GEOLOGY OF PALEOPROTEROZOIC VOLCANIC ROCKS IN THE SQUALL-VARNSON LAKES AREA, SNOW LAKE, FLIN FLON BELT (NTS 63K/16)

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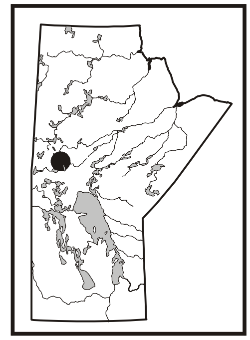

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SUMMARY

New 1:20 000 geological mapping was conducted in the Squall-Varnson lakes area in 1999. It shows the area to consist of felsic orthogneisses and amphibolites that are the more highly recrystallized and deformed equivalents of VMS-hosting rhyolite flows, basalt flows and mafic breccias exposed south of the map area. Felsic orthogneisses form over 70% of the Squall-Varnson lakes area but display only minor alteration of the type that could be attributed to synvolcanic hydrothermal activity. Intercalated mafic flows and mafic breccias indicate that stratigraphy strikes north-northwest. Deformation of the metavolcanic rocks is characterized by a layer-parallel foliation and a prominent north-northeast trending, shallow plunging, elongation lineation.

The Snow Lake fault, a probable early kinematic thrust fault that forms the contact between 1.89 Ga volcanic rocks and 1.84 Ga sedimentary rocks in the map area, cuts at a high angle across volcanic stratigraphy in its structural footwall at the west end of Snow Lake. This feature could represent a thrust ramp on the fault. The potential exists for such a structure to have acted as a structural inhomogeniety during subsequent deformation, thereby localizing dilatent zones and, possibly, gold mineralization.

INTRODUCTION

The Snow Lake area, at the east end of the Paleoproterozoic Flin Flon Belt, is host to 10 producing and past-producing volcanic-hosted massive sulphide (VMS) mines (Fig. GS-1-1) with production plus reserves of 25.4 million tonnes (Bailes and Galley, 1996). 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., 1995; Bailes and Galley, 1996).

Oceanic arc volcanic rocks in the map area (Fig. GS-1-2) were mapped at 1:20 000 scale in 1998 and 1999 (Schledewitz and Bailes, 1998; Bailes and Schledewitz, 1999). The objective was to upgrade geological mapping of these volcanic rocks to a level compatible with that already existing for the VMS-hosting volcanic rocks to the south. This contribution discusses the results of this geological mapping program and assesses its implications for mineral exploration east of Squall Lake and

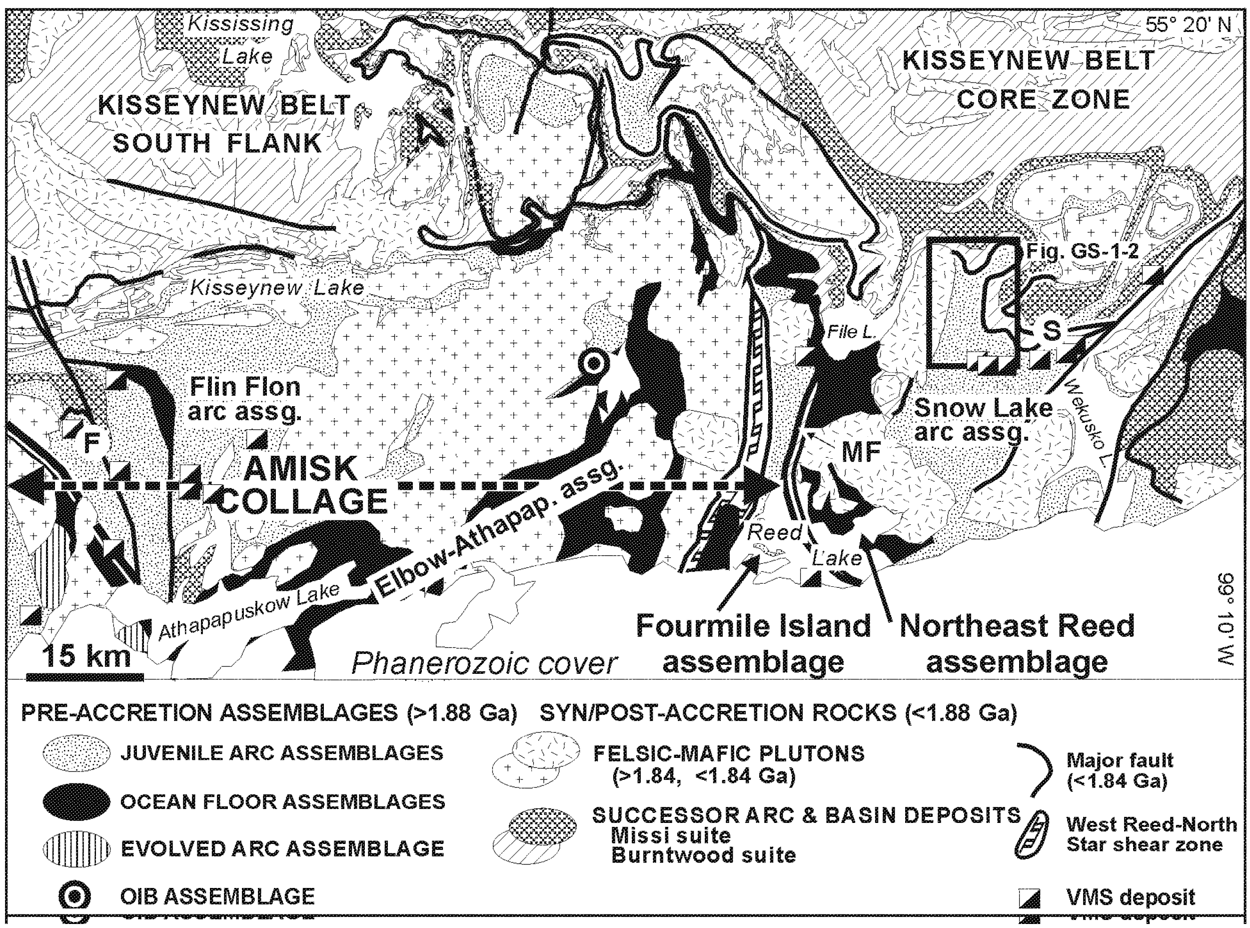

Figure GS-1-1: Simplified geological map of the central and eastern portion of the Flin Flon Belt showing major tectonostratigraphic assemblages and plutons, and locations of mined VMS deposits. F: Flin Flon, S: Snow Lake, MF: Morton Lake faults zone. Rectangle shows location of the map area.

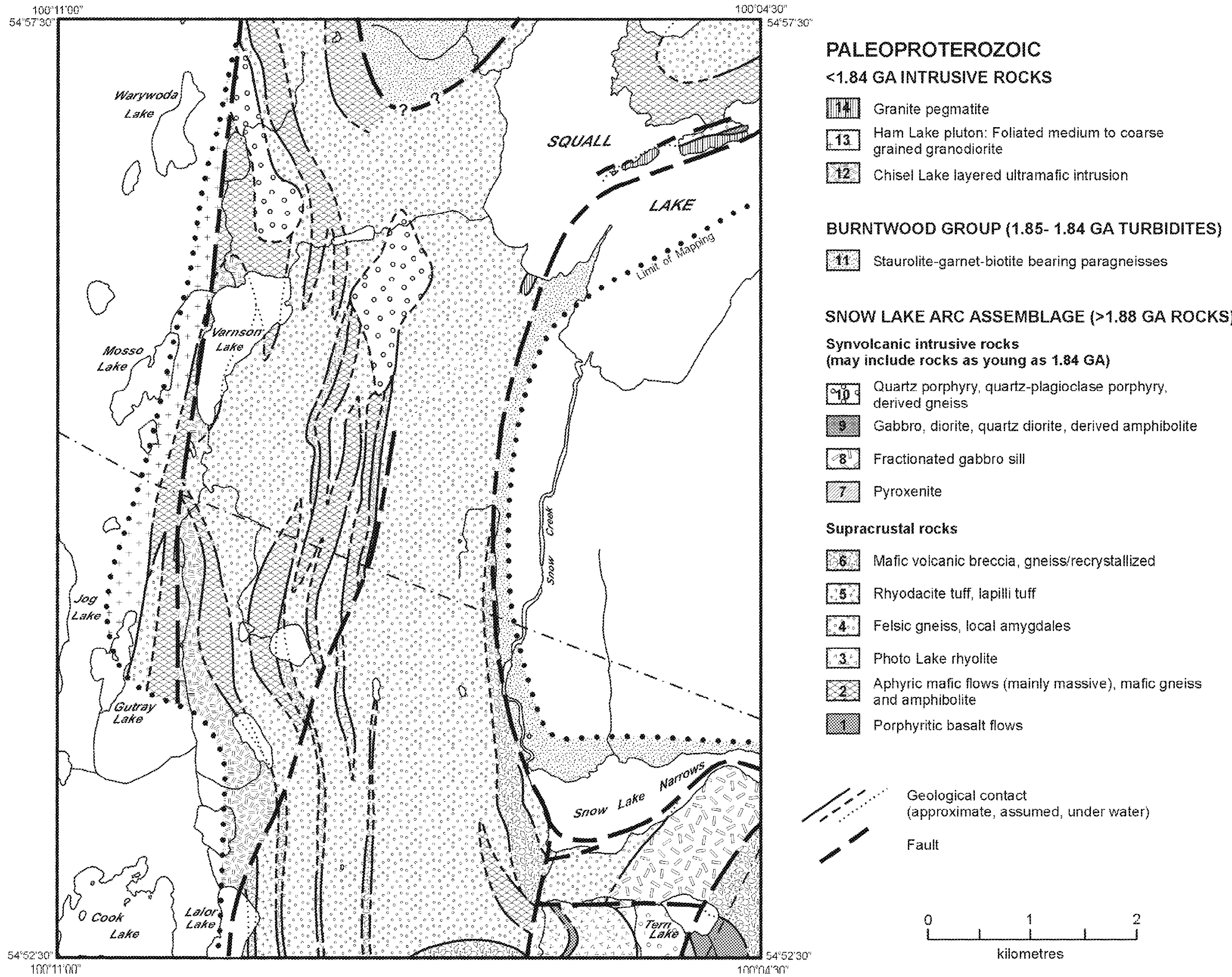

Figure GS-1-2: Simplified geology of the Squall-Varnson lakes map area.

Snow Creek.

REGIONAL AND LOCAL SETTING

VMS deposits at Snow Lake are mainly contained in the Snow Lake arc assemblage, which displays a temporal evolution from a primitive to mature to arc rift setting (Bailes and Galley, 1996, in press). VMS deposits at Snow Lake occur prominently in both the primitive and mature arc volcanic successions. Volcanic rocks between Squall Creek and Varnson Lake correlate to the south with the mature arc portion of the Snow Lake arc assemblage and, therefore, they have potential to host base metal VMS deposits.

Most of VMS-hosting portion of the Snow Lake arc assemblage has been mapped in detail at scales that range from 1:20 000 to 1:5000 (Bailes and Galley, 1992, 1993; Bailes et al., 1996, 1997). However, prior to this project, equivalent rocks in the Squall-Varnson lakes area had only been mapped at a reconnaissance 1 inch to 1 mile (1:63 360) (Harrison, 1949). This older work showed the volcanic rocks in the area to be largely grey gneissic and banded rocks interpreted to have formed by "granitization" of mafic volcanic rocks by "quartz-eye" granite. Elsewhere in the Snow Lake area, Harrison (1949) typically used this unit designation to depict slightly altered felsic metavolcanic rocks as well as strongly silicified and altered mafic flows. To the south, these "grey gneissic rocks" contain numerous VMS deposits.

VOLCANIC ROCKS IN THE SQUALL-VARNSON LAKES AREA

The 1.89 Ga Snow Lake arc assemblage in the Squall-Varnson lakes area consist mainly of massive felsic volcanic rocks and lesser amounts of heterolithologic mafic breccia, mafic flows and synvolcanic intrusions (Schledewitz and Bailes, 1998; Bailes and Schledewitz, 1999). The relationship of these units is poorly understood due to a combination of poor quality outcrops (moss and lichen covered), massive monotonous lithologies, absence of facing directions, and obliteration of most primary features during 1.81 Ga regional metamorphism and deformation. Primary rock lithologies are recognized only in the south half of the map area due to a northerly increase in metamorphic recrystallization. Rocks of the Squall-Varnson lakes area are briefly described below by unit number as shown on Preliminary Map 1999F-1 (Bailes and Schledewitz, 1999).

Porphyritic basalt (unit 1)

Porphyritic basalt flows outcrop east and southwest of Tern Lake. At both localities the flows are pillowed, pyroxene and pyroxene-plagioclase phyric, and correlate with mature arc basalts to the south. The basalts east of Tern Lake correlate with the Threehouse formation whereas those west of Tern Lake correlate with a pre-Threehouse unit (Bailes et al., 1997) within the Photo Lake rhyolite. The latter basalt is only exposed in a single small exposure but is important as it: 1) provides the only reliable facing direction (southeast) available for the VMS-hosting Photo Lake rhyolite; and 2) indicates that the rhyolite was deposited in a subaqueous environment.

Aphyric basalt (unit 2)

Massive aphyric basalt and basaltic andesite flows, which include rare pillowed and amoeboid pillow breccia portions, form approximately 10 percent of the map area. These flows may contain 1-10% 2-30 mm quartz amygdales and are identical to, and probably are the more strongly recrystallized equivalent of, the Bolloch Lake basalt which outcrops just south of the map area (Bailes et al., 1997). The Bolloch Lake basalt displays the elevated light rare earth element (LREE) geochemistry typical of mature arc basalts (Bailes, 1997). The units of aphyric basalt in the map area, which are smaller than the Bolloch Lake basalt, occur throughout this felsic-dominated sequence. They likely represent individual flows that punctuated the dominantly felsic volcanism but could also reflect, in some instances, structural repetition by folds or layer-parallel faults.

Photo Lake rhyolite (unit 3)

The Photo Lake rhyolite hosts the Cu-Zn-Au rich Photo Lake VMS deposit. In the Squall-Varnson lakes map area, this unit outcrops south of Tern Lake (Fig. GS-1-2) and consists of a monotonous sequence of massive aphyric to sparsely porphyritic felsic rocks and derived felsic gneisses. The felsic gneisses contain local quartz amygdales, scarce quartz-filled gas cavities and rare massive lobes consistent with their protolith being mainly felsic flows. No internal subdivisions of the Photo Lake rhyolite were mapped and no facing directions were observed.

Photo Lake rhyolite is locally altered as evidenced by the presence of porphyroblasts of garnet, acicular amphibole, biotite and chlorite. A prominent alteration zone was observed just west of the narrow unit of pillowed basalt (unit 1a). This zone, observed in three small outcrops, consists entirely of garnet, chlorite and biotite and closely resembles the 'pipe-like' alteration that is normally found only in the immediate footwall of massive sulphide deposits elsewhere in the Snow Lake area. Unfortunately, this VMS-prospective zone of alteration is truncated to the north and west by late brittle faults.

Felsic gneiss (unit 4)

Massive, featureless, quartzo-feldspathic biotite-bearing gneisses of unit 4 dominate the map area. They are interpreted to have been derived largely from felsic metavolcanic rocks because: 1) they are intercalated with basalt flows; 2) they locally contain large quartz amygdale (to 7 cm in size); 3) they commonly contain phenocrysts of quartz; and 4) they correlate to the south with the rhyolite flows at Bolloch Lake. The felsic gneisses locally include hypabyssal felsic intrusions (unit 10) that are virtually impossible to distinguish from the extrusive rocks due to metamorphic recrystallization. Recognizing these hypabyssal intrusions is particularly difficult in the northern half of the map area where the felsic gneisses are most strongly recrystallized and contain domains of metamorphically recrystallized granitoid-textured rocks. Some of the abrupt "cut offs" of units of basalt (unit 2) and heterolithologic mafic breccia (unit 6) by unit 4 felsic gneisses may reflect intrusive rather than stratigraphic contacts.

The distribution of intercalated basalt flows and mafic volcaniclastic rocks indicates an overall northerly strike for the primary stratigraphy; this is less rigorously recorded in the widely distributed outcrops in the northern one third of the map area. No facing directions were observed in the felsic gneisses (unit 4) nor in the intercalated mafic rocks (units 2, 6). However, to the south, rare facing directions in correlative strata are consistently to the west and southwest.

The relationship of the felsic gneisses of unit 4 to the Photo Lake rhyolite (unit 3), host to the Photo Lake Cu-Zn-Au VMS deposits, is not known as these units are separated by faults with indeterminate offsets. Felsic gneisses of unit 4 are along strike from, and probably correlate to the south, with the Bolloch Lake rhyolite. The Bolloch Lake rhyolite, although broadly similar in chemistry to the Photo Lake rhyolite, is geochemically different enough to be a separate, discrete unit but still belongs to the mature arc sequence (Bailes, 1997).

Rhyodacite tuff, lapilli tuff (unit 5)

A 200 m wide unit of plagioclase phyric rhyodacite tuff and lapilli tuff outcrops in the southwest corner of the map area. It is typically massive, pale buff-weathering and is characterized by 5-15% 0.5-3 mm plagioclase phenocrysts and small plagioclase phyric felsic fragments. Felsic fragments in this breccia are texturally identical to the fine-grained massive dacite tuff. Although no facing directions were identified in this unit, to the south it is bounded to the east and west by mafic volcaniclastic units that display normally size-graded beds, which top to the west.

The rhyodacite is commonly strongly altered with altered varieties characterized by 5-30% garnet and 10-60% amphibole porphyroblasts; the most altered outcrops locally contain up to 5% disseminated pyrite.

Mafic volcaniclastic rocks (unit 6)

Mafic volcaniclastic rocks comprise 30 - 120 m thick units that are locally intercalated with mafic (unit 2) and felsic gneisses (unit 4) west of Snow Creek. Similar mafic volcaniclastic units are also intercalated with the felsic-dominated volcanic sequence at Bolloch Lake. This suggests that the sequence in the map area is simply an along-strike equivalent of the Bolloch Lake section.

The mafic volcaniclastic units are rarely as well preserved as those in the Bolloch Lake area due to deformation and metamorphism. Tectonically flattened clasts are coarsely recrystallized and have obscured fragment-matrix relationships. In the southwest part of the map area, where best preserved, they include well-bedded mafic wacke and intercalated heterolithologic mafic breccia. The latter include minor felsic clasts in addition to the dominant mafic clast population.

A unit of mafic volcanic breccia just east of Snow Creek is atypical as it includes both felsic fragmental rocks and domains of silicified, altered breccia in addition to the dominant heterolithologic mafic breccia. Altered breccia has a bleached appearance, resembles an intermediate to felsic rock, and contains 10-40% acicular 2 - 7 mm amphibole porphyroblasts. Fragments in the altered breccia are commonly nebulous and in most strongly altered varieties are no longer distinguishable from the matrix. A formational sulphide unit has been encountered in drill holes on the east side of this unit (G. Kitzler, HBED, pers comm., 1998).

Mafic breccia units east of Tern Lake are along strike equivalents of Threehouse formation breccias. They include monolithologic and heterolithologic mafic breccia that locally include scoria clasts. To the south these rocks are intercalated with pillowed mafic flows that display the same texture (phenocryst populations) and compositions as do fragments in the mafic breccia.

Synvolcanic intrusive rocks (units 7-10)

The volcanic stratigraphy in the map area is cut by a number of small intrusions including pyroxenite, melagabbro, gabbro (unit 7), a fractionated gabbro sill (unit 8), gabbro, diorite, quartz diorite and derived amphibolite (unit 9), and quartz- and quartz-feldspar porphyry (unit 10). Many of these intrusions are interpreted to be synvolcanic but some could be younger.

Pyroxenite, melagabbro and gabbro (unit 7) outcrop southeast of Tern Lake (Fig. GS-1-2) and correlate to the south with a suite of mafic intrusions that have been interpreted by Bailes et al. (1997) to be feeders for Threehouse formation basalts. South of the map area these intrusions locally contain amygdales and, when intruded into basal Threehouse mafic volcaniclastic rocks, locally form peperites.

A fractionated gabbro sill south of Snow Lake and north of Tern Lake is composed of equigranular fine- to medium-grained gabbro (unit 8a), coarse-grained gabbro with bladed amphiboles and interstitial plagioclase (unit 8b) and coarse-grained quartz diorite also with bladed amphiboles (unit 8c). Compositional zonation in the sill indicates it tops to the west-northwest and, if this sill is synvolcanic, the hosting volcanic rocks also would top west-northwest. This sill is over 800 m thick and is truncated to the south by the Tern Lake fault, to the north by the Snow Lake fault and to the east by the Edwards Lake fault (Fig. GS-1-2). Adjacent to the Snow Lake and Tern Lake faults the sill is commonly bleached and overprinted by garnet and amphibole porphyroblasts. If the alteration of the sill is related to the faults then these faults predate 1.81 Ga regional metamorphism.

Gabbro, diorite, quartz diorite and derived amphibolite (unit 9) form small bodies throughout the map area. Although the age of these intrusions is unknown, similar intrusions south of the map area have been interpreted to be synvolcanic (Bailes et al., 1997). Fine-grained gabbro bodies that have been recrystallized in the north half of the map area (unit 9e) are virtually indistinguishable from recrystallized massive basalts (unit 2c).

Small bodies of quartz- and quartz-feldspar porphyry occur locally in the map area. In the Bolloch Lake area to the south Bailes et al. (1997) has demonstrated some of these intrusions to be synvolcanic: 1) they are cut by gabbro intrusions that can be linked to overlying extrusive volcanic rocks; and 2) clasts of these intrusions occur in stratigraphically overlying heterolithologic felsic volcanic breccias. In the Bolloch Lake area, some of these intrusions also include fine grained felsic intrusive rocks that are indistinguishable from extrusive aphyric to sparsely porphyritic felsic volcanic rocks.

Burntwood greywacke turbidites (unit 11)

Greywacke, siltstone and mudstones of the Burntwood Group were deposited by turbidity currents (Bailes, 1980) at about 1.841 Ga (Machado and Zwanzig, 1995). They were subsequently structurally imbricated with the 1.89 Ga volcanic rocks in the Snow Lake area during southwest-directed thrusting (e.g., Snow Lake fault) between 1.840 and 1.839 Ga prior to intrusion of the 1.83 Ga Ham Lake pluton. During 1.81 Ga regional metamorphism these rocks were recrystallized, in the map area, to middle almandine-amphibolite facies mineral assemblages and overprinted by porphyroblasts of staurolite, garnet and biotite.

<1.84 Ga intrusive rocks (units 12-14)

Post-1.84 Ga intrusive rocks in the map area include the layered Chisel Lake ultramafic intrusion (unit 12), the Ham Lake felsic pluton (unit 13) and granite pegmatite (unit 13). The Chisel Lake intrusion (unit 12) is of uncertain age but intrudes previously folded volcanic rocks of the Snow Lake arc assemblage (Bailes and Galley, 1996). It is clearly not synvolcanic and is likely post-1.84 Ga in age as folds older than this have yet to be recognized in the Snow Lake area.

The Ham Lake pluton (unit 13) is one of a number of granite, granodiorite and quartz diorite plutons. They intrude the 1.841 Ga Burntwood Group greywacke turbidites (unit 11) but predate 1.81 Ga regional metamorphism. U-Pb zircon dating indicates that they were intruded between 1.84 and 1.83 Ga (David et al., 1996).

Granite pegmatite (unit 14) outcrops most prominently on Squall Lake. It intrudes both Snow Lake assemblage volcanic rocks and Burntwood Group metagreywacke. On an island in Squall Lake, the pegmatite intrudes into, and cross cuts, a late, brittle, post-metamorphic fault. Thus the pegmatites of unit 14 are likely much younger than, and unrelated to, the 1.83 Ga Ham Lake pluton.

STRUCTURAL GEOLOGY

The map area is part of a complicated structural domain at Snow Lake that is dominated by 1.84-1.81 Ga fold-thrust style tectonics (Connors, 1996; Lucas et al., 1996). Individual allochthons of volcanic rocks are bounded by thrust faults (e.g., Snow Lake fault) and are typically separated by intervening imbricates of younger (ca. 1.84 Ga) Burntwood Group sedimentary rocks (Connors, 1996; David et al., 1996). The thrust package has been subsequently modified by: 1) intrusion of 1.84-1.83 Ga granitic plutons (e.g., Ham Lake pluton); 2) northeast-trending and plunging open folding (e.g., Threehouse synform, F_3 of Kraus and Williams, 1998); and 3) ca. 1.81 Ga regional metamorphism to lower to middle almandine-amphibolite facies mineral assemblages (Froese and Moore, 1980; David et al., 1996).

The form and extent of the Photo Lake rhyolite is economically important, as it is host to the Photo Lake Cu-Au-Zn VMS deposit. Bailes et al. (1997) show the Photo Lake rhyolite to be bounded to the east, west and south by faults. The northern boundary of the Photo Lake rhyolite was previously thought to be the Snow Lake fault and to coincide with the south shore of Snow Lake. However, the distribution of units between the south shore of Snow Lake and Tern Lake (Fig. GS-1-2) requires that the Photo Lake rhyolite be terminated by a west-trending fault through Tern Lake. The distribution of units also requires that this west-trending fault be truncated to the west and east of Tern Lake by north-trending faults. This essentially confines the Photo Lake rhyolite to a small fault-bounded terrane, and its relationships to other rhyolites units in the area uncertain.

The Snow Lake fault (Fig. GS-1-1 and GS-1-2) defines the southern boundary of a tectonic slice of 1.84 Ga Burntwood Group greywacke, likely correlates to the west with the Loonhead Lake fault at File Lake (Connors, 1996), and is considered to be a regional-scale F_1 structure (terminology of Kraus and Williams, 1998). In the map area (Fig. GS-1-2), the Snow Lake fault displays two important features: 1) it crosscuts volcanic stratigraphy at a high angle along the south shore of Snow Lake; and 2) it appears to truncate a younger, post-metamorphic (i.e., <1.81 Ga) north-trending fault (Edwards Lake fault) in contradiction to its apparent F_1 age (>1.83 Ga). Although offset of the Snow Lake fault by a west-trending younger fault through Snow Lake could explain both of these features, there is no evidence in outcrop west of Snow Lake that such a late structure exists. For this reason, we suggest that the angular truncation of units is a result of ramping on the Snow Lake fault/thrust. This ramping is observed only at the west end of Snow Lake and reflects an up-section jump on the fault of approximately 3 km. Since this structure formed early in the deformation history of rocks at Snow Lake, it likely constituted a prominent structural heterogeneity that may have influenced subsequent deformational episodes.

Harrison (1949) showed the northern boundary of Snow Lake arc assemblage volcanic rocks with Burntwood Group, east of Snow Creek, to trend northwest of Squall Lake. Froese and Moore (1980) show the same contact to trend northeast of Squall Lake. Our mapping agrees with that of Froese and Moore (1980) and indicates that the volcanic rocks east of Snow Creek are structurally repeated in a dome and basin interference fold pattern cored by the Squall Lake pluton. The prominent foliation in the map area dips steeply in the south half of the map area but becomes progressively more shallow-dipping and locally folded (probably by F_2) in the north half. Stretch lineations in the volcanic rocks typically have an azimuth of around 25° and vary in plunge from about 25° in the south to virtually horizontal in the north. This means that deformed VMS deposits in these volcanic rocks can be anticipated to plunge shallowly to the north-northeast in the south and subhorizontal in the north half of the map area.

ECONOMIC IMPLICATIONS

VMS deposits

Snow Lake arc assemblage volcanic rocks of the map area correlate to the south with similar rocks that are host to prominent Cu-Zn-Au-Ag-bearing VMS mineral deposits, including the small, but metal-rich Photo Lake VMS deposit just south of the map area. The area also includes the large, base metal-poor, subeconomic Cook Lake deposit. Important features observed during mapping that relate to VMS exploration are as follows:

1. Felsic gneisses in the map area are within a sequence that is identical to, and correlates with, the Bolloch Lake rhyolite. No known VMS deposits occur in well-explored areas of Bolloch Lake rhyolite.
2. Areas displaying prominent VMS-style alteration are not common in the map area. A zone of strongly altered rocks is present southwest of Tern Lake, but is truncated to the north and west by faults. Rusty-weathering outcrops with bleaching and garnet-amphibole rich zones occur locally in the vicinity of the small lake 2.5 km south of Varnson Lake.
3. Deformed amygdales, phenocrysts and fragments display a prominent elongation lineation suggesting that any VMS deposits in the map area will be strongly rodded. Lineations in the area plunge shallowly to near horizontally in a direction just east of north.
4. North of the map area, the Snow Lake arc assemblage volcanic rocks are repeated in dome and basin style fold interference patterns.

Gold deposits

The Snow Lake and McLeod Road faults form the south and north boundaries, respectively, of the tectonic slice of Burntwood Group greywacke at Snow Lake. Whereas major gold deposits at Snow Lake area are located in proximity to, and in the structural hanging wall of, the McLeod Road Fault (Galley et al., 1988; Schledewitz, 1997, 1998; Gale, 1997), no significant gold deposits have been found in association with the Snow Lake Fault. However, the apparent ramping on the Snow Lake Fault, identified during this project, has implications with regard to the ability of this structure to form dilatent zones and localize gold during subsequent folding (e.g., Threehouse synform) and structural tightening. This is worth considering in light of prominent arsenic and gold grain anomalies in till at Tern Lake that Kaszycki et al. (1996) suggest may reflect "a zone of strong alteration associated with fault-hosted mineralization, similar to that observed with the Nor-Acme and other Au deposits in the town of Snow Lake".

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