Geology of the Galbraith-Attitti Lakes Area, Attitti Block (part of 63M-1 and -2) [1]

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The Galbraith-Attitti lakes area lies in the north-central Attitti Block which represents the highly metamorphosed northern extension of the Flin Flon granite-greenstone belt (Figure 1). Mapping of the area directly to the south as part of the Wildnest-Tabbernor Transect led to the recognition of widespread metavolcanic rocks, minor iron formation, and significant Fe-Mg metasomatism, carbonatization, and aluminous alteration (Ashton and Leclair, 1991). Mapping in 1995 was intended to extend this work northward and to further investigate the mineral potential of the Attitti Block. The area was last mapped by Pyke (1961) at 1:63,360 scale.

The study area is centred about 30 km east of Pelican Narrows and 55 km northwest of Flin Flon, Manitoba. Field work was carried out by a four-person crew over a five-week period and consisted of hip chain and compass traverses and shoreline mapping. Topographic relief ranges over 50 m, with supracrustal rocks generally occupying the low areas and granitoid rocks dominating the ridges.

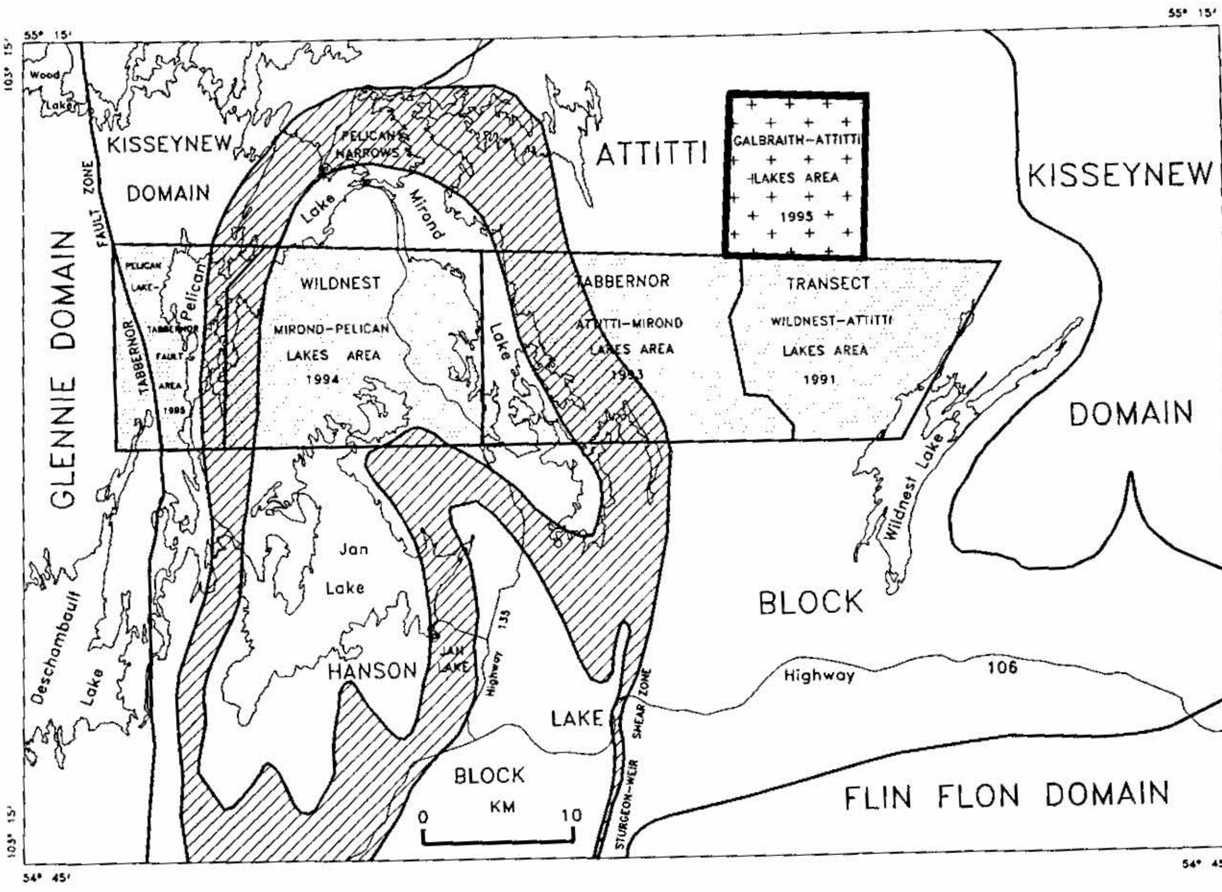

Figure 1 - Location of study area and Wildnest-Tabbernor Transect (dots). Approximate outline of the Pelican Slide and rooted Sturgeon-weir Shear Zone in diagonal stripes.

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1. General Geology

The Galbraith-Attitti lakes area is mainly underlain by highly metamorphosed supracrustal rocks broadly representing the northern extension of the Proterozoic Amisk Group. A thin unit of variably magnetite-rich arenaceous gneisses northwest of Galbraith Lake is tentatively interpreted as part of the Missi Group (Figure 2). The area is bounded and intruded by the 1865 to 1845 Ma suite (Ansdell and Kyser, 1991) of leucocratic to mafic granodiorites and tonalites.

Primary features have generally been obliterated by the combined effects of upper amphibolite facies metamorphism and several deformational events. Early deformation has produced widespread unit repetition and a layer-parallel regional foliation. These fabrics are overprinted by a pervasive, generally northeast-plunging stretching lineation and by a set of southeast-plunging minor folds, both of which are related to southwest transport of the Attitti Block over the Archean Pelican Window (Ashton *et al.*, 1993; Ashton and Shi, 1994). These structures are overprinted and variably rotated by a widespread set of tight north-trending folds. Late north-northwest-trending faults mark the change to brittle conditions during uplift.

2. Unit Descriptions

a) Intermediate to Mafic Volcanic Suite

Dark green to black **mafic volcanic rocks (Am)** form units up to 100 m wide over much of the map area. Most are fine to medium grained, homogeneous to weakly layered, and consist of approximately equal proportions of hornblende and plagioclase with minor clinopyroxene. Up to 15 percent red garnet is present at some outcrops and locally defines metre-scale layering.

Volcanic rocks of intermediate composition (Ai) are locally interlayered with their mafic counterparts. They contain variable proportions of hornblende, biotite, quartz, and plagioclase with local garnet and cummingtonite. Most are better layered than the mafic rocks which may suggest a volcaniclastic origin.

Pale green, medium- to coarse-grained lenses, containing 10 to 50 percent clinopyroxene, 0 to 20 percent garnet, 0 to 10 percent carbonate, 30 to 60 percent plagioclase, and sulphide concentrations, comprise up to 30 percent of the intermediate to mafic volcanic rocks. They range in form from centimetre-scale pods to thick layers traceable over several metres. Some of these lenses may represent sweats but most are probably the metamorphosed products of syn-volcanic epidote alteration.

Mafic calc-silicates (Amc) occur along the east side of Lowe Bay. They contain abundant clinopyroxene, Ca-rich amphibole, biotite, and plagioclase, with minor carbonate and sulphides. They are thought to originate by pre-metamorphic carbonatization of mafic volcanic rocks.

The intermediate to mafic volcanic suite is thought to include the high-grade equivalents of andesitic to basaltic volcanic and volcaniclastic rocks. Some of the more homogeneous mafic rocks may have been derived from diabases and gabbros.

b) Felsic to Intermediate Volcanic Suite

A diverse suite of felsic to intermediate gneisses containing 5 to 30 percent combined biotite, hornblende, garnet, and clinopyroxene occurs throughout the area, but generally at a stratigraphic position between mafic volcanic and sedimentary rocks. Traces of pyrrhotite are present in most specimens and chalcopyrite, garnet-anthophyllite alteration, and magnetite concentrations occur locally.

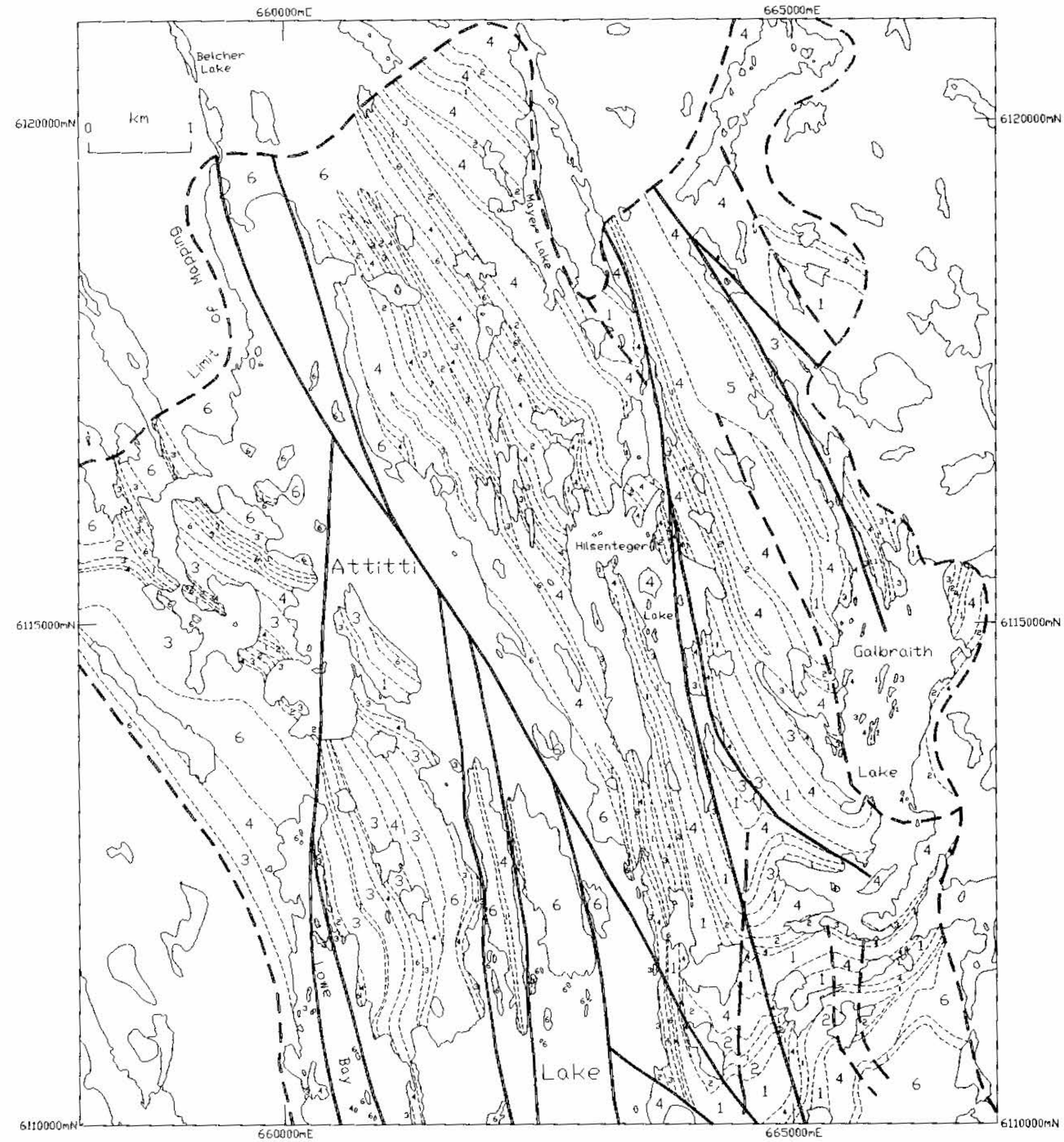
A volcanic, volcaniclastic, and/or hypabyssal origin is implied for the felsic to intermediate suite by its compositional similarity to lower-grade volcanic rocks, its close spatial association with mafic volcanic rocks, and by the near-ubiquitous presence of disseminated sulphides and associated alteration.

Several units have been recognized. The most common is a fine- to medium-grained, grey to white, **felsic to intermediate volcanic unit (Ad)** containing 15 to 30 percent combined hornblende, biotite and local garnet. Typical rocks generally display a weak centimetre- to decimetre-scale layering, some of which is probably primary. They are interpreted as dacitic flows and tuffs.

The dacitic volcanic and volcaniclastic (Ad) rocks commonly grade into **felsic calc-silicates (Adc)** containing diopside, minor sphene, and carbonate. This calc-silicate replacement may affect an entire unit or be quite patchy, ranging in thickness from a few centimetres up to a few tens of metres. The process is not restricted to the dacitic rocks, as it commonly affects several lithologies across strike. The largest masses occur in regional fold hinges where carbonate was likely remobilized during metamorphism and deformation. The calc-silicate rocks probably represent the metamorphosed equivalents of carbonatized volcanic and volcaniclastic rocks, although some may have originated as calcareous tuffs.

Interlayered with the dacites are thin layers of grey-white, fine- to less commonly medium-grained **felsic gneisses (Ar)** containing less than 15 percent biotite±hornblende. They are interpreted as metamorphosed rhyolites and rhyodacites. **Carbonatized varieties (Arc)** contain clinopyroxene and minor carbonate.

A unit of grey-white medium- to coarse-grained **quartz-rich gneisses (Ag)** has also been grouped with the felsic to intermediate volcanic suite. They contain about 10 percent biotite, 30 to 70 percent quartz, and 30 to 70 percent seriate feldspar, with local centimetre-size garnet porphyroblasts and abundant magnetite. The unit has a medium- to coarse-grained, pink leucosome, likely indicating an abundance of K-feldspar. Centimetre-scale layers containing up to 20 percent sillimanite with associated garnet and biotite are interpreted as sheared equivalents. The high proportion of partial melt material



LEGEND

6 - Gneissic to migmatitic granodiorite-tonalite
5 - Quartzofeldspathic gneiss
4 - Mixed metasedimentary rocks
3 - Felsic volcanic suite
2 - Intermediate volcanic suite
1 - Mafic volcanic suite

Figure 2 - Simplified geological map of the Galbraith-Attitti lakes area; solid lines=faults; and dashed lines=fold traces.

may suggest that they are diatexites derived from felsic volcanic or sedimentary precursors. The unit may also have been affected by pre-metamorphic silicification and aluminous alteration.

c) Sedimentary Rocks

Epiclastic sedimentary rocks generally occur as thin recessive sequences intercalated with rocks of the volcanic suite. Two units have been distinguished: 1) a heterogeneous sequence of mixed argillaceous to arenaceous biotite±hornblende±garnet±graphite gneisses, and 2) a more homogeneous sequence of aluminous biotite-garnet-graphite±sillimanite wackes.

The **mixed sedimentary rocks (As)** differ from the more homogeneous biotite-rich aluminous wackes by containing significant quantities of hornblende which, together with biotite, forms 20 to 35 percent of the rock. Garnet and cummingtonite commonly occur in minor abundances, and graphite forms up to several percent in places. The rocks typically weather grey to rusty and are variably layered. Although many leucocratic end members strongly resemble some of the rhyolitic to dacitic rocks, they contain graphite, which is taken to indicate a sedimentary origin. Their similarity to the dacites suggests a gradation from volcanic flow rocks into pyroclastic and epiclastic equivalents. The unit probably represents a variety of precursors, including calcic wackes, arenites, and tuffaceous rocks.

The more homogeneous **aluminous** garnet-biotite± sillimanite **wackes (Aw)** occur in layers tens to hundreds of metres in apparent thickness and are particularly abundant between Galbraith and Attitti lakes (Figure 2). Typical outcrops consist of grey, fine- to medium-grained psammopelites and almost completely melted pelites interlayered on a scale of decimetres to metres. White medium-grained partial melt occurs throughout and as centimetre-scale layers containing coarse seriate white plagioclase porphyroblasts. The aluminous wackes generally contain 15 to 30 percent biotite, 5 to 15 percent pink euhedral garnet and minor graphite. Sillimanite and tourmaline are minor constituents at many occurrences.

The mixed metasedimentary rocks (As) and most of the aluminous wackes (Aw) are correlative with the syn-volcanic Welsh Lake Assemblage exposed in the northern Amisk Lake area (Heaman *et al.*, 1993; Reilly, 1993). Some of the more extensive units of aluminous wacke (Aw) may represent infolded Burntwood Group rocks (Baldwin *et al.*, 1979) structurally emplaced from the Kisseynew Domain; however, extensive units of aluminous wackes are also known from the southern Flin Flon Domain (e.g. Wolf Lake area) where they are considered to be part of the syn-volcanic (Ashton, 1990; Ansdell and Connors, 1994) Welsh Lake Assemblage.

A thin unit of grey, fine- to medium-grained **quartzofeldspathic gneiss (Az)** is exposed northwest of Galbraith Lake (Figure 2). Typical outcrops include 25 to 65 percent medium-grained, white to pink, partial melt which lacks the seriate texture of the graphitic aluminous wacke leucosome. The rocks contain 20 to 30 percent ferromagnesian minerals including 15 to 20 percent biotite, 0 to 13 percent hornblende, 0 to 13 percent red anhedral to subhedral poikiloblastic garnet, and 0 to 3 percent magnetite.

The quartzofeldspathic gneisses (Az) are in sharp and probable tectonic contact with the aluminous wackes (Aw). Although they could be of felsic volcanic origin, their composition, broad homogeneity, magnetiferous nature, and locally pink leucosome, suggest correlation with Missi meta-arkoses, which are exposed 15 km to the north along the road linking Pelican Narrows and Sandy Bay. The Missi Group has been bracketed in the Flin Flon area between 1847 (Ansdell, 1993) and 1842 Ma (Heaman *et al.*, 1992).

d) Plutonic Rocks

In the Wildnest-Attitti lakes area, the inferred 1865 to 1845 Ma plutonic suite was divided into gneissic to migmatitic granodiorite-tonalites and a second unit of more leucocratic equivalents, one of which yielded a U-Pb zircon crystallization age of 1852 +6/-4 Ma (Heaman *et al.*, 1993). The same plutonic suite **(Gd)** occurs in the Galbraith-Attitti lakes area, but is more complex making the two end members more difficult to distinguish. This is because their compositions grade into one another and because the derived partial melts are similar to the leucogranodiorites.

The **gneissic to migmatitic granodiorite-tonalite (Gdh)** is well foliated and commonly contains abundant inclusions and schlieren of medium-grained intermediate to mafic material and 25 to 75 percent partial melt. The grey, medium-grained paleosome contains 5 to 15 percent hornblende and 5 to 15 percent biotite. The leucosome is coarser grained, white, and contains 5 to 10 percent hornblende, and 0 to 5 percent biotite.

The **leucogranodiorite** end member **(Gdb)** is distinguished on the basis of a lower colour index, a higher biotite:hornblende ratio, and weaker foliation. Typical samples are white to pink, medium grained, and contain 5 to 15 percent biotite±hornblende. The presence of accessory magnetite probably accounts for a weak linear aeromagnetic high located immediately east of the map area (Geological Survey of Canada, 1970).

e) Ultramafic Rocks

Medium- to coarse-grained, grey brown ultramafic rocks **(Um)** occur in a small body bounded by leucogranodiorite and heterogeneous metasediments at the north end of Hilsenteger Lake. They appear to consist of anthophyllite, clinopyroxene, and hornblende and are highly magnetic. A weak fracture cleavage is exhibited parallel to the main regional foliation, suggesting emplacement prior to at least most of the regional deformation.

Similar small bodies of ultramafic rock occur in leucocratic granodiorite-tonalites of the Wildnest-Attitti lakes area (Ashton and Leclair, 1991).

f) Late Medium-grained to Pegmatitic Granitoid Rocks

Deformed pink and white **granitoid dykes and irregular segregations (Gp)** occur throughout most of the area, generally comprising about 15 percent of most outcrops. They range from medium grained to pegmatitic and occur as concordant sheets and near-concordant transposed dykes about one metre thick. Typical rocks are leucocratic, containing several percent biotite and local garnet. The suite was probably emplaced during and immediately following the peak of metamorphism. A sheared sample of similar pegmatite from 20 km southwest of the study area yielded a U-Pb zircon age of 1806 ±2 Ma (Ashton *et al.*, 1992).

Rare weakly deformed to **massive pink pegmatites (Pg)** occur as concordant sheets and cross-cutting dykes, most of which are steeply oriented at about 060°. They average 30 cm in thickness and contain less than 5 percent biotite books and rare tourmaline crystals up to 3 cm. They are tentatively correlated with the ca. 1770 Ma Jan Lake Suite (Macdonald and MacQuarrie, 1978; Bickford *et al.*, 1987; Ashton *et al.*, 1992, 1993; Ashton and Shi, 1994).

3. Metamorphism

Widespread partial melting of the granodiorite-tonalite suite and most supracrustal rocks, together with the absence of hypersthene, indicates that the Galbraith-Attitti lakes area was metamorphosed at upper amphibolite facies conditions. Sillimanite-K-feldspar assemblages in the quartz-rich gneisses (Ag) suggest that the second sillimanite isograd was exceeded.

Peak pressures are bracketed between 6 and 8 kbar by the presence of sillimanite as the only Al_2SiO_5 polymorph and by the absence of prograde cordierite in pelitic rocks. P-T studies in the Wildnest-Attitti lakes area to the south suggested that peak conditions were in the 6.6 to 7.9 kbar, 630° to 725°C range (Ashton and Digel, 1992), although the generally higher degree of partial melting in the present area suggests that these may represent minimum values. A U-Pb zircon date of 1807 +3/-2 Ma obtained from a felsic volcanic rock sampled in the southern Attitti Lake area is interpreted as the age of peak metamorphism (Heaman *et al.*, 1992).

4. Structure

a) D_1 and D_2 Structures

The earliest regional foliation (D_1) was enhanced or overprinted by a D_2 isoclinal folding event which produced extensive unit repetition. Large granodioritic to tonalitic plutons were highly attenuated at this time producing thin, but continuous, units traceable over tens of kilometres.

b) D_3 Structures

D_3 deformation produced a set of southwest-verging minor folds and a northeast-plunging stretching lineation, both of which are best developed in the western part of the area where the regional foliation dips consistently northeast. Intrafolial minor folds plunge gently to moderately southeast. The down-dip stretching lineation is part of a widespread linear fabric seen throughout the Attitti Block to the west (Ashton *et al.*, 1993). Both the minor folds and stretching lineation are thought to result from southwestward thrusting of the Attitti Block over Archean rocks of the Pelican Window and are broadly coeval with the formation of the Pelican Slide (Ashton *et al.*, 1993; Ashton and Shi, 1994) and Sturgeon-weir Shear Zone (Ashton *et al.*, 1987; Lewry, 1994).

c) D_4 Structures

The large regional fold dominating the area is the northern extension of the Ewen Lake Synform (Pyke, 1961; Ashton and Leclair, 1991). It is a tight, gently north-plunging, D_4 structure with a moderately to steeply east-dipping axial plane. Early D_3 structures are rotated in the hinge of the Ewen Lake Synform producing a complex outcrop pattern. D_4 minor folds displaying a similar appearance and geometry to the megascopic fold are common throughout the area. A linear fabric developed parallel to the fold hinge is particularly common in the hinge of the megascopic fold.

d) D_5 Structures

Topographic lineaments help to define a set of late mainly north-striking brittle faults. Rare exposures consist of retrogressed cataclastic rocks displaying a strong fracture cleavage. Faults were inferred where outcrops adjacent to marked lineaments contain abnormally abundant fractures lined with hematite, quartz and/or epidote. A component of sinistral displacement has been inferred regionally (Pyke, 1961; Ashton and Leclair, 1991) and some dip slip is suggested by the disappearance or thinning of units across individual faults. The faults may have developed late during D_4, but remained active for some time. They are probably correlative with a widespread set which includes the Ross Lake (Stauffer and Mukherjee, 1971), Waskwei-Granite Lake (Ashton *et al.*, 1987), Maligne Lake (Lewry, 1994), Sandy Narrows, and Tabbernor faults (Ashton and Balzer, this volume).

5. Mineral Potential

As the Galbraith-Attitti lakes area is a metamorphosed extension of the Flin Flon volcanic belt, it has significant potential for volcanogenic massive sulphide (VMS) and gold mineralization. VMS deposits are known in the Attitti Block (e.g. Schotts Lake VMS deposit; Pearson, 1986; Coombe Geoconsultants Ltd., 1991) and local oxide- and sulphide-facies iron formations indicate that the region was hydrothermally active prior to metamorphism. Several garnet-anthophyllite occurrences to the south mark metamorphosed zones of Fe-Mg metasomatism, and zones of aluminous alteration have also been reported (Ashton and Leclair, 1991).

Disseminated pyrrhotite and chalcopyrite are present throughout the volcanic rocks in the Galbraith-Attitti lakes area. An outcrop of dacitic gneisses (Ad) in Lowe Bay (UTM 660381E, 6111832N) contains about 1 percent chalcopyrite with trace pyrrhotite.

Garnet-anthophyllite-biotite±cordierite±sulphide rocks occur at several localities (see accompanying map). Similar rocks occur at virtually all volcanogenic massive sulphide deposits in amphibolite facies rocks of the Reindeer Zone and elsewhere (Ashton, 1979; Coombe Geoconsultants Ltd., 1991). They are thought to mark zones of syn-volcanic Fe-Mg metasomatism and are suggested as focal points for future exploration programs. However, due to the intense deformation and highly attenuated nature of all units in the Galbraith-Attitti area, potential massive sulphide bodies may have become detached from their alteration zones.

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