METALLOGENIC STUDIES OF GRANITE-ASSOCIATED MINERALIZATION IN THE ACKLEY GRANITE AND THE CROSS HILLS PLUTONIC COMPLEX, FORTUNE BAY AREA, NEWFOUNDLAND

by

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Abstract

Cassiterite-bearing quartz-topaz greisen occurs in easterly trending veins and pods within the Ackley Granite, and as larger pods at the granite contact in the Sage Pond - Gisborne Lake area.

Minor anomalous radioactivity is associated with east-northeast trending fractures, and with aplite veins, near the roof of a riebeckite-bearing peralkaline granite which was emplaced late in the intrusion history of the Cross Hills Plutonic Complex.

Metallogenic models for granitoid mineralization in the Fortune Bay area suggest evolution of magmatic fluids during latest pluton emplacement and crystallization, with vertical rise and ponding of these fluids at or near the granite roof.

Introduction

This project is designed to develop metallogenic and exploration models for granite-associated mineralization in the Ackley Granite and Cross Hills Plutonic Complex, southeastern Newfoundland. It commenced in April, 1983. Field data collected during the 1983 field season will form the basis for a Ph.D. study by the author at Memorial University of Newfoundland.

Previous Work

Regional mapping in the area has been performed by Bradley (1962), Williams (1971), O'Brien and Nunn (1980), O'Brien et al. (1980a,b) and Dickson (1983).

Subeconomic aplite-pegmatite molybdenum deposits have long been known in the Rencontre area, and occur within the granite at the contact of a fine to medium grained porphyritic phase of the Ackley Granite with volcanic rocks of the Belle Bay Formation (Figure 1). The geology, geochemistry and exploration history of these deposits were described in detail by Whalen (1976, 1980, 1983).

Cassiterite-bearing quartz-topaz greisen veins have recently been identified by Esso Minerals Limited, and by the Newfoundland Department of Mines and Energy (Dickson, 1982; Dickson and Howse, 1982) in the Anesty Hill - Sage Pond area (Figure 1). These veins occur within a fine to medium grained, porphyritic marginal phase of the Ackley Granite and increase in concentration and size toward the granite contact (Dickson, 1983).

A peralkaline phase of the Cross Hills Plutonic Complex with minor anomalous radioactive zones has been identified by Saarberg Interplan, and anomalous assay values to a maximum of 285 g/t Sn, 133 g/t Ta, 2334 g/t Nb, 68 g/t U, 968 g/t Th, and 2% Zr have been reported by Hopfengartner (1982).

Work Performed - 1983 Field Season

(1) Quartz-topaz veins were mapped in detail along the Ackley Granite contact between Rabbit Pond and Gisborne Lake (Figure 2).

(2) Samples were collected from the quartz-topaz veins in the Sage Pond area (Figure 2) and from the molybdenite prospects at Motu, Ackley City, Crow Cliff - Dunphy Brook, and Wyllie Hill for geochemical analysis and for fluid inclusion studies (Figure 1). All known molybdenum occurrences in the Ackley Granite were examined and sampled, and samples were collected

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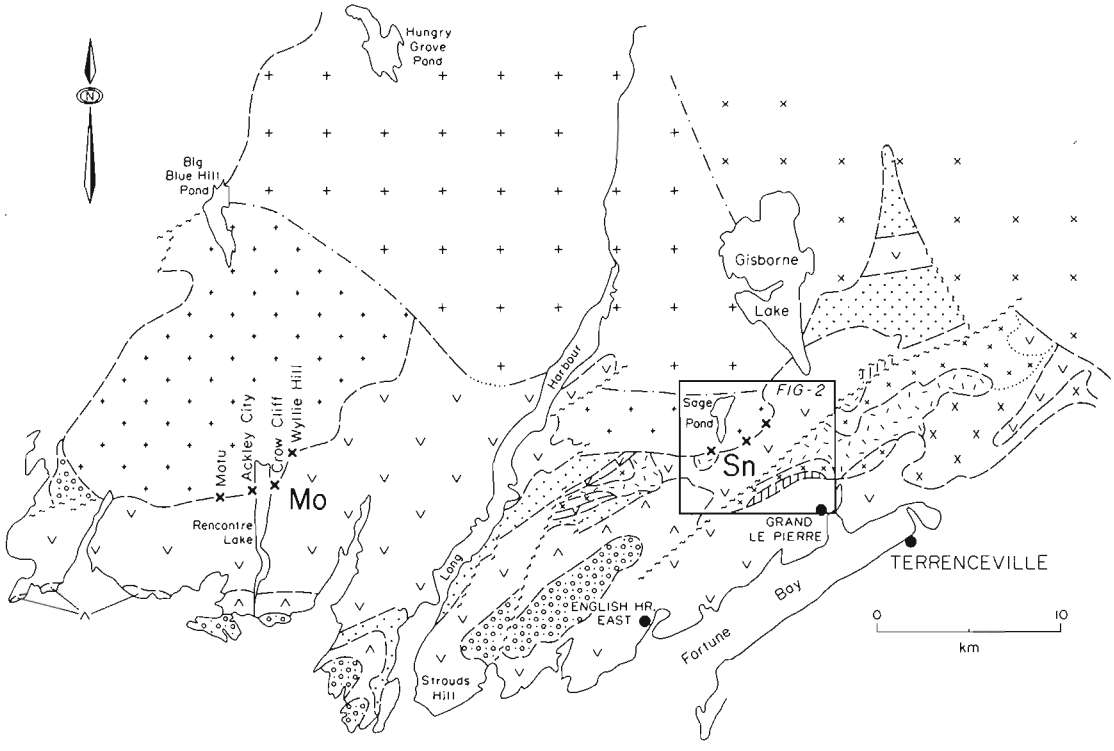


DEVONIAN - ACKLEY GRANITE

- *Massive, porphyritic coarse grained biotite granite.*
- *Massive, uniform coarse grained biotite granite.*
- *Fine to medium grained porphyritic biotite granite.*

DEVONIAN or PRECAMBRIAN - CROSS HILLS PLUTONIC COMPLEX

- *Fine to medium grained peralkaline granite.*
- *Medium to coarse grained hornblende biotite granodiorite.*
- *Fine to medium grained biotite granite (alaskite?).*
- *Gabbro-diabase multiple intrusions.*

PRECAMBRIAN - LONG HARBOUR GROUP

- Rencontre Formation - *red sandstone and conglomerate.*
- Mooring Cove Formation - *felsic tuff, ash flows and massive felsite.*
- Anderson's Cove Formation - *fine to medium grained gray sediment.*
- Belle Bay Formation - *felsic flow and pyroclastic rocks, basalt flows.*

Figure 1

General geology north of Fortune Bay, Newfoundland.

from the Strouds Hill fluorite prospect at the south end of Long Harbour (Figure 1).

(3) The Cross Hills Plutonic Complex west of Grand Le Pierre and Precambrian volcanic rocks between the Cross Hills Plutonic Complex and the Ackley Granite were mapped at a scale of 1:15,000 (Figure 2). Several traverses were made over the Cross Hills Plutonic Complex to the east of Grand Le Pierre.

General Geology (Figure 1)

Plutonic rocks in the area of interest to the north of Fortune Bay intrude Precambrian subaerial metavolcanic and metasedimentary rocks of the Long Harbour Group (Williams, 1971; O'Brien and Nunn, 1980) in the Avalon terrane of the Newfoundland Appalachians (Williams and Hatcher, 1983).

The Long Harbour Group has been subdivided into four separate conformable formations (Bradley, 1962; Williams, 1971; O'Brien and Nunn, 1980). The stratigraphically lowest Belle Bay Formation is dominated by felsic ash flow deposits and epiclastic sediment with minor basalt flows, and is overlain by fine to medium grained sedimentary rocks of volcanic derivation belonging to the Anderson's Cove Formation. The overlying Mooring Cove Formation consists of interbedded silicic flows, felsite (commonly with peralkaline affinity; O'Brien, personal communication, 1983) and mafic flows. The Rencontre Formation, a red to purple fining-upward conglomerate to sandstone sequence, overlies the Mooring Cove Formation.

The Cross Hills Plutonic Complex intrudes the Belle Bay and Anderson's Cove Formations and consists of a complex mixture of diabase, gabbro, granodiorite,

alaskite, and peralkaline granite, along with abundant xenoliths and roof pendants of silicic volcanic and mafic intrusive-extrusive rocks. The Cross Hills Plutonic Complex has not been dated; however, observation that gabbroic phases are cut by the Ackley Granite, and that there is a general lack of deformation and metamorphic effects has led to a consensus that these plutonic rocks are Devonian in age (Bradley, 1962; O'Brien and Nunn, 1980). The peralkaline granite phase of the Cross Hills Plutonic Complex is geochemically comparable to peralkaline silicic volcanic rocks of the Mooring Cove Formation (O'Brien, personal communication, 1983), and an age of Devonian or Precambrian may be inferred for both. The generally accepted stratigraphic ages for both units are depicted in Figures 1 and 2, pending resolution of this problem.

The Devonian Ackley Granite occupies an area of 3000 km^2 and has been divided into seven major units based on texture, mineralogy and geochemistry (Dickson, 1983), with the three most differentiated southern units having a silica content of greater than 72%. Fine grained, extremely differentiated marginal granite phases occur along and near the southern contact of the Ackley Granite, and exhibit strong trace element variation trends (Whalen, 1976, 1980, 1983; Dickson, 1983). The marginal phases hosting mineralization are fine grained to porphyritic, miarolitic biotite 'alaskite' granite, and minor occurrences of tuffisite are present. Quartz crystals and quartz-feldspar pegmatite patches are ubiquitous in the fine grained granite of the Rencontre area but are rare to absent in the fine grained granites in the Sage Pond - Gisborne Lake area. In the Fortune Bay area, the Ackley Granite cuts the Belle Bay and Anderson's Cove Formations as well as gabbroic rocks of the Cross Hills Plutonic Complex, and has been dated at about 355 Ma (Bell et al., 1977; Dallmeyer et al., 1983).

Geology, Sage Pond - Grand Le Pierre Area (Figure 2)

Volcanic Complex (Units 1 and 2)

The English Harbour volcanics (Bradley, 1962) south of the Cross Hills Plutonic Complex consist of massive to slightly fractured, light to dark rhyolite flows, welded ash flow deposits, breccias, and tuff (Unit 1a).

North of the Cross Hills Plutonic Complex, rocks mapped as belonging to the Belle Bay volcanic formation and the Anderson's Cove terrestrial metasedimentary formation (Bradley, 1962; O'Brien and Nunn, 1980) consist of a strongly foliated volcanic to volcano-sedimentary sequence (Unit 1b) composed of coarse, locally welded rhyolite breccias and tuff, waterlain tuff and sediment, slate, siltstone, quartz-sericite schist, diabase and basalt flows (Unit 1c). These rocks exhibit rapid lateral and vertical facies variations. They appear to be in fault contact with a massive banded to brecciated ash flow unit (Unit 1d) containing minor (<2%) disseminated and fracture-filling pyrite which occurs along the southern contact of the Ackley Granite. In the western part of the map area, purple-brown ash flow and fine tuff units (Unit 2) of the Mooring Cove volcanics (Bradley, 1962) overlie purple welded to nonwelded, massive to layered breccias, banded rhyolite, basalt flows, and minor siltstone.

Moderate to tight chevron folding of the layered tuff and siltstone and the ash flow banding occurs locally. This factor, coupled with the massive nature of the rocks, makes definitive structural and/or stratigraphic analyses of the volcanic sequence difficult. Bradley (1962) and O'Brien and Nunn (1980) suggested that large scale moderate to tight folding of the volcanic sequence occurred along an east-northeast axis.

The Anderson's Cove Formation is absent from the succession in this area, which suggests a local disconformity or unconformity.

Cross Hills Plutonic Complex (Unit 3)

Three main intrusive phases occur in the Cross Hills Plutonic Complex to the northwest of Grand Le Pierre.

3a: A fine to coarse grained diabase-gabbro unit intrudes Precambrian volcanic rocks and is composed of multiple intrusions of diabase and gabbro. Veining by fine to pegmatitic gabbro is common.

3b: A fine to medium grained, orange, 'alaskitic', miarolitic biotite granite intrudes the diabase-gabbro and locally intrudes volcanic country rocks. Extensive stoping of the gabbro-diabase is common and vertical subparallel biotite granite dikes trending 070° to 080° occur near the southern margin of the gabbro-diabase unit.

3c: A fine to medium grained purple-brown, miarolitic, riebeckite peralkaline granite occurs to the south and also above the biotite granite and has intruded the gabbroic and

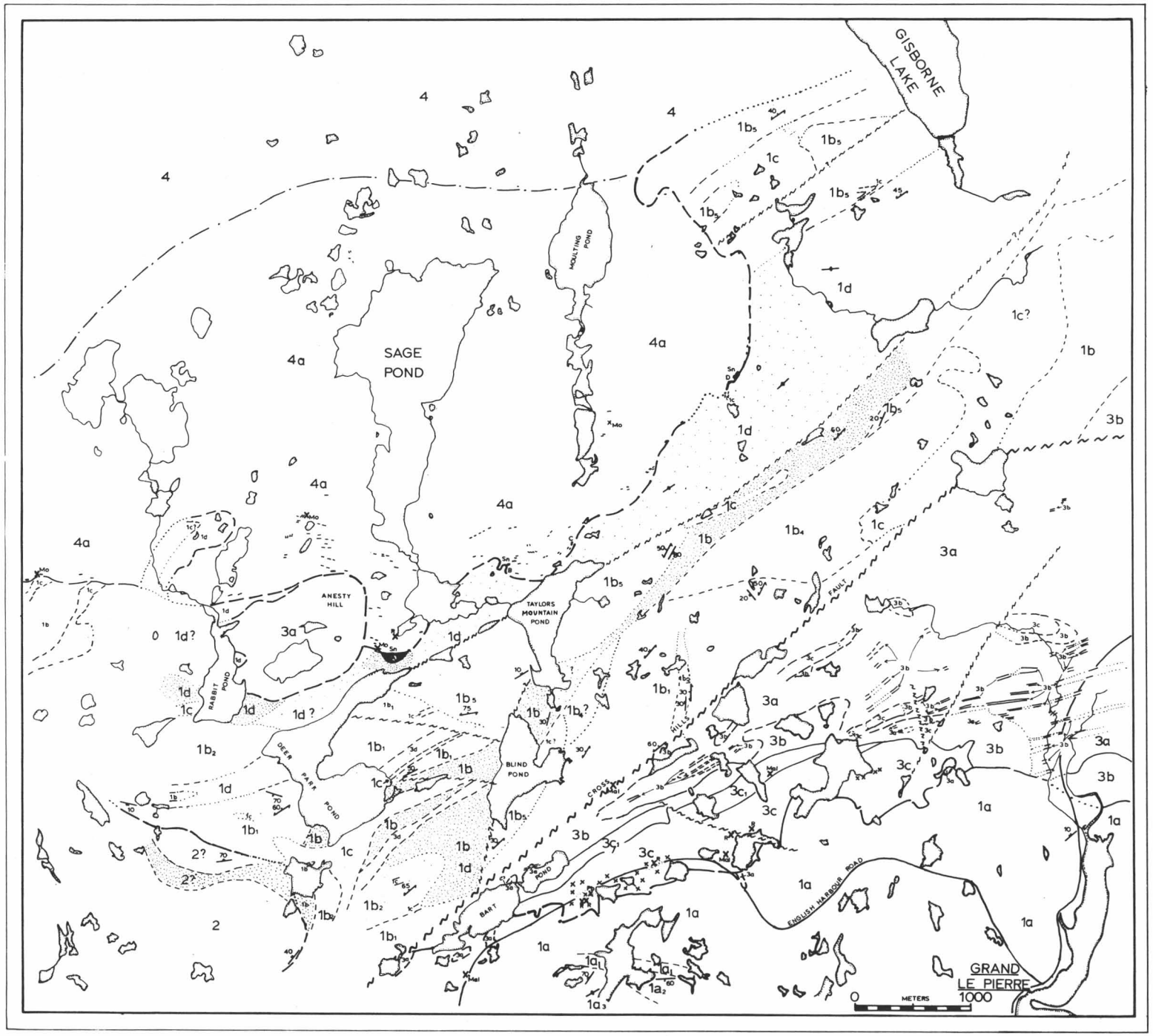


Figure 2: *Geology of the Grand Le Pierre - Sage Pond area, Fortune Bay, Newfoundland.*

LEGEND (Figure 2)

PLUTONIC ROCKS

DEVONIAN - ACKLEY GRANITE

Quartz-topaz and/or quartz-muscovite greisen. Less than 10 by 2 m except where lettered.

4a *Fine to medium grained, orange quartz-feldspar-porphyritic granite.*

4 *Medium to coarse grained equigranular biotite granite.*

DEVONIAN - possibly PRECAMBRIAN - CROSS HILLS PLUTONIC COMPLEX

3d *Very fine grained, red-brown aplite (?).*

3c *Fine to medium grained, miarolitic red-brown peralkaline granite;* $3c_1$*, orange to red-brown mottled aplite.*

3b *Fine to medium grained biotite (''alaskite?'') granite.*

3a *Diabase-gabbro multiple intrusions; can contain up to 30% veins and stockwork of 3b.*

VOLCANIC AND SEDIMENTARY ROCKS

HADRYNIAN - LONG HARBOUR GROUP

2 Mooring Cove Formation: *fine red-brown tuff and layered welded ash-flow units.*

1 Belle Bay Formation: *felsic pyroclastic and sedimentary rocks, felsic flows, and basalt flow.*

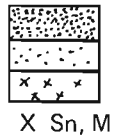
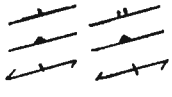
1d *Rheoignimbrite: massive welded and layered ash-flow tuff, breccia, and nonwelded massive tuff.*

1c *Foliated to massive vesicular basalt flow, agglomerate, and/or diabase.*

1b *Foliated felsic breccia, ignimbrite, tuff and flow, minor welded units and sediment:* $1b_1$*, purple breccia and minor welded breccia and massive flow;* $1b_2$*, gray, locally welded breccia;* $1b_3$*, bedded to laminated fine to coarse sediment;* $1b_4$*, dark green, fine to medium grained, massive waterlain tuff or sediment* $1b_5$*, laminated to bedded gray, fine silicic tuff, phyllite and sericite schist; minor coarse breccia.*

1a *Massive buff to green, nonwelded polylithic breccia, vesicular and/or feldspar porphyritic flow:* $1a_1$*, welded gray breccia with devitrification textures;* $1a_2$*, massive to bedded, medium to coarse, red and green sediment;* $1a_3$*, welded laminated ash-flow deposits.*

SYMBOLS

2% pyrite, sericite alteration, and gossanous	
1-2% disseminated and stringer pyrite, may be gossanous	
Hematite-limonite alteration	
>1000 g/t Sn assay; visible molybdenite and galena	X Sn, Mo, Pb
Malachite stain related to minor chalcocite and bornite	X Mal
Anomalous radioactivity, maximum 6 x background	X R
Bedding (tops known, unknown)	
Flow layering (inclined, vertical)	
Foliation (inclined, vertical)	

volcanic rocks. The riebeckite granite contains late fine grained veins, and tuffisite breccias related to gas-release from the crystallizing magma. Granophyric texture is common, and small granitic pegmatite patches are locally present. In the western part of the area mapped in detail, a mottled, orange-brown aplite unit ($3c_1$) with sharp vertical contacts occurs between the biotite granite and medium grained peralkaline granite. In the east, the contact between biotite granite and peralkaline granite is marked by a gradual color change. The northern boundary of the medium grained peralkaline phase is noted by a decrease of 30 to 50% in background total count radioactivity.

Three areas of peralkaline granite to the north and east of the main exposure occur topographically above biotite granite and probably form the upper portion of east-northeast trending biotite granite dikes. Red-brown aplite (Unit 3d) intrudes the Belle Bay Formation east of Deer Park Pond.

West of Grand Le Pierre, the Cross Hills Plutonic Complex appears to mark a phase of south-southeast/north-northwest crustal extension. Initial multiple intrusion of gabbro-diabase occurred, followed by stoping and intrusion of the gabbro and diabase by biotite granite. Differentiation to form a roofward or marginal peralkaline phase may have taken place in the larger silicic magma chambers.

Preliminary investigation of the Cross Hills Plutonic Complex east of Grand Le Pierre indicates a comparable history, with diabase being the more abundant mafic intrusive rock stoping into the volcanic rocks. East-northeast trending diabase dikes also commonly intrude the Precambrian volcanic rocks. Fine to medium grained biotite granite is the most common silicic lithology east of Grand Le Pierre, with minor patches of peralkaline granite noted. A medium to coarse grained hornblende-biotite granodiorite with abundant volcanic and diabase xenoliths is confined to the eastern portion of the complex; it has intruded the main diabase unit, and has locally been intruded by gabbro and thin aplite dikes. The relationship between the hornblende-biotite granite and the biotite granite has not been observed. Diabase, stoped by granite, occurs at the Southeast Bight Hills.

Ackley Granite (Unit 4)

The Ackley Granite consists of fine to medium grained, miarolitic, quartz-feldspar porphyritic biotite granite in its southern exposures (Unit 4a) and grades northward into a medium to coarse grained biotite granite (Unit 4). Phenocryst content averages from 10 to 20%. A coarse porphyritic phase with 40 to 50% phenocrysts is host to the greisen veins southeast of Moulting Pond. Topographic relief over the granite is gentle with little exposure, whereas the volcanic country rocks to the south form rugged topographic features and are well exposed.

The dip of the granite contact varies from vertical to shallow, with possible roof pendants present west of Anesty Hill and east of Moulting Pond.

Mineralization and Alteration, Sage Pond - Grand Le Pierre Area (Figure 2)

Volcanic Sequence

Extensive sericite alteration, commonly with 1 to 2% disseminated and fracture-filling pyrite and local zones of up to 5% pyrite, occur throughout the volcanic sequences in the area. Minor alteration with stockwork pyrite is a common feature marginal to the Ackley Granite and has been described from the molybdenite showings in the Rencontre area (Whalen, 1976); it probably resulted from late magmatic-hydrothermal processes associated with emplacement of the Ackley Granite. The pyritic alteration zones in the map area are in part related to the Ackley Granite. However, many of the pyritic zones may have a tectonic and/or synvolcanic origin. No base metal mineralization was observed; however, a potential exists for both gold mineralization and base metal mineralization within the volcanic sequence.

Peralkaline Granite - Cross Hills Plutonic Complex (Figure 2)

Throughout the peralkaline granite, zones of hematite and limonite stain occur with possible sericitic alteration and about 2 to 5% pyrite, and are developed over an area of 1000 by 200 m along the English Harbour road. Local 'veins' of gray-green intense sericitic alteration have been noted over a strike length of 30 m and a width of 3 m. These veins contain 1 to 5% disseminated and fracture-filling pyrite with trace amounts of galena. The alteration is related to late east-northeast fractures and breccia zones in the pluton.

A zone of anomalously radioactive patches from 2 to 5 times background, trending 070°, was noted in the granite over a strike length of 100 m southeast of Bart Pond. Individual anomalous patches are

less than 2 by 0.5 m, and are related to hairline fractures near the granite roof. Several 2 m diameter areas of anomalous radioactivity up to 6 times background were noted elsewhere and are associated with hairline fractures or late aplitic veins in the peralkaline granite.

Traces of chalcocite with minor malachite stain were noted in two separate, late crosscutting quartz veins (maximum width 1 m) in the granitic phases of the Cross Hills Plutonic Complex.

A general metallogenic model suggests marginal and roofward concentration of volatile and ore elements in a silicic magma chamber with potential mineralization (Nb, Zr, Sn, Th, F?) at or near the roof contact either as aplite or pegmatite sheets, or as veins in postcrystallization fracture zones. A possibility exists for economic mineralization in late crystallizing differentiates.

Quartz-Topaz Veins in the Ackley Granite

The main concentration of white, medium to coarse grained quartz-topaz veins occurs between Rabbit Pond and Gisborne Lake at and near the south contact of a fine to medium grained porphyritic marginal phase of the Ackley Granite. Quartz-topaz veins have been noted as far west as Long Harbour and have been observed within the granite up to 3 km from the contact. They increase in concentration and size southward, with the largest quartz-topaz outcrops occurring at convex undulations of the granite contact. Veins are podiform-elongate with a predominant easterly trend (080° to 110°) and are generally less than 10 by 2 m. They form knobs of outcrop or suboutcrop in weathered granite till or in areas of weathered granite subcrop.

Subparallel quartz-topaz ± pyrite ± hematite ± molybdenite ± fluorite vein swarms (fracture-fillings to 3 m wide veins) underlie massive quartz-topaz outcrop (50 by 6 m) at the Esso Minerals Ltd. drill site southwest of Moulting Pond. Sericitization and bleaching (± pyrite) of the host orange-red granitic quartz-feldspar porphyry is limited to within 1 m of individual veins and is generally narrower than vein width. Gray-green muscovite-quartz-topaz greisen commonly occurs marginal to massive quartz-topaz but can occur as individual veins. Fine fracture networks are common in the unaltered granite host and minor disseminated pyrite may be present in granite near the veins. Intense fracture networks with pyrite coatings are present in the volcanic rocks adjacent to the granite contact.

South of Anesty Hill, massive quartz-topaz rock (± pyrite ± fluorite with occasional grains of molybdenite) outcrops over an area of 200 by 60 m within a convex south lobe of the granite. Gently dipping layering (20° to 40° south), defined by variation of topaz and quartz content and of grain size, suggests an area where fluorine-rich fluids were ponded near the granite roof. Rhyolite outcropping immediately south and west of the Anesty quartz-topaz body is strongly sericitized, suggesting that the greisen zone plunges to the south and west under the rhyolite.

A generalized model is envisaged in which fluorine ± tin-rich magmatic fluids evolved from a rapidly crystallizing marginal granite phase and rose along east trending fractures in consolidated granite to collect in embayments at the granite margin and roof (see Dickson, 1983). A potential exists for large tonnage, low grade stockwork deposits in addition to high grade vein and massive greisen deposits.

Comparable mechanisms involving extreme differentiation, roofward migration of molybdenum-rich magmatic fluids, and collection of these fluids in pockets at the granite roof have been proposed for the origin of the molybdenite deposits in the Rencontre area (Whalen, 1976, 1980, 1983; Dickson, 1983).

Minor Copper Occurrences, Grand Le Pierre Area

Minor malachite stain associated with chalcocite and/or bornite mineralization in fractures was noted (1) in sheared rhyolite breccia in the Cross Hills Fault zone northeast of Bart Pond (Figure 2); (2) in rhyolite breccia approximately 5 m west of the contact of the granodiorite phase of the Cross Hills Plutonic Complex on the Grand Le Pierre - Terrenceville road; and (3) in rhyolite on the west side of the English Harbour road at the southwest limit of the area mapped (Figure 2).

Other Occurrences of Alteration and Mineralization, Fortune Bay Area

(i) Several beryl crystals up to 3 by 1 cm were noted in a 50 by 20 cm quartz pocket in the fine grained phase of the Ackley Granite to the southeast of Big Blue Hill Pond (UTM 343 967, 1M/14).

(ii) Three molybdenite flakes (up to 1 cm) were noted in a roadside quartz vein on the east margin, and fluorite veinlets were observed near the

western margin of the Berry Hill Stock on the Burin Peninsula.

(iii) Silicified and/or sericitized zones (in fine grained Precambrian tuff and sediment) with 1 to 5% disseminated and/or stringer pyrite were noted over a width of up to 70 m on the Monkstown road (east of the Burin Highway). Minor fine grained chalcopyrite may be present locally. Other pyrite occurrences are present on the Burin Highway. These may represent synvolcanic hydrothermal exhalative or subvolcanic epithermal processes, and a potential for base metal and/or gold mineralization is evident.

A blue phosphate-rich mineral, tentatively indentified as lazulite, was noted in a 50 by 10 m quartz-specularite vein at UTM 888 877 on NTS 1M/9, immediately north of the Monkstown Road.

(iv) Molybdenite occurrences reported at Hungry Cove Pond and at Spout Brook, and a Mo-Bi showing at Big Blue Hill Pond (Anderson, 1965) could not be located. A vertical quartz vein with maximum dimensions of 1.5 m by 5 cm containing minor pyrite and possible trace wolframite was observed at the Big Blue Hill Pond locality.

(v) Swarms of narrow, subvertical quartz-muscovite greisen veins were noted at two localities southeast of Big Blue Hill Pond (UTM 356 937 and 364 948; 1M/14); grab samples analyzed 1150 and 130 g/t tin, respectively. Veins observed have a maximum dimension of 30 cm by 10 m and trend 060° to 070°. A maximum vein density is 2 to 3 per metre.

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