1995b). Oceanic arc assemblages include tholeiite, calc alkaline and rare shoshonite and boninite suites similar to those forming in modern intra-oceanic arcs (Stern et al., 1995a).

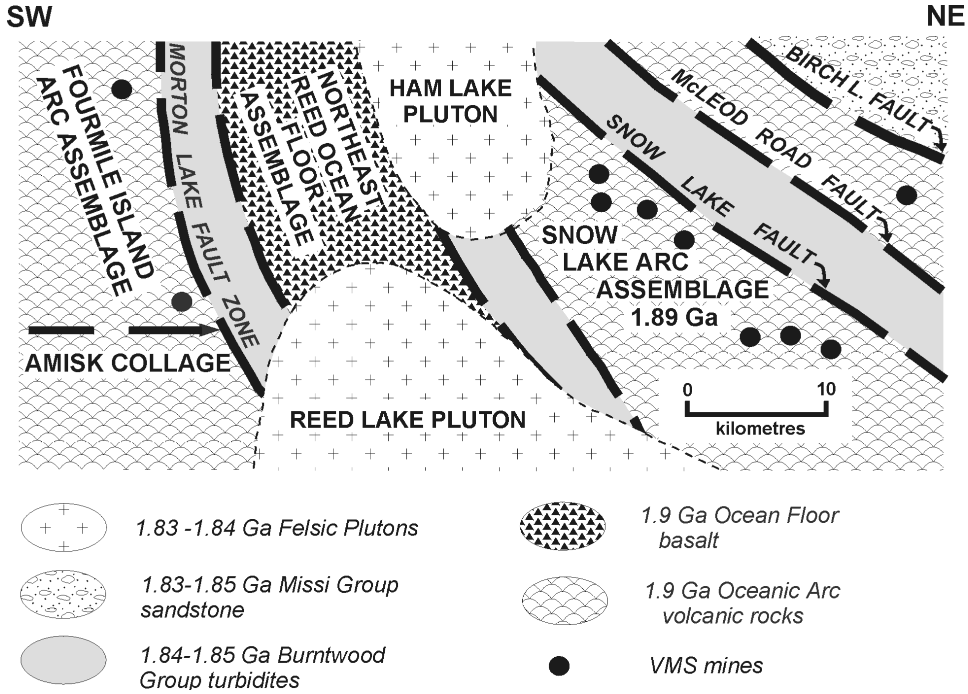

Figure GS-1-3: Schematic cross section showing a series of allochthons in the Reed Lake - Snow Lake area (bottom left to upper right in Fig. GS-1-2). Panels of 1.89 Ga volcanic rocks are separated by thrust faults and panels of 1.84 Ga Burntwood Group sedimentary rocks. The allochthons of volcanic and younger sedimentary rocks are cut by late successor arc (1.84-1.83 Ga) granite plutons. VMS mines are restricted to arc assemblages; 7 of the 10 mines in the Snow Lake area located in an allochthon composed of Snow Lake arc assemblage rocks.

The Snow Lake area is dominated by 1.84-1.81 Ga fold-thrust style tectonics (Connors, 1996) that is distinct from the central and western portions of the Flin Flon Belt. The entire Snow Lake portion of the Flin Flon Belt is interpreted as a south-verging, allochthonous imbricate that was emplaced between 1.84 and 1.81 Ga (Syme et al., 1995; Lucas et al., 1996) over the previously amalgamated collage of oceanic and arc rocks ("Amisk collage") to the west (Fig. GS-1-3). Individual allochthons of volcanic rocks, besides being bounded by thrust faults, are also generally separated by intervening imbricates of younger (ca. 1.84 Ga) sedimentary rocks (Connors, 1996; David et al., 1996). Syme et al. (1995) interpret the base of the thrust stack to be the Morton Lake Fault Zone (Figs. GS-1-2 and GS-1-3). The thrust package has been subsequently modified by: 1) intrusion of 1.84-1.83 Ga granitic plutons; 2) northeast trending and plunging open folding (F3 of Kraus and Williams, 1998); and 3) 1.82-1.81 Ga regional metamorphism to lower to middle almandine amphibolite facies mineral assemblages (Froese and Moore, 1980; David et al., 1996).

The fact that volcanic rocks in the Snow Lake area occur in fault-bounded tectonic slices or allochthons (Fig. GS-1-3) has significant implications for mineral exploration. For example, volcanic stratigraphy and mineralization in individual allochthons may be completely different and unrelated: oceanic arc volcanic rocks in the Snow Lake assemblage allochthon have a much greater potential to host VMS deposits than does the adjacent Northeast Reed assemblage allochthon (Fig. GS-1-3). For this reason, the stratigraphy and lithogeochemistry of volcanic rocks between the McLeod Road and Birch Lake faults is an important indicator of their inherent mineral potential.

VOLCANIC ROCKS OF THE MCLEOD ROAD - BIRCH LAKE ALLOCHTHON

Introduction

Volcanic rocks between Snow and Birch lakes have not been dated, but for reasons to be discussed below are likely the same age as the 1.89 Ga (David et al., 1996) volcanic rocks of the Snow Lake arc assemblage. They are bounded to the south and north respectively by ca. 1.85-1.84 Ga Burntwood Group turbidites and Missi Group fluvial-alluvial sedimentary rocks (David et al., 1996) and by the semiconformable McLeod Road and Birch Lake faults (Fig. GS-1-2). The faults, commonly suggested to be thrusts (Russell, 1957; Froese and Moore, 1980), predate the 1.81 Ga (David et al., 1996) regional metamorphic event and have been recrystallized, along with adjacent volcanic and sedimentary rocks, to lower to middle almandine-amphibolite facies mineral assemblages.

The distribution of volcanic rock lithologies between Snow and Birch lakes, slightly modified from the 1:5000 mapping of Galley et al. (1988), is shown in Figure GS-1-4. Our work shows this bimodal basalt-rhyolite sequence to be monoclinal and top to the north and northeast. The sequence is openly folded about the northeast-trending F3 (fold terminology as outlined by Krause and Williams (1998)) Threehouse syncline and locally affected by north northwest-trending folds of indeterminate age adjacent to the McLeod Road Fault, northwest of the town of Snow Lake. Major units have been named in Figure GS-1-4 for ease of reference, but, because these units are lensoid and discontinuous, the names are only relevant to the area immediately north of the town of Snow Lake. Primary features of these units have not previously been documented and, for this reason, moderately detailed descriptions are included below.

Mafic flows

Three mafic flow units (Bounter zone, Three zone and Birch Lake) were observed in the McLeod Road-Birch Lake section (Fig. GS-1-4). The Bounter zone basalts comprise a series of flows that are <30m thick and discontinuous along strike, and occur within a dominantly mafic volcaniclastic portion of the section. They were deposited subaqueously and display both pillowed (Fig. GS-1-5) and amoeboid pillowed facies. The Bounter zone basalts are porphyritic with up to 10% plagioclase (0.5-2mm) and 0 to 5% pyroxene (1-4mm) (pseudomorphed by amphibole) phenocrysts. They contain up to 10% quartz amygdales and are locally epidotized.

The Three zone basalts form a 300m thick unit that directly underlies the Birch Lake basalt. These basalts are dominantly massive, with up to 50% pyroxene (2-10mm) phenocrysts. They have been mapped as gabbros in the past, but local pillow selvages, complete pillows (Fig. GS-1-6) and up to 25% carbonate- and feldspar-filled amygdales (1-5mm) attest to their origin as volcanic flows. Three zone basalts occur along strike from pyroxene-rich mafic volcaniclastic rocks to the west.

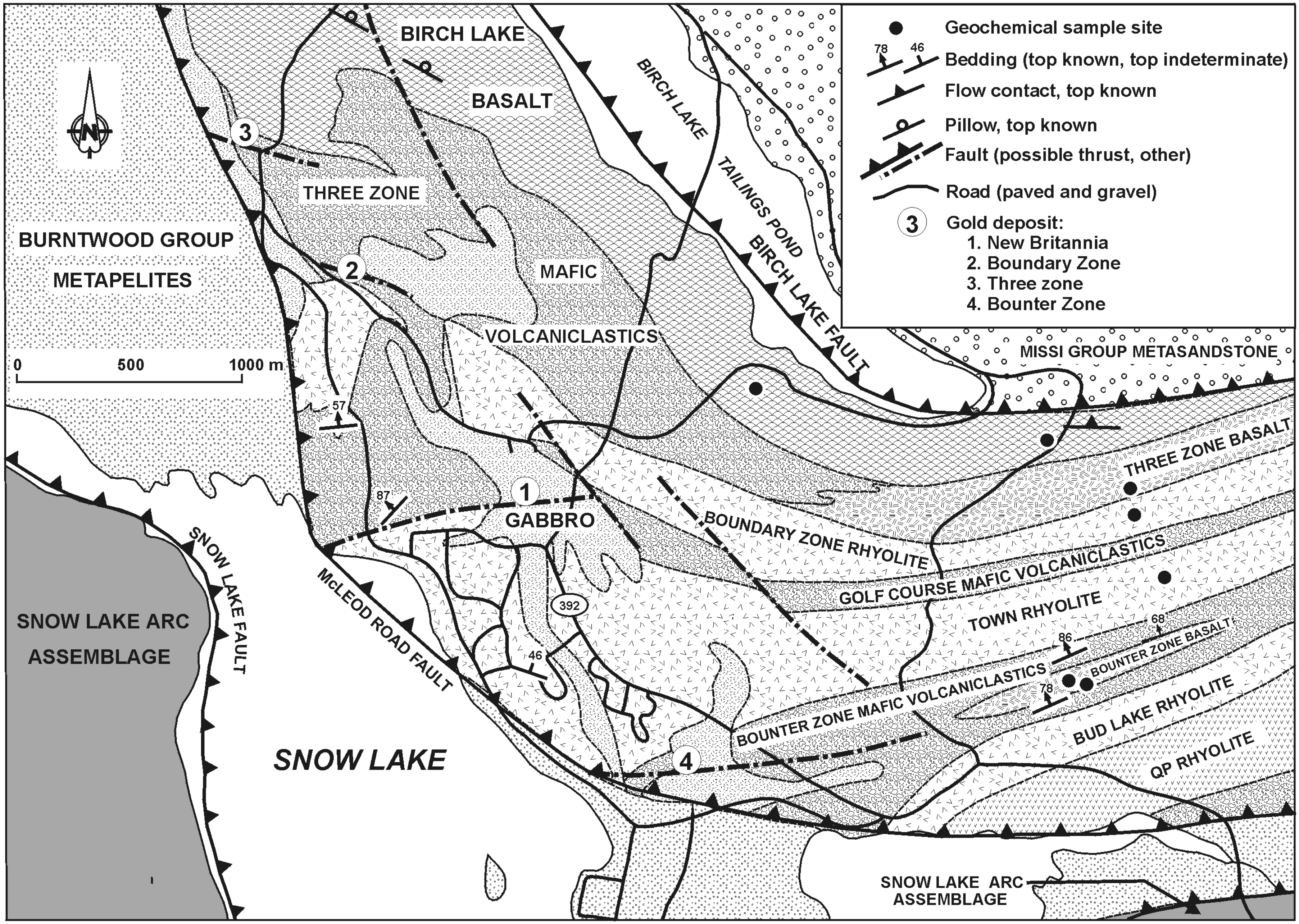

Figure GS-1-4: Volcanic rocks north of the town of Snow Lake comprise a bimodal basalt and rhyolite sequence composed of subaqueously deposited flows and volcaniclastic rocks. They are part of an allochthon that is bounded to the south by the McLeod Road fault and to the north by the Birch Lake fault. The volcanic units are truncated and deformed along the sole thrust (McLeod Road fault) in a manner that suggests westerly translation of the volcanic domain upon the underlying rocks.

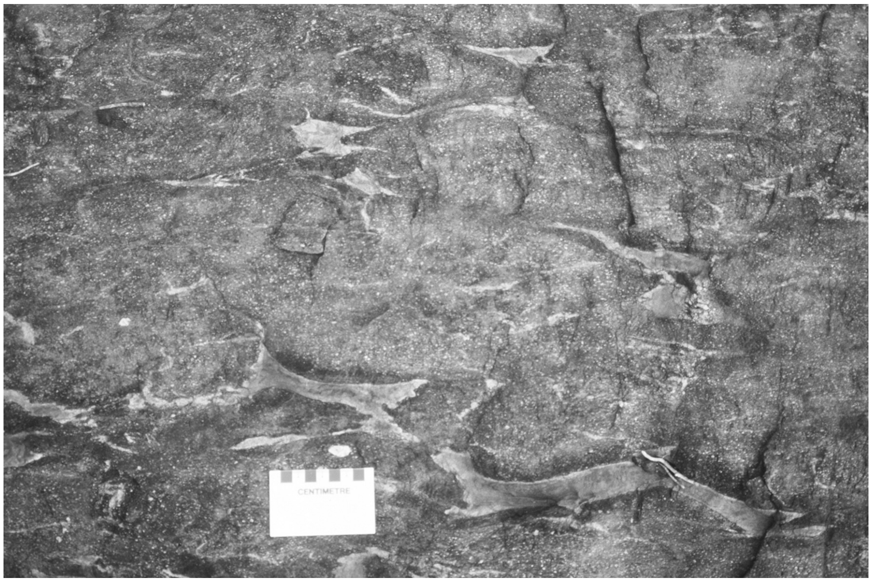

Figure GS-1-5: Plagioclase and pyroxene (pseudomorphed by amphibole) phyric pillowed Bounter zone basalt.

Birch Lake basalt forms a 360 m thick unit that tops the McLeod Road-Birch Lake section. It consists of massive to pillowed aphyric flows that are distinct from the stratigraphically underlying flows in that they contain no amygdales and are not epidotized. Massive flows may display gabbroic textures. Pillowed flows are characterized by thin selvages and negligible interpillow hyaloclastite. Quartz-rimmed gas cavities up to 12 cm in diameter are present in some flows (Fig. GS-1-7).

Mafic volcaniclastic rocks

Four units of mafic volcaniclastic rocks, varying from 100 to 400 m thick, are intercalated with basalt and rhyolite flows in the McLeod Road-Birch Lake section (Fig. GS-1-4). They consist mainly of matrix-supported, mafic, heterolithologic breccia (Fig. GS-1-8) with subsidiary mafic wacke beds that display normal size grading (Fig. GS-1-9) and rip-up clasts. They are interpreted as subaqueous debris flow and sediment gravity deposits because of their turbidite bed forms and their intercalation with pillowed mafic flows. Fragments in the mafic breccia beds display a heterolithologic clast population that varies widely in the abundance and size of contained amygdales and phenocrysts; some beds include minor amounts of felsic and intermediate clasts in addition to the dominant mafic porphyritic types.

Felsic volcanic rocks

Felsic volcanic units, varying from 100 to 500 m thick, form distinct units in the McLeod Road-Birch Lake section (Galley et al., 1988; Fig. GS-1-4). These felsic units include subaqueous rhyolite flows characterized by massive lobes and intervening microbreccia (Fig. GS-1-10), as well as heterolithologic and monolithologic breccias. The flows vary from sparsely quartz-phyric to porphyritic (up to 15% combined quartz and plagioclase, 0.5 - 5 mm). Individual felsic units, depicted in Figure GS-1-4, typically consist of more than one flow, as well as intervening units of felsic breccia. Gas cavities to 7 mm and polygonal cooling joints occur in massive rhyolite lobes.

The QP rhyolite (Fig. GS-1-4) is characterized by 5% quartz phenocrysts (2-4mm) and 5% plagioclase (1-3mm) phenocrysts. It is interpreted to be a flow as it contains quartz amygdales and quartz-rimmed gas cavities, and is locally flow banded.

GEOCHEMISTRY

Volcanic rocks in the McLeod Road-Birch Lake allochthon share a number of physical features in common with those that occur south of Snow Lake in the Snow Lake arc assemblage: 1) strongly pyroxene phyric mafic volcaniclastic rocks (Bounter zone, Golf course, Three zone) that closely resemble the mature arc Threehouse formation of the Snow Lake arc assemblage (Bailes and Galley, 1996); 2) Birch Lake basalt flows have similar flow morphologies, thin pillow selvages, lack of vesicles and absence of epidotization as do arc rift Snow Creek basalts of the Snow Lake arc assemblage (Bailes and Galley, 1996).

In this section we discuss the chemistry of the volcanic rocks of the McLeod Road-Birch Lake allochthon and compare them to their potential counterparts in the Snow Lake arc assemblage.

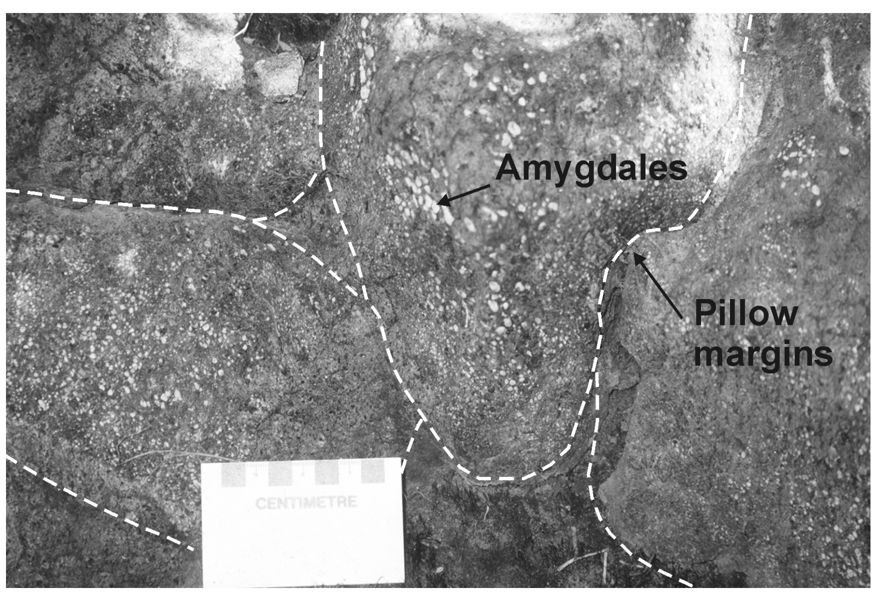

Figure GS-1-6: Strongly amygdaloidal, pyroxene (amphibole) phyric, pillowed, basalt from top of Three Zone basalt unit. The flow is conformably overlain, without structural break, by a pillowed Birch Lake basalt flow.

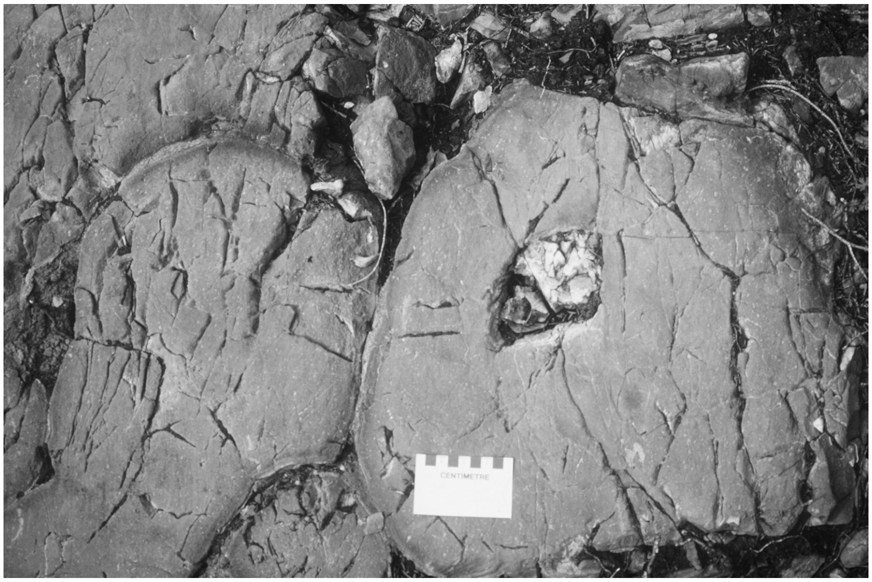

Figure GS-1-7: Aphyric pillowed basalt with large quartz-filled gas cavity, Birch Lake basalt. Note thin pillow selvages, absence of amygdales and paucity of interpillow hyaloclastite.

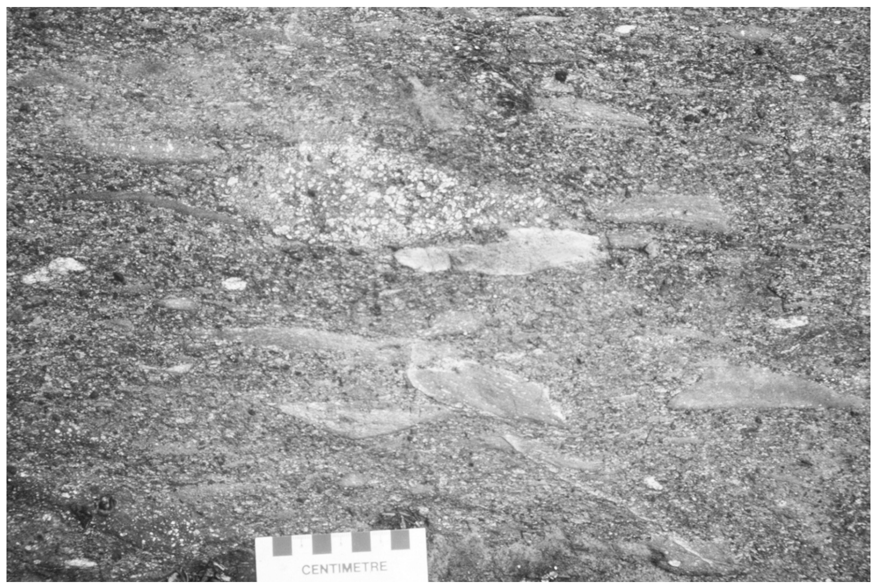

Figure GS-1-8: Heterolithologic, matrix-supported, mafic breccia, Golf Course mafic volcaniclastics. Fragments vary from aphyric to strongly porphyritic. Matrix contains abundant 2-7 mm pyroxene phenocrysts (dark) pseudomorphed by amphibole.

Figure GS-1-9: Normally size-graded mafic wacke, Bounter zone mafic volcaniclastics. Size grading is defined by phenoclasts of plagioclase (white) and pyroxene (dark).

Figure GS-1-10: Massive lobes of rhyolite (white) in recrystallized rhyolite microbreccia (grey), Town rhyolite.

Basalt

Two samples of Bounter zone basalt, one of Three zone basalt and two of Birch Lake basalt were analyzed (see Fig. GS-1-4 for sample locations). The Bounter zone and Three zone basalts plot in the oceanic island arc field in a plot of Cr vs. Ti (Fig. GS-1-11a) and display high contents of Th relative to Nb (Fig. GS-1-11g), a feature characteristic of subduction-related magmas formed within oceanic arc tectonic settings (Gill, 1981; Tarney et al., 1981). They display the same low rare earth element (REE), Th, Ti, Zr and Y contents relative to mid-ocean ridge basalts (MORB) as do the primitive and mature arc basalts of the Snow Lake arc assemblage (Figs. GS-1-11c, e, g). Stern et al. (1995a) has suggested that this may reflect derivation of this type of magma from a depleted, refractory mantle source.

The two samples of Birch Lake basalt display geochemical characteristics of ocean floor basalts (Fig. GS-1-11a) and show no depletion of Nb relative to Th (Fig. GS-1-11c). Overall, their rare earth element (REE) contents are comparable to values shown by MORB, with the exception that one sample displays low Zr and Hf.

Rhyolite

The two rhyolite samples, one from the Town rhyolite and the other from the Boundary zone rhyolite, display similar REE profiles characterized by flat HREE values, a negative Eu anomaly, and high LREE values (Fig. GS-1-12) consistent with the rhyolites having a common genesis.

Comparison to the Snow Lake Arc Assemblage

Geocehmistry of oceanic arc basalts and rhyolites in the McLeod Road-Birch Lake allochthon are comparable to those of the mature arc portion of the Snow Lake arc assemblage. The Bounter zone and Three zone basalts display negative Nb, Zr and Hf anomalies and low overall HREE contents on MORB-normalized plots (Fig. GS-1-11e, g), similar to Threehouse Lake basalt (Fig. GS-1-11f) in the Snow Lake arc assemblage. The Town and Boundary zone rhyolites are geochemically indistinguishable from the Photo Lake and Ghost Lake rhyolites of the Snow Lake arc assemblage on chondrite-normalized REE diagrams (Figure GS-1-12a, b).

The Birch Lake basalt displays a MORB-like geochemical signature that is similar to that of the Snow Creek basalt of the Snow Lake arc assemblage (Fig. GS-1-11b, d). Bailes and Galley (1996, in review) interpret the Snow Creek basalt to be a product of arc extention. Because there is no indication of a fault separating the Birch Lake basalt from the underlying arc volcanic rocks, it too may be a product of arc rifting.

The physical and geochemical similarity between the McLeod Road-Birch Lake allochthon and upper part of the Snow Lake arc assemblage strongly suggests that these two sequences are correlative. This implies that the McLeod Road-Birch Lake allochthon is a structural repetition of the upper part of the Snow Lake arc assemblage.

STRUCTURAL IMPLICATIONS

Prior to this study very little was known about the structural setting of volcanic rocks between Snow and Birch lakes, including facing direction and their relationship to volcanic rocks in adjacent allochthons. Harrison (1949) and Galley (1988) indicated that the sequence was isoclinally folded and D. Ziehlke (pers. comm., 1993) suggested that this style of folding extended east for several kilometers.

Our work suggests that the volcanic rocks in the McLeod Road-Birch Lake allochthon are not isoclinally folded but, rather, are monoclinal and face north (Fig. GS-1-4). In addition, our work suggests that the volcanic rocks between Snow and Birch lakes are stratigraphically and geochemically similar to the upper part of the Snow Lake arc assemblage (see above) and may simply be a thrust repetition of a part of the Snow Lake arc assemblage. This has been modified by subsequent F_3 (Threehouse) open folding, such that the entire volcanic section is broadly warped along with the adjacent Burntwood Group metapelites, Missi Group meta-arkoses, and bounding McLeod Road and Birch Lake faults.

Folds other than F_3 are rarely observed in the McLeod Road-Birch Lake allochthon, northwest of the town of Snow Lake. These folds have a north-northeast, shallow-plunging fold axis, and an east-north-east moderately steep dipping axial plane. These folds were interpreted by Galley et al. (1998) to have been produced during F_1 folding coincident with development of the McLeod Road fault. However, subsequent work by Krause and Williams (1998) and Schledewitz (1998) indicate a more complex and as yet incompletely resolved history for these folds.

ECONOMIC IMPLICATIONS

VMS Deposits

Both the McLeod Road and Birch Lake faults truncate volcanic units at a slight to moderate angle. This is clearly apparent on the McLeod Road fault in Figure GS-1-4. The fact that the McLeod Road fault cuts across volcanic stratigraphy in the McLeod Road-Birch Lake allochthon means that older volcanic strata are likely to be preserved in the allochthon to the east. Because volcanic rocks exposed directly north of Snow Lake are comparable to the post-VMS Threehouse and Snow Creek units of the Snow Lake arc assemblage (see section of geochemistry), we suggest that volcanic rocks with higher prospectivity for VMS deposits may be encountered down section to the east. The presence of the Osborne Lake Cu-rich VMS deposit in this allochthon to the east of the map area is consistent with this premise. Primitive arc rhyolites that have considerable potential to host VMS deposits (Bailes and Galley, 1996, in press) can be identified by their characteristic, flat chondrite-normalized REE patterns near 10x chondrite (see Fig. GS-1-12d).

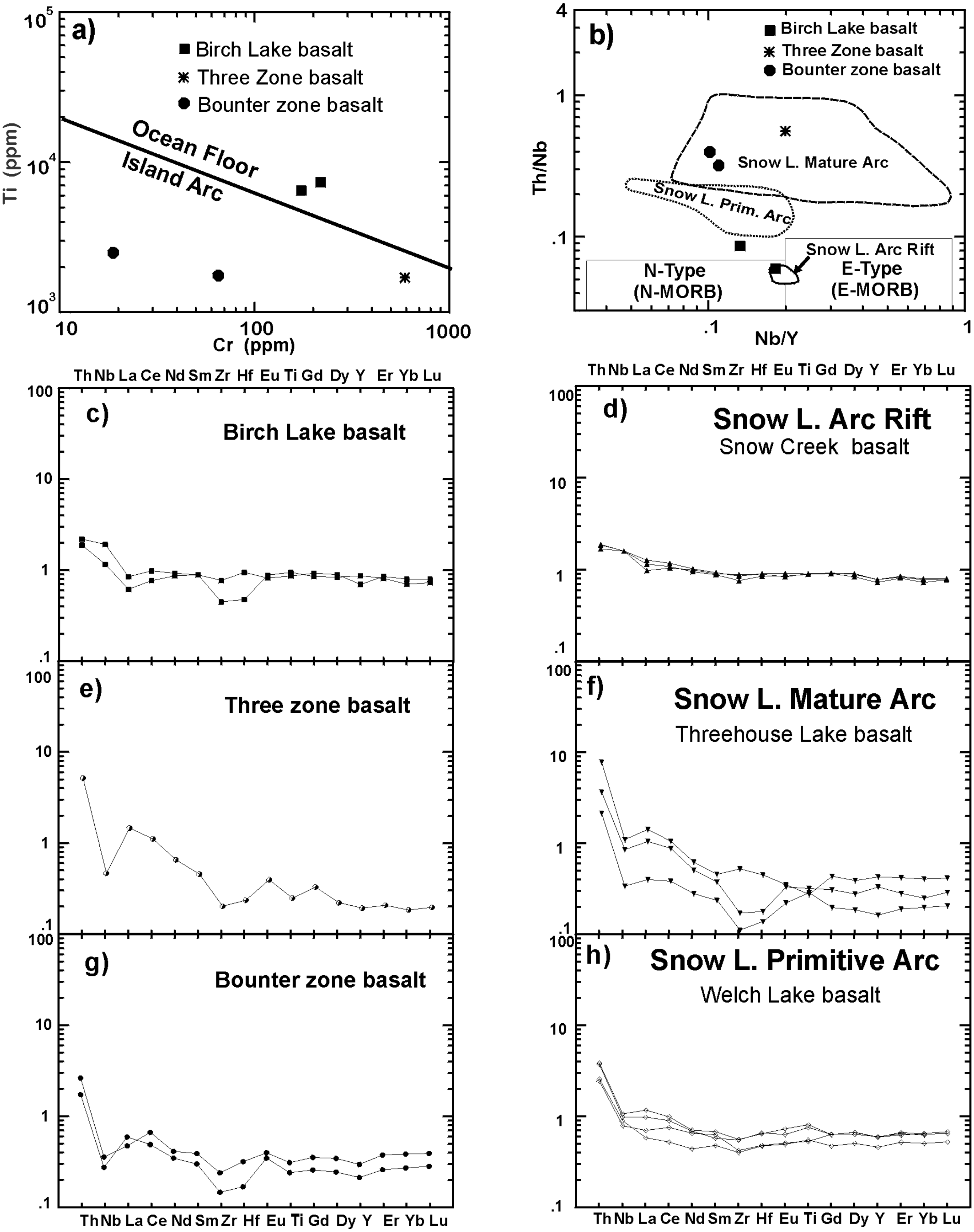

Figure GS-1-11: McLeod Road-Birch Lake basalt flows plotted on various basalt discrimination diagrams and compared with Snow Lake arc assemblage samples: a) Ti vs. Cr (after Pearce, 1975); b) Th/Nb vs. Nb/Y (after Pearce, 1983); c-h) MORB-normalized incompatible element diagrams, with elements arranged in order of increasing incompatibility in MORB-source mantle from left to right (after Sun and McDonough, 1989; modified by Stern et al., 1995b).

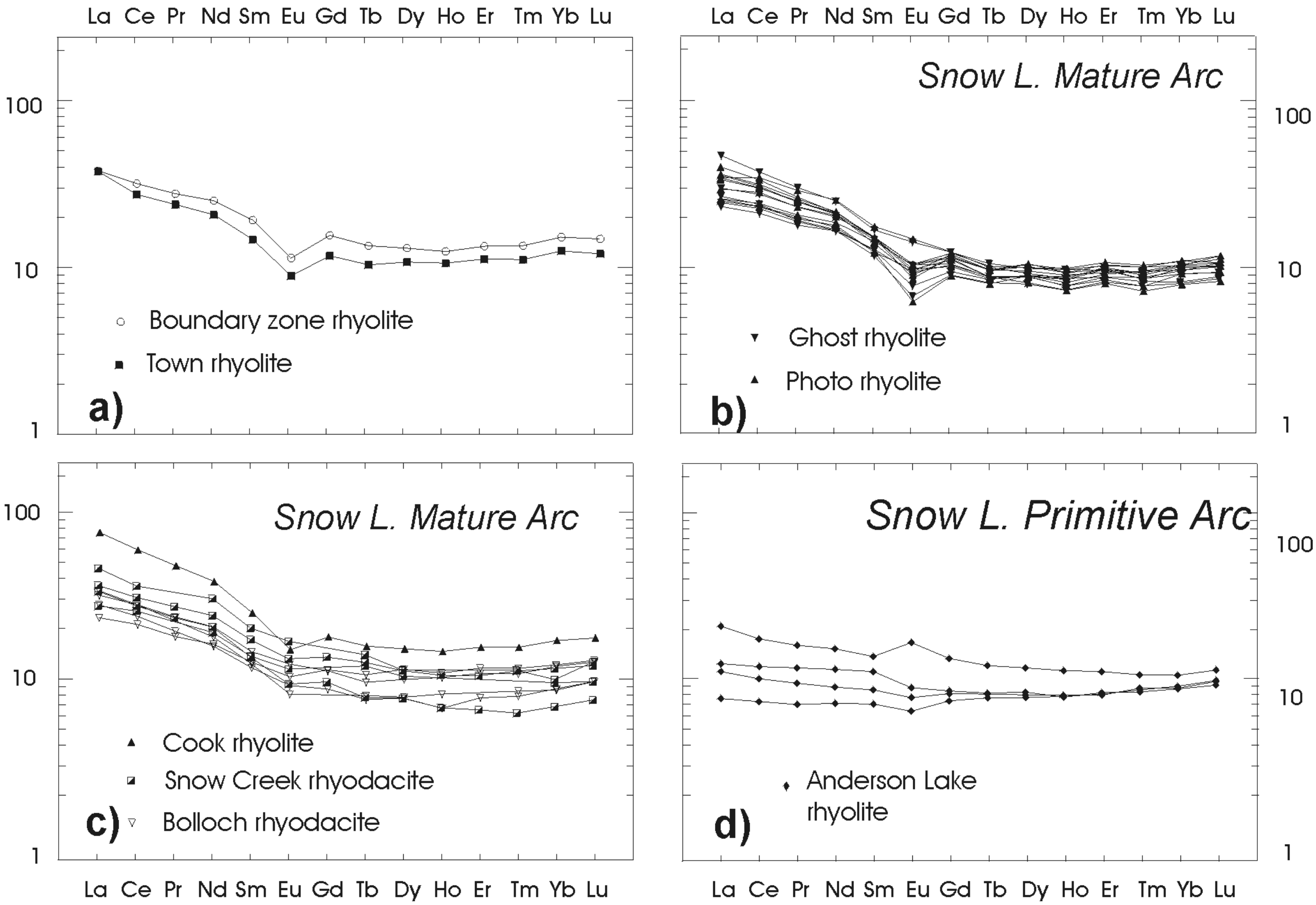

Figure GS-1-12: Chondrite-normalized REE patterns for Boundary zone and Town rhyolite compared to various mature and primitive arc rhyolites from the Snow Lake arc assemblage.

Gold Deposits

Regardless of origin, the common feature for all the significant gold deposits north of Snow Lake is proximity to the McLeod Road Fault (Galley et al., 1988; Schledewitz, 1997, 1998; Gale, 1997). Thus following the McLeod Road Fault is potentially an important first order criteria for identifying areas with gold potential.

Our examination of volcanic rocks in the structural hanging wall to the McLeod Road Fault indicates that they display considerable structural discordance to the fault trace. In comparison, the underlying Burntwood Group metapelites are in structural concordance. This is supported by the presence of a very distinctive unit of coarsely garnet-porphyroblastic metasediment (the Corley Lake member of Bailes (1980)) in the immediate structural footwall of the McLeod Road Fault, on surface and at the 915 m (3000 ft.) level in the New Britannia mine. In addition, Ian Fieldhouse (pers. com., 1998) reports that minesite exploration drill holes also intersect this coarsely garnet-porphyroblastic metasedimentary unit where they penetrate the structural footwall of the fault. Therefore we suggest that the McLeod Road fault (and areas of high gold potential?) can be extrapolated regionally on the basis of the distribution of this unit where it outcrops at or near the upper contact ot the Burntwood Group metapelites. Thus, presence of the Corley Lake member at the upper contact of the Burntwood Group metapelites southwest of Cleaver Lake (Schledewitz, 1998) and north of the Squall Lake dome (Bailes, 1975) suggest that the McLeod Road Fault probably follows the southeast shore of Squall Lake and curves over the Squall Lake dome, rather than projecting through Cleaver Lake to Angus Bay on Herblet Lake, as previously suggested by Russell (1957) and Froese and Moore (1980).

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