

New Insights into the Geology of the Murmac Bay Group, Rae Province, Northwest Saskatchewan

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Hartlaub, R.P. (1999): New insights into the geology of the Murmac Bay group, Rae Province, Northwest Saskatchewan; in Summary of Investigations 1999, Volume 2, Saskatchewan Geological Survey, Sask. Energy Mines, Misc. Rep. 99-4.2.

Mapping at 1:20 000 scale was conducted in several key areas of the western Nevins Lake Block north of Lake Athabasca to help better characterize a package of supracrustal rocks termed the Murmac Bay group (Macdonald, 1983). The Nevins Lake Block (including the Beaverlodge Domain) (Figure 1) lies within the Rae Province (Hoffman, 1990) and is bounded by the Black Bay Fault Zone to the west, the St. Louis Fault to the north, and the Oldman-Bulyea Shear Zone in the east. To the south, the Nevins Lake Block is unconformably overlain by Paleo-Mesoproterozoic sediments of the Athabasca Group (Sibbald, 1982). The Nevins Lake Block is predominantly composed of sedimentary and volcanic rocks of the Murmac Bay group, which unconformably overlie the 3.0 Ga (Van Schmus *et al.*, 1986) Lodge Bay Granite and have been intruded by a suite of granitic intrusions termed the "North Shore Plutons" (Macdonald, 1984). The oldest

recorded age for these intrusions is 2356 ± 14 Ma (Van Schmus *et al.*, 1986), although their true age is still debated (Bell and Bikerman, 1985; Van Schmus *et al.*, 1986; O'Hanley *et al.*, 1994).

This work extends mapping coverage to the north and north-east of an initial transect along the north shore of Lake Athabasca (Hartlaub and Ashton, 1998). The goals of this multi-year project are to: 1) recognize and characterize the basement to the Murmac Bay group; 2) identify the age and tectonic environment of volcanism and sedimentation within the Murmac Bay group; and 3) constrain the nature and age of metamorphism and plutonism within the western Nevins Lake Block. In accomplishing these goals it is hoped that a better tectonic framework for the southwestern portion of the Rae Province will be developed. This should prove useful in future genetic modeling of mineral deposit types in northwestern Saskatchewan.

1. General Geology

Two main packages of rocks have been identified in the study area. To the south of the Zenith Lake shear zone (Figure 2), rocks that characterize the Murmac Bay group predominate. These include quartzitic, psammitic, and psammopelitic to pelitic sedimentary rocks as well as mafic and rare felsic to intermediate volcanic rocks. Carbonate, oxide facies iron formation, gabbro, and ultramafic rocks are minor components. These Murmac Bay group rocks have been intruded by a large variety of moderately foliated to massive granitic and leucogranitic rocks as well as later diabase and lamprophyre dykes. Around Donaldson Lake, the supracrustal rocks have been injected by numerous sheets of weakly foliated to massive granodioritic to granitic rock

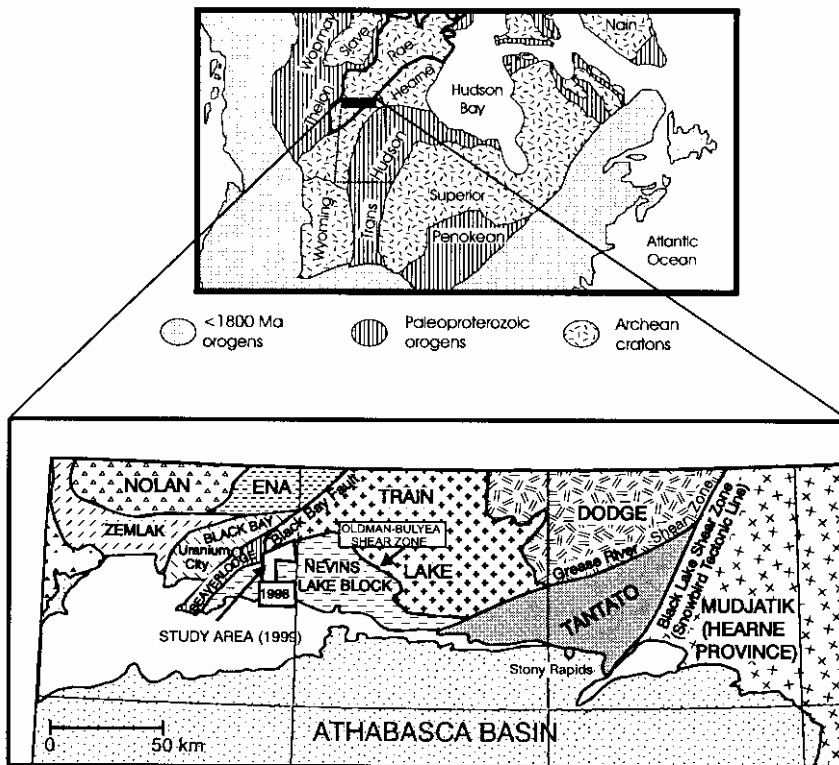


Figure 1 - Regional geology of the Rae Province, north of Lake Athabasca, Saskatchewan (after Hoffman, 1990 and Lewry *et al.*, 1990).

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(Donaldson Lake Gneiss of Tremblay, 1972). A large leucogranitic body exposed east of Yahyah Lake, which has an unclear relationship to the surrounding quartzite, may represent an exposure of older basement.

North of the Zenith Lake shear zone, granodioritic to granitic rocks predominate and locally contain numerous inclusions of mafic rock. Volcaniclastic rocks and intermediate rocks of possible volcanic origin constitute about 15 percent of the exposures. This predominantly plutonic suite of rocks appears to be distinctive of the Train Lake Domain (Ashton and Card, 1998; Ashton *et al.*, this volume), which lies to the north and east of the Nevins Lake Block (Figure 1). Rocks that characterize the Murmac Bay group, such as quartzite, psammite, iron formation, and carbonate, were not identified northeast of Prince Lake.

Three ductile deformational events, several brittle deformation events, and two metamorphic events are distinguished. D₁ deformation produced a strong planar fabric in rocks throughout the area. Brittle-ductile shearing in the Zenith Lake shear zone likely commenced at this time. Recumbent isoclinal folding (D₂) occurred during the latter parts of this shearing

event. Northeast-trending, open to close folds formed during D₃, the final ductile deformation event. Brittle shearing along the St. Louis Fault due to reactivation of the Zenith Lake shear zone may also have occurred during D₃. An initial metamorphic event, synchronous with D₁ and D₂, reached middle amphibolite facies conditions in the southwest and grades to granulite facies conditions in the northeast. A second metamorphic event (M₂) of slightly lower grade occurred during D₃.

2. Description of Rock Types

a) Possible Archean Basement

Yahyah Lake Granite (Gy)

Pink to white, coarse-grained granite to leucogranite is exposed east of Yahyah Lake. The rock is well foliated and locally displays sharp strain gradients. Hornblende±biotite generally make up 10 percent of the rock, with trace hematite present locally. The contact between this unit and the surrounding quartzite is generally highly strained. At several locations in the

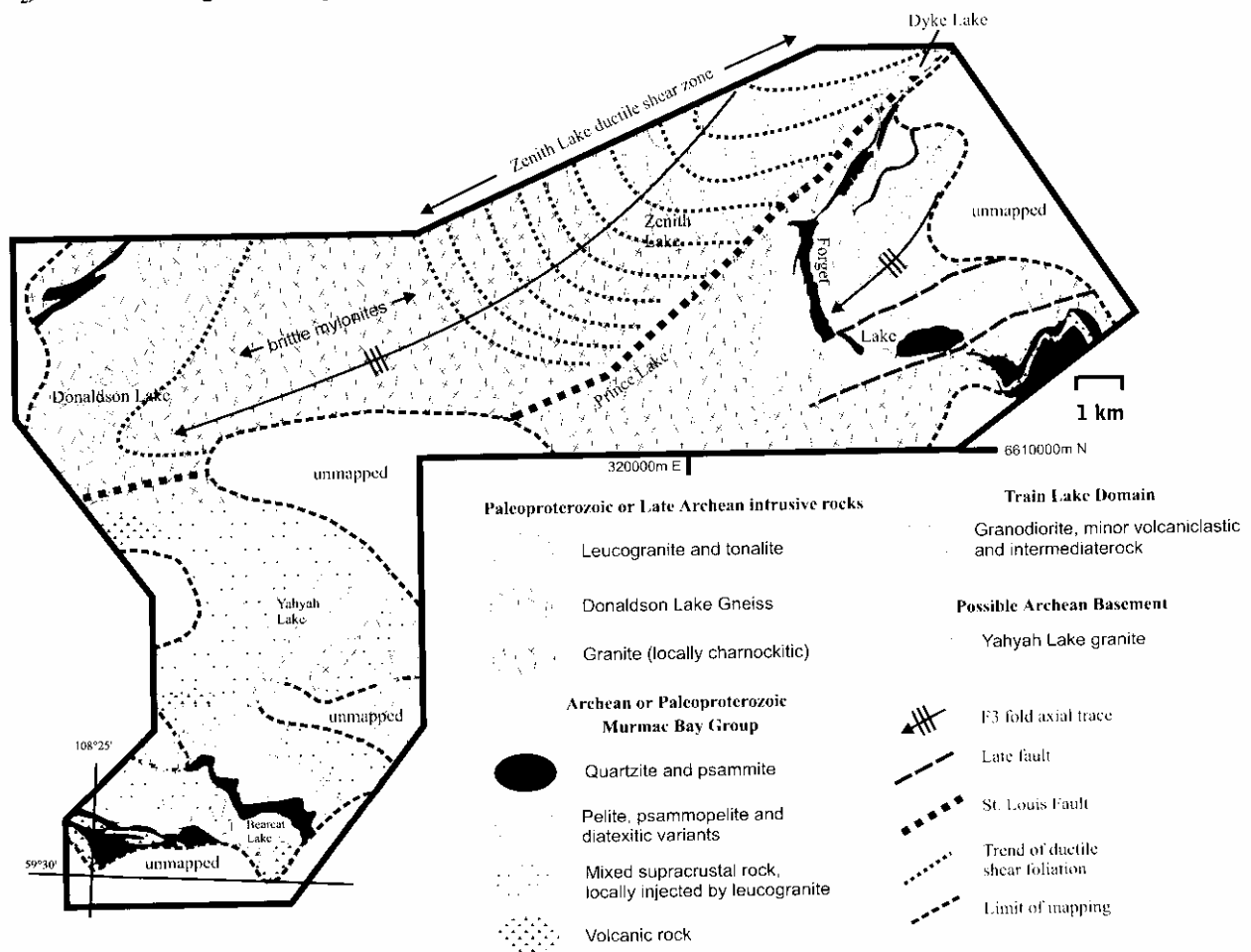


Figure 2 - Simplified geological map of the study area.

east, however, there appears to be a conformable contact between the granite and interlayered quartzite-oxide facies iron formation, suggesting the granite is older than the Murmac Bay group and possibly the same age as the 3.0 Ga Lodge Bay Granite.

b) Murmac Bay Group

Quartzite (Q)

Well-layered, white to pale-yellow, fine-grained quartzite forms about 3 to 5 percent of the Murmac Bay group. Although this unit is generally thin and discontinuous, a 10 to 50 m wide layer of quartzite with a strike length of several kilometers is exposed along the west shore of Forget Lake. Less deformed quartzite immediately to the south contains sedimentary structures and clasts (Harper, 1983a; Hartlaub and Ashton, 1998), but neither were noted in the present study area.

Psammite (Ps) to Psammopelite (PsP)

Fine- to medium-grained, pink to white psammite to psammopelite is moderately to well layered on a decimetre scale. Psammopelitic rock is the dominant unit around Forget Lake, where it represents 30 to 40 percent of exposed rock. It is composed of quartz and feldspar with up to 15 percent biotite, 0 to 5 percent garnet and, locally, trace graphite, cordierite, and sillimanite. Psammopelite grades into quartzite and more commonly into pelite, as well as locally pelitic to psammopelitic diatexite (Ps_d). These diatexitic rocks have a nebulous foliation and contain 10 to 20 percent garnet and 5 to 10 percent biotite, as well as rare graphite and sillimanite.

Calcic Psammopelite (Csp)

Calcic psammopelite is dark grey, fine grained, and contains quartz, feldspar, 5 to 10 percent biotite, 5 to 15 percent hornblende, and trace sulphides. Garnet porphyroblasts up to 2 cm in diameter are present locally, but rarely exceed 5 percent of the rock. These rocks are generally interlayered on a metre scale with mafic volcanic rocks or psammites and psammopelites. The common association of this unit with mafic volcanic rock suggests a volcanoclastic origin.

Pelite (P)

Ten to fifty metre-wide zones of well-layered, fine-to medium-grained, brown to rusty-red weathering pelite are sporadically exposed throughout the area. This rock contains 20 to 30 percent biotite±muscovite, trace to 3 percent sillimanite and rare garnet. Graphite is ubiquitous in trace amounts. Layers of quartzite 10 to 50 cm wide are found locally within this unit.

Carbonate/Marble (C)

Light brown to black weathering, massive to layered marble is exposed along the northern shore of Bearcat Lake as well as at a few locations along the west shore of Forget Lake. This unit is generally interlayered with psammite on a metre scale. It is composed of medium-grained calcite and dolomite, with irregular patches of coarse-grained diopside and rare hematite.

Mafic Volcanic Rock (Mv)

Green to black, mafic volcanic rock is fine to coarse grained and includes both massive and layered varieties. The unit is composed of plagioclase and hornblende with trace sulphides and, in the Forget Lake area, up to 5 percent clinopyroxene. Relict pillow structures have been observed in similar mafic volcanic rocks from elsewhere within the Murmac Bay group (Macdonald, 1984; Hartlaub and Ashton, 1998). Although the majority of this unit is interpreted as mafic volcanic in origin, it also probably includes gabbro.

Felsic Volcanic Rock (Fv)

A 10 metre-wide unit of medium-grained, white to grey, felsic volcanic rock, exposed west of Melma Lake in the southwest corner of the area is well layered on a decimetre scale. In addition to quartz and feldspar, it contains 10 percent cummingtonite and trace sulphides. This unit is probably an extension of similar felsic volcanic rock previously mapped several kilometres to the east along strike (Hartlaub and Ashton, 1998).

Ultramafic Rock (Um)

Massive, coarse-grained, rusty-weathering ultramafic rock is exposed at one location several hundred metres west of Forget Lake where it appears to be interlayered with quartzite and pelite. The ultramafic rock is composed of randomly oriented masses of green serpentine with minor amounts of carbonate and trace to several percent sulphides. The lack of primary mineralogy and texture, however, makes it difficult to determine if this unit is intrusive or extrusive. Komatiitic geochemical affinities characterize similar ultramafic rocks at Nicholson Bay (Schwann, 1985; Hartlaub, unpubl. data) and to the northeast of Macintosh Bay (Hartlaub and Ashton, 1998; Hartlaub, unpubl. data).

Oxide Facies Iron Formation (FeF)

Well-layered, steel-blue weathering oxide facies iron formation is interlayered with quartzite at a single outcrop along the north shore of MacRae Lake and at several locations along the eastern margin of the Yahyah Lake Granite. This fine-grained rock consists of alternating centimetre-thick silica and magnetite-hematite-rich layers. Iron formation interlayered with

quartzite or mafic volcanic rock is a common constituent of the Murmac Bay group throughout the Nevins Lake Block (Harper, 1983a, 1983b; Ashton and Card, 1998; Hartlaub and Ashton, 1998).

c) Intrusions

Granite (G)

Coarse-grained, locally migmatitic, orange to white granite outcrops throughout the central part of the area. It contains 15 to 30 percent combined biotite and hornblende and as much as 10 percent hypersthene in the northeast. Garnet porphyroblasts, where present, constitute 1 to 2 percent of the rock. In addition to a moderate to strong S_1 foliation, this unit locally has a well-developed L_1 stretching lineation. The largest exposure of this unit, the Stephens Lake Pluton (Thomas, 1984), is intrusive into the Murmac Bay group and has a 100 to 300 m thick, heterogeneous, inclusion-rich margin. In this heterogeneous zone, up to 50 percent of the rock is massive pink leucogranite (unit G1), which cross-cuts the pluton as well as the S_1 fabric. To the west of Forget Lake along the St. Louis Fault, the Stephens Lake Pluton has been variably sheared. This cataclastic variety of the granite contains abundant chlorite and is strongly hematized in some places.

The Dead Man, Cameron Island, and Macintosh Bay granites along the north shore of Lake Athabasca (Macdonald *et al.*, 1982; Sibbald, 1982; Hartlaub and Ashton, 1998) have a similar appearance and composition to this unit. Therefore, it is interpreted to be part of the "North Shore" suite of granite plutons.

U-Pb zircon work on the Stephens Lake Pluton by Bickford *et al.* (1987) yielded an age of 2440 ± 57 Ma. If this date is taken as the time of igneous crystallization, it suggests that the Murmac Bay group is Archean in age and that the other North Shore Plutons may be older than the 2.0 to 2.35 Ga (Bell and Bikerman, 1985; Van Schmus *et al.*, 1986; O'Hanley *et al.*, 1994) range of ages they have yielded. The U-Pb data for the Stephens Lake Pluton, however, has been interpreted as being influenced by older inheritance, suggesting that the age of the intrusion was younger than 2440 Ma (Bickford *et al.*, 1987).

The Foot Bay Gneiss

A large unit of rock between Prince Lake and Donaldson Lake was called the Foot Bay Gneiss (Tremblay, 1972) because interpretation of protolith had been made difficult due to multiple shearing events (Krupicka and Sassano, 1972). Tremblay *et al.* (1981) interpreted the unit as a metasediment, whereas Thomas and Macdonald (1983) described the unit simply as hornblende and biotitic quartzofeldspathic gneiss. The rock is porphyroclastic, pink, and has an identical mineralogy to other granites in the map area. At a few locations in the Zenith Lake shear zone,



Figure 3 - Coarse-grained orthopyroxene-bearing granite (charnockite) exposed northwest of Prince Lake.



Figure 4 - Strain gradient in charnockite exposed northwest of Prince Lake.

coarse-grained, orthopyroxene-bearing granite (Figure 3), bounded by sharp strain gradients (Figure 4), is probably a relict of the protolith. Cataclastic varieties of this rock in the St. Louis Fault locally have a mylonitic foliation defined by millimetre-scale laminations. Elsewhere the rock is a fine-grained to aphanitic ultracataclasite lacking any foliation. The lack of compositional layering or aluminosilicates, the homogeneity of the unit over an area in excess of 30 km² and coarse-grained charnockitic rocks favour a plutonic protolith for the Foot Bay Gneiss. In addition, the unit can be traced across the St. Louis Fault into the less deformed Stephens Lake Pluton.

The Foot Bay Gneiss yielded a U-Pb zircon age of $2513 +36/-22$ Ma (Tremblay *et al.*, 1981). The two multi-grain analyses from this study lie approximately on the same discordia line as the data from the Stephens Lake Pluton, supporting the suggestion that the two units could be co-magmatic.

Donaldson Lake Gneiss

A heterogeneous zone of mixed supracrustal rock and numerous large sheets of injected granite, are exposed



Figure 5 - Mafic volcanic rock xenoliths in a granitic melt rock (Donaldson Lake Gneiss) exposed west of Donaldson Lake.

around Donaldson Lake (Figure 5). These rocks escaped the multiple shearing events that have deformed the adjacent Foot Bay Gneiss. The injected granite, which makes up >60 percent of this unit, is pink to white, moderately foliated to massive and contains 10 percent biotite±hornblende. Five to twenty metre-wide zones of mafic volcanic rock and quartzite probably of the Murmac Bay group, occur between the granite sheets. This heterogeneous zone of mixed granite and supracrustal rock, termed the Donaldson Lake Gneiss (Tremblay, 1972) was originally interpreted as a metasediment (Tremblay *et al.*, 1981). A sample yielded a 2179 ± 12 Ma U-Pb age (Tremblay *et al.*, 1981).

Tonalite (To)

White to light pink, coarse-grained, massive to weakly foliated tonalite contains 1 to 5 percent biotite and 1 to 5 percent garnet. Well-foliated biotitic inclusions are locally abundant whereas mafic inclusions are rare. The massive nature and well-foliated xenoliths suggest that this unit intruded the Murmac Bay group after the majority of deformation was complete; its garnetiferous nature indicates that the rock may have formed as an anatectic melt of pelite and psammopelite.

Leucogranite (Gl)

Pink, coarse-grained, moderately foliated to massive leucogranite contains 1 to 5 percent, and rarely up to 10 percent, biotite. Inclusions of migmatitic psammopelite are locally abundant. Leucogranite is sheared in late cataclastic zones but is not deformed by S_1 . Locally, this unit contains a strong S_3 fabric, suggesting it was injected after D_2 but prior to, or synchronous with, D_3 . Psammopelitic inclusions suggest that the rock might be derived from partial melting of Murmac Bay group sedimentary rock.

Pegmatite (Peg)

Weakly deformed to massive granitic pegmatite is common everywhere. This unit consists of both thin cross-cutting dykes and larger mappable sheets. Typical samples contain books of coarse-grained biotite as well as rare garnet and muscovite.

Lamprophyre (LI)

Several fine-grained, pale-green to brown-weathering and moderately foliated lamprophyre dykes intrude psammitic and psammopelitic rocks in the north part of the study area. This unit is dark grey to black on the fresh surface and contains numerous biotite and K-feldspar phenocrysts. The lamprophyre dykes crosscut the S_1 foliation yet contain an oblique fabric, which is either of igneous origin or related to D_2 or D_3 .

Lamprophyre (L)

A second generation of vertically dipping, continuous and *en echelon* lamprophyre dykes is common south and east of Yahyah Lake. The dykes strike consistently at 045° to 055° except in rare locations where it is perpendicular to this. These rocks weather a distinctive rusty red-brown, are fine grained, lack a foliation, and crosscut all rocks except the diabase dykes, with which contacts were not observed. They are mineralogically complex and generally contain phenocrysts of biotite and K-feldspar.

Diabase

Black weathering, massive, fine-grained diabase dykes intrude granitic rocks of the Foot Bay Gneiss at several locations between Prince and Donaldson Lake (Figure 6). They strike east-west and contain trace amounts of pyrite and hematite. Similar dykes were noted west of the study area and were found to be particularly numerous adjacent to the Black Bay Fault (Tremblay, 1972).

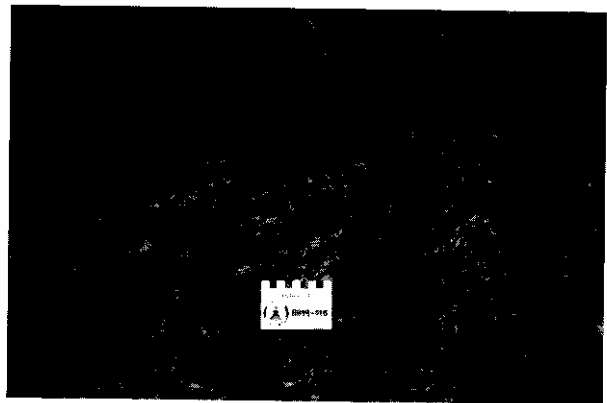


Figure 6 - Diabase dyke (top) crosscutting mylonitic granitic rock of the Foot Bay Gneiss (bottom).

d) Rocks of the Train Lake Domain

Volcaniclastic Rock

Grey, well-layered, medium- to fine-grained migmatitic volcaniclastic rock is exposed sporadically north of the brittle St. Louis Fault. Typically, these rocks contain 15 to 20 percent hornblende, 1 to 5 percent garnet, and rare clinopyroxene. Within the ductile portion of the Zenith Lake shear zone, this unit has a recrystallized sheared texture. Hornblende and garnet porphyroblasts overgrow the mylonitic fabric, suggesting that upper amphibolite facies temperatures outlived the shearing event. Locally, amphibolite forms dismembered layers up to 1 m thick.

Intermediate Rock

Fine-grained light grey intermediate rock contains 5 to 20 percent hornblende, trace magnetite and is well layered on a decimetre scale. Hornblende-bearing leucosomal melt layers are apparent in many outcrops. The well-layered and fine-grained nature of the rock suggests that the protolith of this unit may be an intermediate volcanic.

Granodiorite

Coarse- to medium-grained, migmatitic granodiorite is the predominant rock in the Zenith Lake shear zone. This white-weathering rock contains 10 to 15 percent hornblende±orthopyroxene±clinopyroxene, as well as trace magnetite and hematite. It displays excellent strain gradients where it grades from a coarse-grained rock into a medium-grained, strongly recrystallized blastomylonite. Hornblende blastesis overgrows this early mylonitic fabric.

Quartz Syenite

Several outcrops of massive, pink, medium-grained quartz syenite are exposed along the eastern shore of Dyke Lake. This unit crosscuts mylonitic granodiorite and appears undeformed (Figure 7). Similar late pink felsite dykes are recorded from elsewhere in the Train Lake Domain where they are considered part of the same magmatic suite that formed the lamprophyre dykes (Ashton *et al.*, this volume).

3. Structural Geology

Three ductile and several brittle deformational events are distinguished. Tight to isoclinal F_1 folds that transposed bedding and led to the formation of a moderate to strong foliation are defined by gneissic layering. Initial ductile shearing along the moderately south- to southeast-dipping Zenith Lake shear zone likely commenced at this time. Tight to isoclinal, recumbent F_2 folding is found throughout the area but appears to be best developed along the Zenith Lake shear zone. In this area, the fold limbs are commonly

sheared-off (Figure 8), suggesting that the folding was synchronous with the mylonitization. Southwest-plunging open F_3 folds are well developed throughout the area. These folds have an upright northeast-striking axial plane and locally have a strong axial planar fabric defined by biotite growth, quartz flattening and rare clinopyroxene-bearing melt blebs.

At least two brittle shearing events have been previously recognized along the St. Louis Fault (Krupicka and Sassano, 1972; Thomas and Macdonald, 1983). This cataclasis is best developed in a southwest-striking zone along the south side of Prince Lake and in a north-striking zone along the east side of Donaldson Lake. The orientation of brittle mylonitic structures suggests that fabrics formed during the initial brittle shearing event were folded by a regional F_3 fold whose axial trace cores the Foot Bay Gneiss (Figure 2). This brittle event is interpreted to be a higher level splay of the Zenith Lake ductile shear zone. A second brittle shearing event (St. Louis Fault) then reactivated the southeast limb of this fold between Prince and Ace lakes, forming silicified zones of breccia (Figure 9). Late greenschist grade faulting is the last deformational event distinguished. Several fault sets are recognized but the predominant one has a

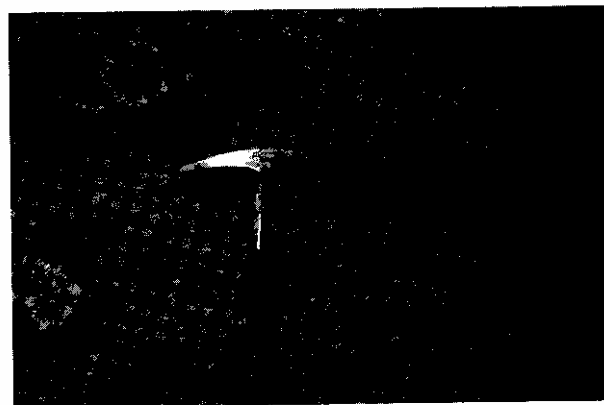


Figure 7 - Massive pink quartz syenite (top) that has cross-cut ductile granodioritic mylonite (bottom) from the Zenith Lake shear zone.

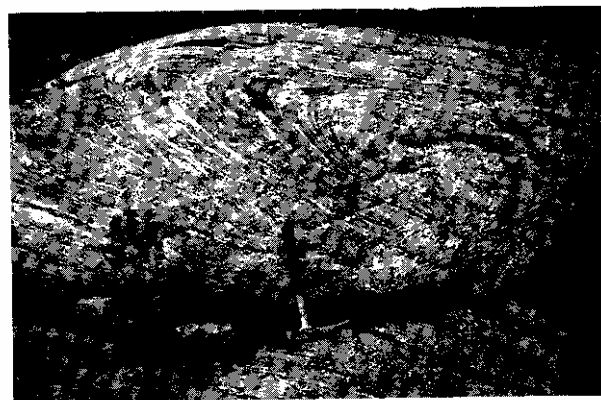


Figure 8 - Recumbent F_2 fold with sheared-off limbs. This structure folds mylonitic granite from the Zenith Lake shear zone.

roughly east-west strike. No sense of displacement was recognized.

Tectonic Implications

A regional F_3 fold originally mapped by Blake (1955) and termed the Zenith Lake structure by Thomas and Macdonald (1983) is interpreted to have refolded the Zenith Lake shear zone into its current orientation. This large southwest-plunging structure is clearly visible on aeromagnetic maps. Rocks in the Zenith Lake shear zone are generally fine to medium grained, porphyroclastic, and completely recrystallized. Strain gradients are locally apparent. A strong stretching lineation is well developed but, due to later refolding, it does not have a consistent orientation. Where good shear sense indicators were recorded (Figure 10), a normal south-side-down sense of displacement is indicated. The true displacement may be different than that recorded, however, due to the refolded nature of the shear zone. It is possible that the Zenith Lake shear zone represents an extension of the Oldman-Bulyea shear zone, which borders the Nevins Lake Block to the east. If this is the case, the northern margin of the Nevins Lake Block should be taken as the Zenith Lake

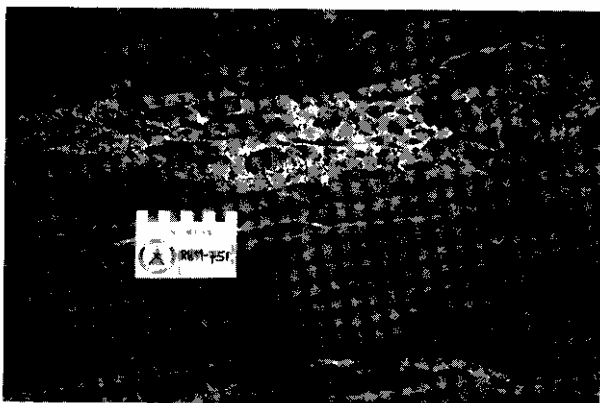


Figure 9 - Silicified breccia zone from within the St. Louis Fault zone.

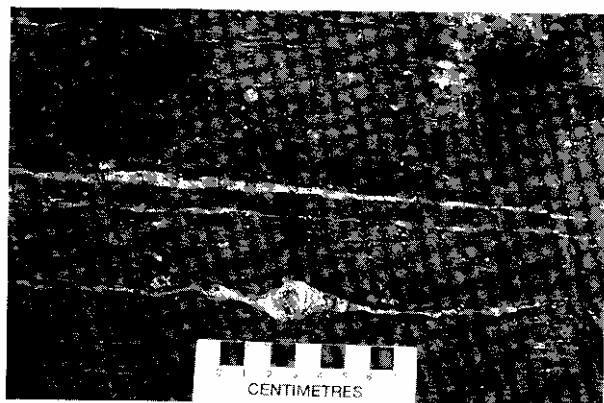


Figure 10 - Sinistral delta porphyroclast in a mylonitic granite from the Zenith Lake shear zone.

shear zone rather than the younger brittle St. Louis Fault.

4. Metamorphic Geology

Peak metamorphic grade increases from southwest to northeast and corresponded to the first two deformational events (D_{1-2}). The widespread hornblende indicates the attainment of amphibolite facies or higher temperatures (Bucher and Frey, 1994). In the southwest, muscovite suggest that the second sillimanite reaction isograd (Evans, 1965; Evans and Guidotti, 1966) has not been surpassed. Just to the north, however, along the north shore of Bearcat Lake, the rocks are migmatitic, indicating that the minimum melting curve has been surpassed (Luth *et al.*, 1964). The first appearance of orthopyroxene is recorded in the Stephens Lake granite in the northeast part of the study area and indicates the onset of granulite grade metamorphism (Spear, 1981; Bucher and Frey, 1994).

Locally, there is evidence of a second metamorphic event that accompanied D_3 deformation. East of Forget Lake, biotite overgrowths on garnets were found to be axial planar to D_3 folds. Northwest of Prince Lake, hornblende and plagioclase overgrowths on garnet and clinopyroxene-bearing axial planar melts were observed. Together, these relationships suggest that the second metamorphic event locally reached upper amphibolite grade conditions. This is consistent with M_2 metamorphic conditions recorded directly to the south (Hartlaub and Ashton, 1998), including cordierite-bearing melts axial planar to F_3 folds.

5. Economic Geology

The supracrustal and intrusive rocks of the Murmac Bay group contain numerous mineral occurrences, including: the Nicholson Bay U-Ni deposit (Sibbald, 1982; Sibbald *et al.*, 1983; Peiris and Parslow, 1987; Peiris, 1991), the Dinty Lake nickel deposit (Hulbert, 1987) and the Archie Lake and Nisikkatch-Hoidas lakes REE prospects (Harper, 1983b, 1986; Hogarth, 1957). Gold mineralization has been discovered in many of the North Shore Plutons and has been mined from the Box and Athona granites (Beavan, 1938; Christie, 1953; Sibbald, 1984; Sibbald and Jiricka, 1986; Quirt, 1987, 1990; Appleyard, 1988, 1989, 1990; and Roberts, 1990).

The discovery this summer of a sulphide-bearing ultramafic body near Forget Lake indicates the potential for undiscovered ultramafic-hosted nickel±PGE deposits in the Nevins Lake Block. The numerous shear zones that bound the Nevins Lake Block represent possible sites for gold mineralization, especially where these shear zones cut mafic rocks.

6. Conclusions

This work leads to several important conclusions:

- 1) The Stephens Lake Pluton is continuous across the St. Louis Fault. Where highly sheared it had previously been included in the Foot Bay Gneiss.
- 2) The northern boundary of the Nevins Lake Block should be placed at the Zenith Lake shear zone, rather than along the later St. Louis Fault. Rocks of the Murmac Bay group were not recognized to the northeast of Prince Lake.
- 3) The Donaldson Lake Gneiss represents a zone of Murmac Bay group rocks that have been flooded by granitic to granodioritic melt rocks.
- 4) Peak metamorphic grade was attained during D₁-D₂ and increased from middle amphibolite facies in the southwest to granulite facies in the northeast, consistent with the increase in metamorphic grade from west to east that was recorded by Hartlaub and Ashton (1998) along the north shore of Lake Athabasca.

7. Acknowledgments

Jeff Coolican and Robert McFadyen provided excellent field assistance. Field equipment, supplies, and financial support were provided by Saskatchewan Energy and Mines. Funding at the University of Alberta was provided by Larry Heaman and Tom Chacko.

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