GS-12 SETTING OF CU-ZN-AU MINERALIZATION AT PHOTO LAKE (PART OF 63K16)

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SUMMARY

Mapping of the Photo Lake area at 1:10 000 scale was completed during a four week field season. This concludes a cooperative mapping program by Manitoba Energy and Mines (MEM) and Hudson Bay Exploration and Development (HBED) begun in 1994 (Bailes and Simms, 1994). The project was designed to facilitate exploration and development on the Photo Lake property after the 1994 discovery of a Cu-Zn-Au rich volcanic-hosted massive sulphide (VMS) zone, now the Photo Lake mine. At stake was the future economic viability of the mining community at Snow Lake.

The 1:10 000 scale map of the Photo Lake area (Bailes *et al.*, 1996a) covers a 25 km^2 area, and shows that the Photo Lake VMS deposit occurs within a different stratigraphic setting than other VMS deposits at Snow Lake area. This is significant as it suggests a potentially new and relatively unexplored target for further investigation. Mapping at Photo Lake has identified the VMS 'mine horizon' and several areas of strongly altered rocks that are likely related to the Photo Lake 'mineralizing event'. The mine-hosting stratigraphy trends north of the map sheet indicating that this area has considerable VMS potential.

INTRODUCTION

Supracrustal rocks at Snow Lake are part of the Flin Flon greenstone belt, one of the largest Paleoproterozoic VMS districts in the world. Recent investigations have shown that the central Flin Flon greenstone belt consists largely of 1.92-1.88 Ga tectonostratigraphic assemblages that were amalgamated to form an accretionary collage ('Amisk collage') prior to emplacement of 1.87-1.83 Ga granitoid plutons (Lucas *et al.*, 1996; Fig. GS-12-1). Juvenile *ca.* 1.89 Ga arc volcanic rocks in the eastern Flin Flon belt at Snow Lake are isotopically distinct from those at Flin Flon (Stern *et al.*, 1992) and probably developed separately from those at Flin Flon, possibly upon an Archean microcontinental fragment (Stern *et al.*, 1995; Lucas *et al.*, 1996).

The eastern Flin Flon assemblages are currently interpreted by Syme *et al.* (1995) to have been tectonically juxtaposed against already accreted rocks of the 'Amisk collage' during 1.84-1.80 Ga southwest-directed collision of rocks of the Kisseynew domain with those of the

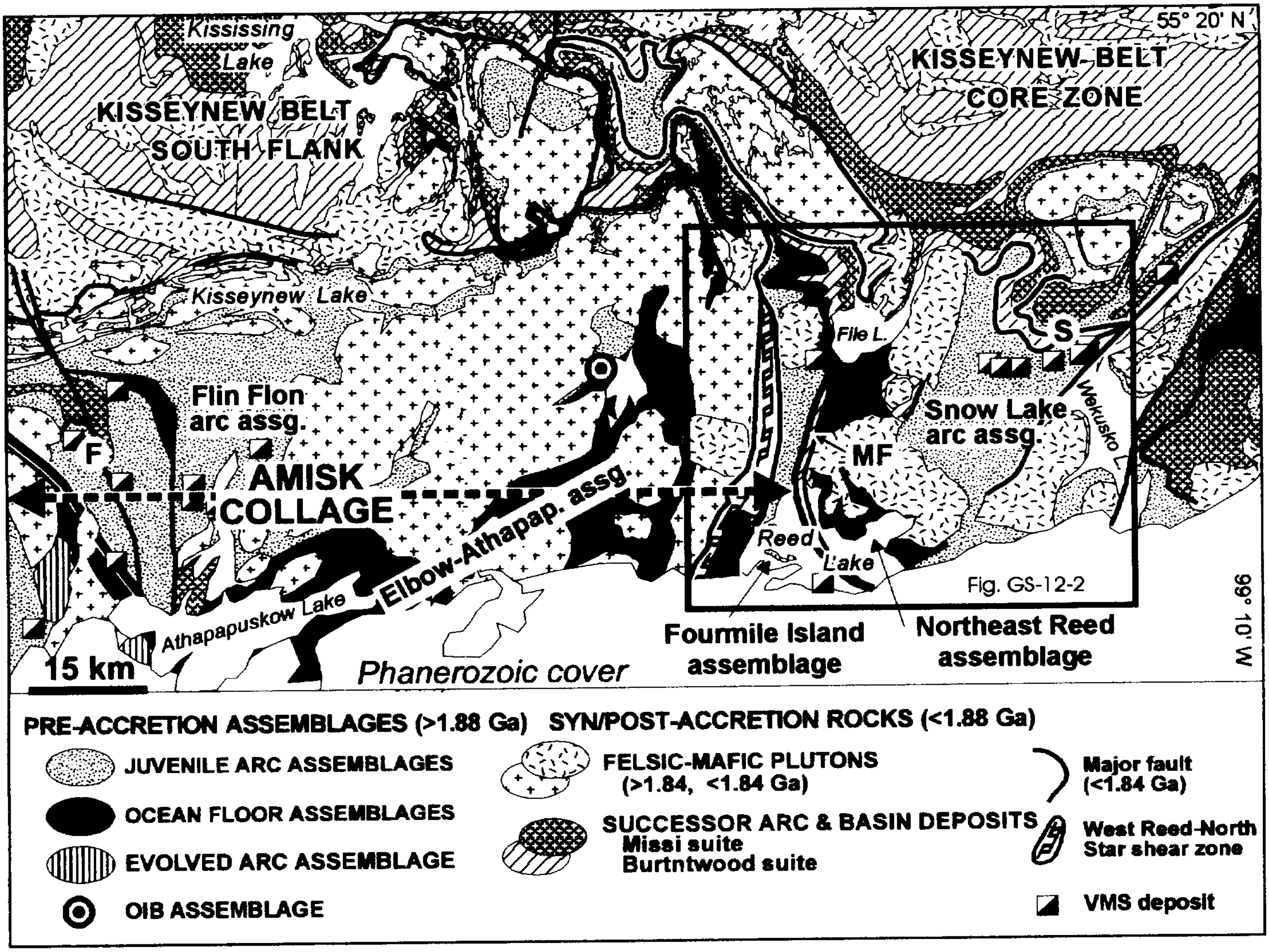


Figure GS-12-1: Simplified geological map of the central and eastern portion of the Flin Flon belt showing major tectonostratigraphic assemblages and plutons, and locations of mined VMS deposits. F: Flin Flon, S: Snow Lake, ML: Morton Lake fault zone. Rectangle shows outline of area depicted in Figure GS-12-2.

Flin Flon belt. The VMS-hosting Snow Lake arc assemblage (Fig. GS-12-2), in which the Photo Lake area occurs, is interpreted to be one of several allochthons in a thrust stack formed during the 1.84-1.80 Ga deformational event (Syme *et al.*, 1995, 1996).

The >6 km thick VMS-hosting oceanic arc sequence at Snow Lake records, in its stratigraphy and geochemistry (Bailes and Galley, 1996), a temporal evolution from a relatively more primitive to an evolved arc (Fig. GS-12-3). VMS deposits at Snow Lake can be subdivided into Cu-rich, Zn-rich and Cu-Zn-Au types. Cu-rich deposits, mainly at Anderson and Stall lakes, occur in a flow-dominated, bimodal (basalt-rhyolite) sequence dominated by primitive arc tholeiite. Zn-rich types (*e.g.* Chisel Lake) occur in a volcaniclastic-dominated, relatively more evolved sequence. The recently discovered Cu-Zn-Au rich VMS deposit at Photo Lake also occurs in the more evolved arc sequence but within a rhyolite-dominated section. The relationship between the evolved arc-hosted Photo Lake Cu-Zn-Au rich and the Chisel Lake Zn-rich mineralization is not known, although Bailes and Simms (1994) tentatively suggest that the Photo Lake deposit may be hosted by younger strata than those at Chisel Lake. Mapping in 1996 at Photo Lake was undertaken to fill a gap between 1:5000-1:10 000 scale coverage of the Chisel Lake (Bailes *et al.*, 1995b) and the Photo Lake (Bailes *et al.*, 1996a) areas.

PHOTO LAKE GEOLOGY

The Photo Lake area (Bailes *et al.*, 1996a; Fig. GS-12-4) consists largely of *ca.* 1.89 Ga metavolcanic and associated synvolcanic intrusive rocks, intruded by the synkinematic Chisel Lake layered mafic to ultramafic pluton. All rocks are overprinted by lower to middle almandine amphibolite facies mineral assemblages produced during a *ca.* 1.81 Ga regional metamorphic event that reached approximately 5 kb and 535° C at Photo Lake (Menard and Gordon, 1995). Although all rocks are metamorphic those that have recognizable primary features are referred to by their original names without metamorphic prefixes.

The volcanic and sedimentary rocks at Photo Lake include an 'older' and 'younger' sequence. The 'older' sequence consists largely of felsic flows, volcaniclastic rocks and gneisses whereas the 'younger' sequence comprises dominantly mafic voclaniclastic rocks of the Threehouse formation.

Bailes and Simms (1994) report evidence for a potential unconformity at the base of the younger Threehouse sequence, which they suggest explains angular truncation of 'older ' stratigraphic units at its base. A corollary of this interpretation is that the pre-Threehouse rocks must have been tilted (deformed) and eroded prior to deposition of the Threehouse sequence raising the possibility that the Photo Lake 'mine horizon' could be truncated at the base of this sequence.

Older volcanic rocks

Older volcanic rocks at Photo Lake occur on the north limb of a major east southeast trending syncline (Fig. GS-12-4) that is cored by the younger Threehouse formation. The older volcanic rocks consist mainly of massive felsic volcanic rocks and lesser amounts of heterolithologic mafic and felsic breccia, with minor amounts of mafic flows and local synvolcanic bodies of quartz and quartz-feldspar porphyry. No reliable stratigraphic section for these rocks has been recognized, in part due to a combination of poor quality outcrops (moss and lichen covered), massive monotonous lithologies, absence of reliable facing directions, and obliteration of subtle primary features during widespread synvolcanic hydrothermal alteration and subsequent regional metamorphism. This is in sharp contrast to comparable pre-Threehouse strata on the south limb of this syncline that at Chisel Lake display a well defined, dominantly north facing stratigraphy with many volcaniclastic units and ubiquitous facing criteria. The dramatic contrast between the older, pre-Threehouse section, on the south limb of the syncline (at Chisel Lake) and on the north limb of the syncline (at Photo Lake) is a significant, but as yet unexplained, feature of Snow Lake geology.

In the absence of a well defined stratigraphy, the legend for pre-Threehouse strata in the Photo Lake map area (Bailes *et al.*, 1996a; Fig. GS-12-4) is arbitrarily given in order from mafic to felsic compositions. The following description of units is also given from mafic to felsic, without regard to stratigraphic order.

Undivided basalt, basaltic andesite and fine grained amphibolite

Mafic flows are a minor rock lithology in the Photo Lake map area. The only volumetrically significant unit is centred on Bolloch Lake. It consists mainly of massive aphyric basalt and basaltic andesite flows with lesser pillowed flows and amoeboid pillow breccia. These flows typically contain 1-10%, 2-30 mm quartz amygdales. Locally the flows are intercalated with thin, volumetrically minor volcaniclastic units including heterolithologic mafic breccia, mafic scoria lapilli tuff and mafic wacke. Bedding in the mafic wacke indicate the Bolloch Lake basalt to be a steep dipping, south to southwest facing unit. The Bolloch Lake basalt varies in width from less than 300 m wide at the north border of the map sheet to 1.3 km east of Bolloch Lake. This over 7 km long unit is abruptly truncated 3 km east of Bolloch Lake by a north trending fault. Offset on this fault is significant as the Bolloch Lake basalt is not repeated in the map area to the east. The presence of large amygdales in the basalt and intercalation with scoria lapilli tuff suggest that it is more likely to have been deposited in a moderately shallow environment than in a deep water environment.

One other unit of basalt occurs in the pre-Threehouse sequence, and it is exposed only in a single tiny exposure 4.3 km northeast of Bolloch Lake. The main significance of this porphyritic pillowed basalt unit is that it is in the middle of the monotonous felsic sequence that hosts the Photo Lake VMS deposit and provides the only reliable facing direction (SE) available in this economically important volcanic section.

Undivided mafic volcaniclastic rocks

Thick units of mafic heterolithologic breccia occur in three localities in the Photo Lake map area: northeast of Bollock Lake, stratigraphically overlying the Bolloch Lake basalt, and stratigraphically overlying the Photo Lake mine 'horizon'. Minor amounts of mafic volcaniclastic rocks, including mafic wacke and scoria lapilli tuff, are also intercalated with the Bolloch Lake basalt.

The unit of breccia northeast of Bolloch Lake is composed dominantly of plagioclase phyric mafic volcanic fragments. Over 50% of this mafic breccia is silicified and feldspathized. Altered breccia has a bleached appearance, resembles an intermediate to felsic rock, and contains 10-40% acicular 2 to 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. The mafic breccia forms a >600 m wide unit that trends north of the map area an undetermined distance and is truncated to the southeast by a body of fine grained felsic rocks and a north-trending fault. The domain of fine grained felsic rocks is cored by quartz-feldspar porphyry. Because these felsic rocks cut across stratigraphy they may be intrusive; however, at outcrop scale they are indistinguishable from fine grained felsic rocks that elsewhere are mapped as extrusive.

Up to 200 m of mafic heterolithologic breccia outcrop south of, and stratigraphically above, the Bolloch Lake basalt. They are composed mainly of aphyric basalt and basaltic andesite fragments, with lesser amounts of aphyric mafic scoria blocks and rare angular rhyolite and porphyritic basalt clasts. Many of the aphyric basalt clasts contain large quartz amygdales, and are similar in appearance to quartz amygdaloidal basalt flows in the stratigraphically underlying Bolloch Lake basalt. Portions of this unit of mafic breccia are silicified and feldspathized. This alteration varies from selective alteration of individual fragments to widespread alteration of sections up to 70 m thick.

A north-trending, up to 90 m wide, unit of heterolithologic mafic breccia occurs in the middle of the felsic section that hosts the Photo Lake VMS deposit. The breccia has a highly variable clast population that is dominated by aphyric and plagioclase phyric basalt and basaltic andesite. These mafic clasts display a wide range in both phenocryst and amygdale size and abundance. Mafic scoria lapilli and blocks, although a minor component in the breccia, indicate derivation from a source terrane that included pyroclastic material. The mafic breccia is relatively unaltered, in contrast to strong alteration of felsic rocks to the west. This is significant because it indicates that the hydrothermal event that affected the felsic rocks to the west ceased before deposition of the mafic breccia. We suggest that the alteration that effects the felsic rocks to the west was likely produced by the hydrothermal event responsible for the Cu-Zn-Au sulphide mineralization at the Photo Lake mine. A corollary of this is that the unexposed interval between the unaltered mafic breccia and the altered felsic rocks is the Photo Lake 'mine horizon'.

Undivided dacite, andesite flows

Medium to dark grey green weathering, massive, aphyric, quartz amygdaloidal volcanic rocks occur within the dominantly felsic domain directly east and northwest of Ghost Lake. They display irregular and often gradational contacts with the felsic rocks, and are internally variable in colour and composition. In the past these rocks have been mapped as mafic to intermediate flows (Harrison, 1949; Williams, 1966; Bailes and Galley, 1992) but chemical analyses indicate that they are typically dacitic in composition. Their irregular distribution, gradational contacts and internal variability is consistent with them being altered rocks, with one interpretation being that they are simply chloritized equivalents of the bounding rhyodacite and rhyolite lithologies. This interpretation is also consistent with their high alkali contents. The question then is whether this lithology is a discrete map unit or whether the characteristically high vesicle and gas cavity content simply controlled primary permeability and, consequently, a higher degree of alteration by through-going hydrothermal fluids.

Powderhouse dacite

An up to 250 m wide unit of plagioclase phyric dacite tuff and lapilli tuff outcrops 1.8 km southwest of Bolloch Lake. The dacite and an associated heterolithologic breccia are identical to the 'Powderhouse dacite' that forms the stratigraphic footwall to the Chisel Lake area Zn-rich VMS deposits. The dacite tuff northwest of Bolloch Lake is typically massive, pale buff weathering and characterized by 5-15%, 0.5-3 mm plagioclase phenocrysts and small plagioclase phyric felsic fragments. The up to 60m wide unit of breccia to the northeast is composed of a mixture of felsic and mafic clasts. Felsic fragments in this breccia are commonly plagioclase phyric and texturally identical to the fine grained massive dacite tuff. Although no facing directions were identified in the Powderhouse dacite southwest of Bolloch Lake, the unit likely tops to the southwest. This is because bounding mafic wacke units top to the southwest and because the heterolithologic breccia, which is near the base of the type Powderhouse section south of Chisel Lake, is located on the northwest side of the unit.

Many of the dacite and the associated heterolithologic breccia outcrops are strongly altered. Altered dacites are characterized by 5-30% garnet and 10-60% amphibole porphyroblasts; the most altered outcrops locally contain up to 5% disseminated pyrite. Because this unit forms the stratigraphic footwall to the Zn-rich VMS deposits in the Chisel Lake area, this alteration may be economically significant.

There are some structural and stratigraphic problems with the section that underlies the Powderhouse dacite southwest of Bolloch Lake. The major problem is that the mafic wacke unit that apparently underlies the Powderhouse dacite appears to correlate with the younger Threehouse sequence. Bailes and Simms (1994) speculate that the section may include layer-parallel faults.

Undivided rhyolite, dacite and felsic metavolcanic gneiss

The older volcanic sequence at Photo Lake is dominated by felsic volcanic rocks. Most of these felsic rocks are aphyric to sparsely porphyritic nondescript massive units, that locally include portions that are distinctly quartz phyric, or include minor breccia and quartz amygdales. The two largest domains of undivided felsic volcanic rocks occur in the vicinity of Bolloch and Ghost lakes. The relationship of these felsic rocks to the Photo Lake rhyolite, host to the Photo Lake Cu-Zn-Au VMS deposits, is not known as they are separated by faults with indeterminate offsets.

At Bolloch Lake the undivided felsic rocks form approximately half of an over 1.3 km thick sequence, with the remainder of the sequence consisting of intercalated units of the previously described Bolloch Lake basalt and a variety of heterolithologic mafic volcaniclastic units. Distribution of the intercalated mafic volcaniclastic rocks indicates an overall northwest strike to the stratigraphy, that is also recorded more subtly in the distribution of felsic units. Rare facing directions in the Bolloch Lake section are consistently to the southwest, but interpreting the entire section as southwest facing is risky due to the scarcity of top indicators. The abundance of felsic rocks increases to the northwest of Bolloch Lake reflecting an along strike thinning of the intercalated basalt and heterolithologic mafic breccia units. There is also a less pronounced, southwest (upward?) increase in felsic rocks. Primary structures and phenocryst are typically not well preserved in massive felsic units north of Bolloch Lake due to strong recrystallization during regional metamorphism. Units south of Bolloch Lake, which are less strongly recrystallized, can locally be demonstrated to consist of domains (lobes?) of massive rhyolite and intervening domains of monolithologic breccia (microbreccia?). In general the felsic volcanic rocks in the Bolloch Lake area are aphyric to sparsely porphyritic. Alteration of the felsic volcanic rocks is common, but is most prominent in the area just north of Bolloch Lake. Amygdaloidal 'dacites' north of Chisel Lake may represent altered equivalents of the undivided felsic rocks at Bolloch Lake.

At Ghost Lake the undivided felsic rocks are similar to those that occur in the Bolloch Lake area north of Chisel Lake. They are typically aphyric to sparsely porphyritic massive rhyolite with interspersed irregular domains of amygdaloidal 'dacite'. The rhyolite locally contains domains with prominent quartz amygdales, supporting an interpretation that the amygdaloidal 'dacites' are simply altered equivalents of the rhyolites.

Photo Lake rhyolite, felsic metavolcanic gneiss

The Photo Lake rhyolite consists of a monotonous sequence of massive aphyric to sparsely porphyritic felsic rocks and derived felsic gneisses. They locally contain quartz amygdales and quartz-filled gas cavities. This, and local observation of massive lobes and intervening microbreccia, is consistent with the rhyolites being mainly flows. This unit hosts the Cu-Zn-Au rich Photo Lake VMS deposit.

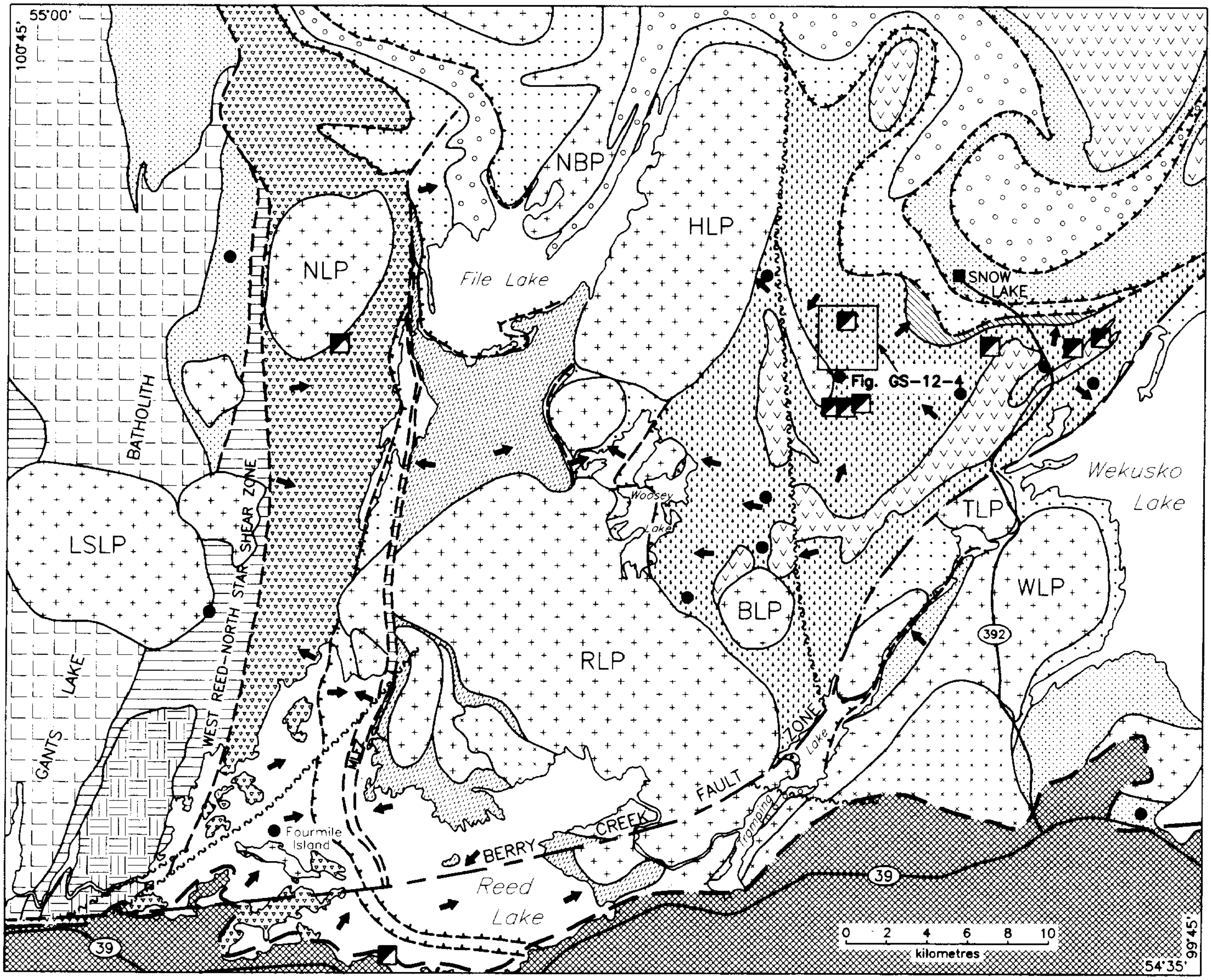
No internal subdivisions of the Photo Lake rhyolite were mapped and no facing directions for these strata were observed. The only indication of the strike of units is provided by a north-northwest trending unit of heterolithologic mafic breccia. The rhyolites are tentatively interpreted to top to the east-northeast on two imperfect criteria. One indication of topping direction is that rhyolites to the west of the unit of heterolithologic mafic breccia are strongly altered whereas the mafic breccia is relatively unaltered. This suggests that the mafic breccia was deposited after the hydrothermal event that effects the western rhyolite package. This topping direction is consistent with the occurrence of strongly altered 'footwall' rocks on the southwest side of the Photo Lake VMS (pers. com. HBED geologists, 1994).

Although Photo Lake rhyolites appear the same in the field, they comprise two suites; one with low Zr contents (averaging 25 ppm), and another with high Zr contents (averaging 85 ppm). The two suites show no systematic distribution. Both suites display the same elevated LREE contents, weak Eu depletion anomalies and flat HREE profiles.

Many outcrops of the Photo Lake rhyolite display the effects of alteration. Altered rocks contain prominent porphyroblasts of garnet, acicular amphibole, biotite and chlorite. A prominent zone of altered rhyolite occurs 700 m northwest of the Photo Lake VMS deposit. These altered rocks typically contain 15-30%, 2-12 mm garnet and 5-40%, 1-6 mm dark green amphibole porphyroblast in irregular patches and anatomosing veins. They also contain 2% sulphides, mainly pyrrhotite with some pyrite and rare chalcopyrite. This zone of alteration has been traced over 1 km to the north in a series of widely spaced, generally small outcrops. Rocks in three small outcrops in this zone, at the north edge of the map area, consist entirely of garnet, chlorite and biotite; they closely resemble 'pipe-like' alteration that is normally found only in the immediate footwall of massive sulphide deposits elsewhere in the Snow lake area. Other zones of altered rocks, present north and west of the Photo Lake deposit, are much weaker, typically composed of sucrosic felsic rocks with 1-3%, 0.5-1 mm garnet and 2-8%, 1-4 mm pale green amphibole porphyroblasts.

Heterolithologic felsic breccia

Only one mappable unit of heterolithologic felsic breccia occurs in the Photo Lake area. This 150 m wide unit outcrops northwest and east of Bolloch Lake, and is bounded to the northeast and southwest by undivided felsic rocks. It is composed dominantly of felsic clasts,



PHANEROZOIC

- Ordovician limestone and dolomite

PALEOPROTEROZOIC

INTRUSIVE ROCKS

- <1.84 Ga granite, granodiorite and tonalite
  - BLP: Bujarski Lake pluton
  - HLP: Ham Lake pluton
  - NBP: Nelson Bay pluton
  - NLP: Norris Lake pluton
  - LSLP: Little Swan Lake pluton
  - TLP: Tramping Lake pluton
  - WLP: Wekusko Lake pluton
- <1.84 Ga gabbro, diorite and quartz diorite
- <1.86 Ga granite, granodiorite and tonalite

TECTONITE

- Shear zone
  - MLFZ: Morton Lake Fault Zone
  - West Reed–North Star Tectonite

POST ACCRETION SEDIMENTARY ROCKS

- Missi suite fluvial–alluvial sandstone and conglomerate (ca.1.85–1.84 Ga)
- Burntwood suite turbidites (ca. 1.85–1.84 Ga)

ARC ASSEMBLAGES

- Subvolcanic tonalite plutons (ca. 1.89 Ga)
- Fourmile Island assemblage
- Snow Lake assemblage (ca. 1.89 Ga)
- Other Arc volcanic rocks

OCEAN FLOOR ASSEMBLAGES

- Reed Lake mafic–ultramafic complex
- Northeast Reed assemblage basalt
- Other ocean floor basalt

- Facing direction

VMS base metal deposit

- Mine
- Deposit
- North limit of Phanerozoic rocks
- Early faults (thrust?)
- Ductile–brittle fault
- Discrete brittle fault
- Boundary of shear/tectonite zone

Figure GS-12-2: Simplified geology of the Reed Lake-Wekusko Lake area, modified from Syme et al. (1995,1996), Morrison et al., (1996), Bailes et al. (1994), Froese and Moore (1980), Rousell (1970), Harrison (1949) and Stanton (1945). The Morton Lake fault zone (MLFZ) is interpreted to be the structural contact between the Amisk collage and various tectonostratigraphic assemblages of the Snow Lake area. Rectangle shows outline of the Photo Lake map area. Simplified geology of the Photo Lake map area is shown in Figure GS-12-4.

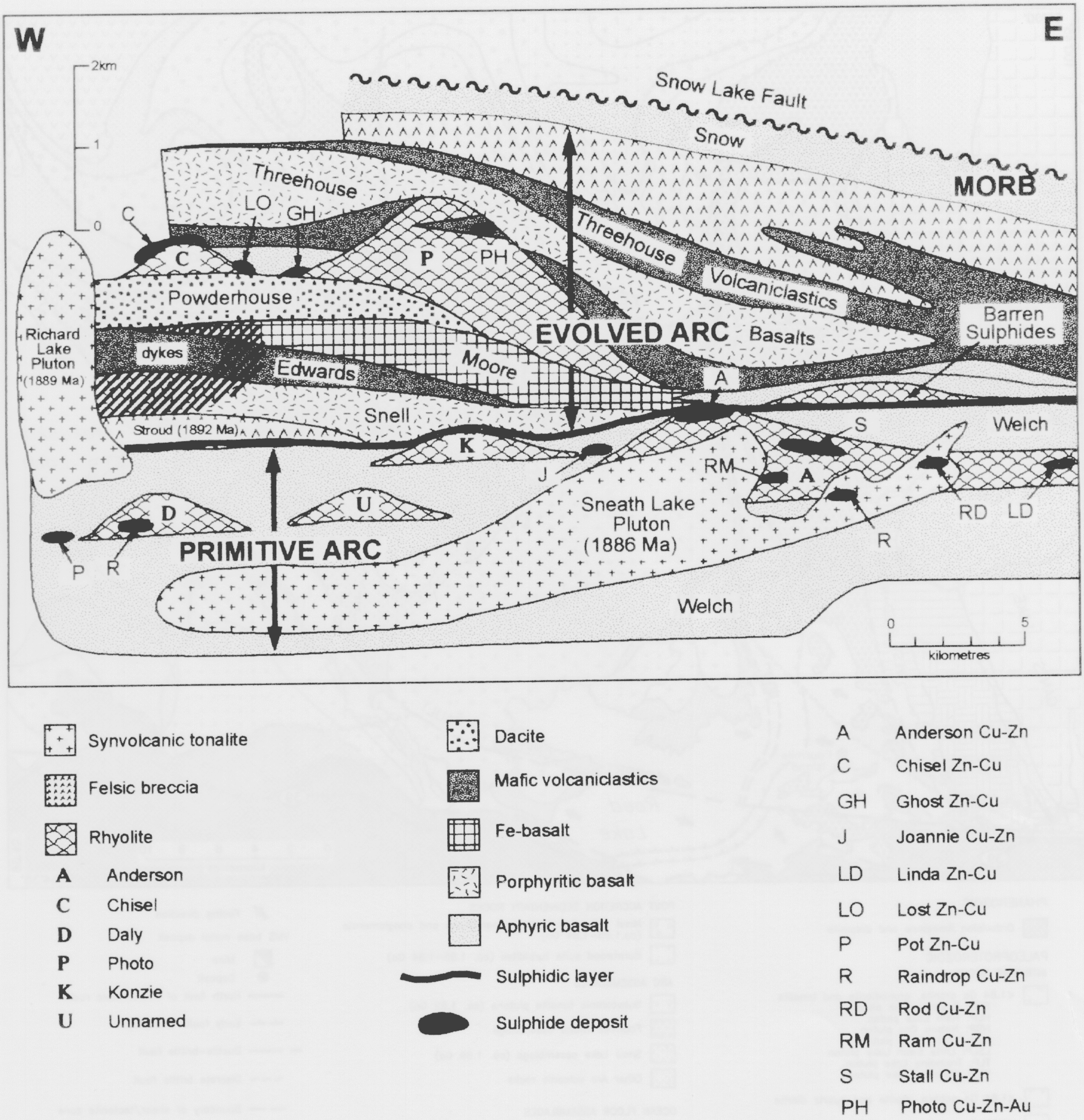


Figure GS-12-3: Schematic geological cross section of the Snow Lake arc assemblage. The Snow Lake arc assemblage is subdivided into a Primitive (or Proto) arc and Evolved arc, and is overlain by basalts with N-MORB geochemistry. The Primitive arc is a bimodal basalt-rhyolite sequence that includes the subvolcanic Sneath Lake tonalite intrusive complex. The Evolved arc is a more heterogeneous sequence, with up to 50% volcaniclastic detritus, that includes a prominent subvolcanic dacite dyke complex and the Richard Lake tonalite pluton.

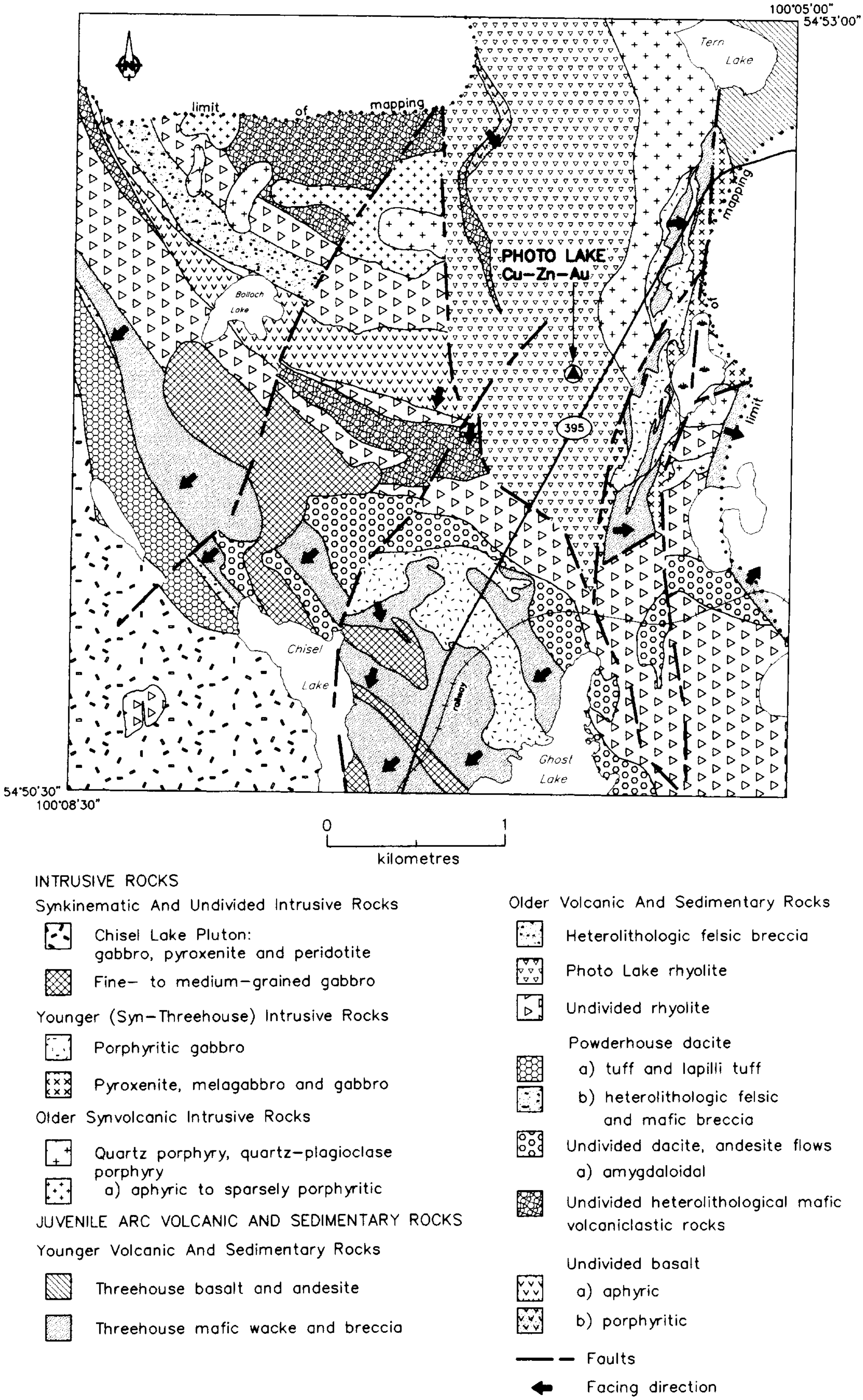


Figure GS-12-4: Simplified geology of the Photo Lake area from Bailes et al. (1996a).

most of them coarsely quartz phyric, but does include up to 10% mafic clasts. The quartz phyric clasts, which contain 5-7%, 1-5 mm quartz phenocrysts, texturally resemble the quartz porphyry that intrudes undivided felsic rocks and the heterolithologic mafic breccia to the northwest. This suggests that the quartz porphyry bodies were shallow, synvolcanic intrusions.

Quartz porphyry, quartz-plagioclase porphyry

Plugs and sills of quartz and quartz-feldspar porphyry occur throughout the Photo Lake area. The largest single body is a sill-like intrusion over 350 m wide and over 2 km long located north of the Photo Lake VMS deposit. Most other intrusions occur north of Bolloch Lake where they form bodies up to 300 m in diameter. Although the quartz porphyry and quartz-plagioclase porphyry bodies may vary in age, most of them appear to be early, possibly synvolcanic, as they are cut by gabbro intrusions that can be linked to overlying extrusive volcanic rocks.

The sill-like intrusion north of the Photo Lake VMS deposit is a massive, featureless, fine grained rock with 4-8%, 1-6 mm quartz and 1-4%, 0.5-3mm plagioclase phenocrysts. The pre-Threehouse age of this intrusion is evident from: 1) rare cobbles of this intrusion in the overlying Threehouse mafic wackes, and 2) cross cutting porphyritic gabbro dykes that are demonstrably synvolcanic with overlying Threehouse basalt. The eastern margin of this intrusion is commonly rusty weathering.

Small stocks and plugs of quartz porphyry and quartz-feldspar porphyry north of Bolloch Lake are considered to be synvolcanic. This is consistent with the presence of clasts of these intrusions in overlying heterolithologic felsic breccia to the southwest. We suggest that much of the spatially related alteration in the section of volcanic rocks near Bolloch Lake may be due to emplacement of these synvolcanic felsic intrusions. Zones of disseminated pyrite are common in these intrusions; some have prominent exploration trenches.

The origin of massive fine grained felsic rocks spatially associated with the Bolloch Lake quartz porphyry and quartz-feldspar porphyry intrusions is uncertain. Although these rocks are indistinguishable from extrusive aphyric to sparsely porphyritic felsic volcanic rocks, their irregular contacts and apparent cross-cutting distribution suggest that they may be in part intrusive. They contain zones of disseminated pyrite comparable to that occuring in the porphyritic intrusions.

Younger volcanic, sedimentary and intrusive rocks

In the Photo Lake area the younger volcanic sequence consists of mafic wacke, mafic breccia, pillowed porphyritic basalt\basaltic andesite, and synvolcanic gabbro intrusions. These rocks are exposed along the south and east margins of the map area. Those at the south margin of the map area occur in a northwest-trending synclinal fold interference structure, 6 km long and 2.5 km wide (locally known as the Chisel basin). Those exposed east of the Photo Lake mine site are at the base of an over 0.5 km thick homoclinal sequence that mainly outcrops east of the map area. In both domains, Threehouse mafic rocks are relatively unaltered and, thus, postdate the prominent synvolcanic hydrothermal event that effected the underlying 'older' volcanic rocks. Since the hydrothermal event is interpreted to be related to the mineralizing episode that produced the Chisel Lake and Photo Lake area base metal sulphide deposits, the Threehouse formation in the Photo Lake map area is not considered prospective for VMS deposits. At Chisel Lake the Threehouse mafic wackes directly and conformably overlie the Chisel Lake mine horizon. Near Photo Lake they appear to unconformably overlie and possibly truncate the Photo Lake ore-hosting stratigraphy (Bailes and Simms, 1994).

Threehouse mafic wacke and breccia

Well bedded mafic wacke forms almost all of the Threehouse formation in the 'Chisel basin', whereas it composes only the basal 100 m of this formation east of Photo Lake. The mafic wacke displays excellent graded bedding, load structures, scour channels and A, AB and ABE Bouma bed zonation, consistent with deposition in a subaqueous environment from turbulent density currents. Inconsistent with this environment of deposition, Bailes (1987) reported the presence of accretionary lapilli in the Threehouse mafic wackes in the Chisel basin. Re-examination of the 'accretionary lapilli' during this project indicates that these structures are post depositional as they locally overprint laminations in the mafic wacke. They are either diagenetic or metamorphic in origin.

Upward coarsening of the Threehouse mafic wacke sequence in the Chisel basin, recorded by a gradual increase in both grain size and bed thickness, indicates a likely increase in topographic relief of the source terrane. Rare preservation of scoria clasts, abundant prominently amygdaloidal basalt clasts in coarser beds, and limited compositional and textural range of detritus suggests that the source may have been a volcanic construct, possibly in part erupted under shallow water to subaerial conditions. The upward coarsening of the sequence could reflect growth of this volcanic construct. Clasts in breccia beds are texturally indistinguishable from intercalated pillowed mafic flows.

Threehouse basalt and basaltic andesite

Pillowed basalt and basaltic andesite flows dominate the upper part of the Threehouse section east of Photo Lake, but only occur sporadically in the Chisel basin section. They include both pyroxene and pyroxene-plagioclase phyric flows that are texturally identical to clasts preserved in breccia beds in Threehouse mafic volcaniclastic rocks, suggesting a common magmatic source for both rock lithologies.

East of Photo Lake the Threehouse section is dominated by mafic flows, whereas in the Chisel basin section it is dominated by mafic volcaniclastic rocks. One interpretation is that the section east of Photo Lake preserves a more proximal portion of this unit than that in the Chisel basin.

Threehouse mafic intrusions

Irregular bodies of porphyritic gabbro and melagabbro are common in Threehouse mafic wackes north of Chisel Lake and east of the Photo Lake mine site. These intrusions include plagioclase phyric gabbro, plagioclase and pyroxene phyric gabbro, melagabbro and pyroxenite. Most intrusions are composed of texturally and compositionally uniform gabbro, but some intrusions show textural and compositional variations that likely reflect crystal settling in a single body. The textural and compositional variation in these intrusions is comparable to those in the overlying Threehouse pillowed basalt and basaltic andesite flows.

Shallow emplacement of the gabbro intrusions is suggested by scattered (<1%) 1-3 mm quartz amygdales and by local prominent zones of quartz amygdales. For example, one of the large intrusions in the Chisel basin has a highly vesicular 3-5 m wide contact phase in which there are 20-30% 2-7 mm quartz amygdales that occur both randomly and in bands. A synvolcanic emplacement of the gabbro intrusions is conclusively demonstrated by the local presence of pepperites. A particularly well developed pepperite is located 30 m east of Photo Lake at the contact of a melagabbro-pyroxenite body with Threehouse mafic wacke. The gabbro displays contorted and amoeboid contacts at all scales, including chilled selvage-like contacts. The gabbro is also present as highly irregular fragments in the mafic wacke, and bedding in the mafic wacke is disrupted and contorted in contact with the gabbro. Theses features are consistent with the gabbro being intruded into unconsolidated, water-saturated Threehouse mafic wacke.

Threehouse formation plagioclase and plagioclase-pyroxene phyric gabbro intrusions at Photo Lake are different in size and shape within the Photo Lake rhyolite and quartz-feldspar porphyry than they are in the adjacent Threehouse mafic wacke. In the competent Photo Lake rhyolite and quartz-feldspar porphyry they are present as 10-30m wide dykes that cut 'stratigraphy' at a high angle, whereas in the Threehouse mafic wacke they form irregular sill-like bodies up to 100 m thick and 1.5 km long. This suggests that after exiting dykes in the underlying competent rock, the mafic magmas ponded in shallow chambers in the unconsolidated water-saturated Threehouse mafic wackes.

The presence of the gabbro intrusions at the base of the Threehouse sequence at Photo Lake and related feeder dykes in the underlying Photo Lake rhyolite indicates that these sequences are structurally intact. A further consequence of this line of reasoning is that angular truncation of the Photo Lake stratigraphy and the quartz-feldspar porphyry intrusion at the base of the Threehouse mafic wackes is most logically interpreted to have been a consequence of an unconformity at the base of the Threehouse formation (Bailes and Simms, 1994). Rare cobbles of the quartz-feldspar porphyry near the base of the Threehouse formation support an unconformable contact.

STRUCTURE

Folds

Recent structural studies in well bedded sedimentary rocks and derived paragneisses (*e.g.* Kraus and Williams, 1995) suggests the following folding episodes have effected rocks of the Snow Lake area between 1840-1800 Ma: F_1 tight isoclinal folds with an associated muscovite cleavage, F_2 folds with a cleavage that is syn- to post-regional metamorphism, F_3 open folds (NNE trending) with an axial planar crenulation cleavage, and rare F_4 folds that are restricted to an area north of Snow Lake. Because the massive rhyolites at Photo Lake do not generally display internal layering or obvious facing directions, the presence or absence of these folds (particularly F_1 or F_2 isoclinal folds) is not immediately obvious. However, we suggest that significant F_{1-2} folds have not affected rocks in the immediate vicinity of the Photo Lake mine because synvolcanic Threehouse gabbro dykes in the Photo Lake rhyolite sequence are relatively undeformed.

Despite the apparent absence of large scale early isoclinal folds in the immediate vicinity of the Photo Lake mine, the host volcanic rocks are strongly deformed. This deformation is recorded by well developed schistosities and prominent stretching lineations. Two prominent cleavages are recognized; an earlier cleavage that generally strikes west-northwest and dips moderately to shallowly to the north-northeast and a younger cleavage that strikes north-northeast and dips steeply. The earlier cleavage is locally deformed by open F_3 folds whereas the younger cleavage is axial planar to the F_3 folds. In well bedded Threehouse mafic wackes of the 'Chisel basin' the early cleavage is locally axial planar to northwest moderate plunging isoclinal (F_{1-2}?) folds. The prominent, ubiquitous stretching lineation in Photo Lake rocks, which is probably a product of combined F_{1-2} and F_3 deformation, plunges moderately to shallowly to the north-northeast.

Faults

Faults locally offset the stratigraphy in the Photo Lake area, but because they have little or no expression in outcrop and occur in monotonous sequences, their along strike definition is poorly constrained. Although most of the faults have only minor offset, and simply jostle the units, the north-trending fault in the centre of the map area separates two very different successions. To the west of this fault there is a south-to southwest-facing mixed-lithology package, whereas to the east there is an east- to northeast-facing rhyolite-dominated package. Recognition of this fault is important as it truncates and offsets the ore-hosting Photo Lake rhyolites.

SETTING OF PHOTO LAKE VMS DEPOSIT

The Photo Lake Cu-Zn-Au VMS deposit occurs within a different stratigraphic setting than other VMS deposits in the Snow Lake area and therefore represents a potentially new and relatively unexplored target. Previous exploration at Snow Lake has targeted either Anderson\Stall-type Cu-rich VMS mineralization, hosted by primitive arc rhyolite bodies, or Chisel-type Zn-rich VMS deposits, spatially associated with evolved arc rhyolite bodies. Photo Lake mineralization is different as it is hosted by evolved arc rhyolite, but is characterized by very high Cu and Au contents.

The Photo Lake deposit is hosted within the largest rhyolite domain in the Snow Lake area, the Photo Lake rhyolite. Until the discovery of the Photo Lake deposit, this domain of rhyolite was generally considered to have low VMS potential. The impact of this discovery was of immediate economic significance to the local economy of the town of Snow Lake, but it is perhaps more important to the local mining community as an indication that this rhyolite domain is much more prospective for economic VMS deposits than was previously considered.

Mapping in the Photo Lake area has identified the location of the Photo Lake VMS 'mine horizon' and several areas of strongly altered rocks that are likely related to the Photo Lake 'mineralizing event' (see above). The map (Bailes *et al.*, 1996a) shows that the mine-hosting stratigraphy trends north of the map sheet indicating that this area has considerable VMS potential. We recommend that a careful approach to tracing VMS mineralization in the Photo Lake area is required as ubiquitous faults may offset the 'mine horizon' and an unconformity at the base of the Threehouse formation may truncate favourable stratigraphy.

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