2017 RECONNAISSANCE TILL-INDICATOR MINERAL AND GLACIAL MAPPING STUDY, HOPEDALE BLOCK, NTS MAP AREAS 13N AND 13M, LABRADOR

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ABSTRACT

In July 2017, a reconnaissance till-indicator mineral, till-geochemistry and glacial mapping study was initiated in the Hopedale Block, Labrador, to test the application of indicator minerals (IM) for tracing mineralization sources. This study is part of a larger collaborative project between the Geological Survey of Canada (GSC) under its Geomapping for Energy and Minerals (GEM) Program, the Geological Survey of Newfoundland and Labrador (GSNL) and the Nunatsiavut Government, to better understand the geology and mineral potential of the Hopedale Block.

The surficial geology north and west of the Hunt and Adlatok rivers consists of thin (less than 2 m) but continuous till veneer on hilltops, with ridged moraine and ice-contact sediments in valleys. South of the Hunt River, there is discontinuous till distribution on hilltops, and postglacial marine and fluvial sedimentation in the Adlatok River valley. Preliminary results from striations and other ice-flow indicators suggest an east-northeast ice-flow, with a (more localized?) east-southeast flow. Preliminary surficial mapping conducted in the in the Sarah Lake area (eastern portion of NTS map area 13M), revealed crescentic ribbed and disintegration moraine, and ice-proximal glaciofluvial deposits bounded by west–east-oriented streamlined landforms (e.g., crag-and-tails). The orientation of the streamlined landforms and moraines suggest that a west–east-flowing ice mass was blocked, with east-northeast and east-southeast deflection, and in-situ melting of the remnant ice. In this area, early deposited till has been re-entrained and eroded, and results of till-geochemical sampling programs may reflect this.

Eight 15–21 kg till samples representing different bedrock types were sent for processing by tabling and heavy-liquid separation to recover the heavy-mineral fraction for gold and indicator mineral grain counts, including kimberlite (KIM) and metamorphic and massive sulphide indicator (MMSIM) minerals. The results of the indicator mineral examinations have already been presented in Open File LAB/1743; the current contribution explains these results as they relate to the bedrock and mineral occurrences proximal to sample sites.

Grain counts revealed gold, and the metamorphic and massive sulphide indicator minerals galena, chalcopyrite, molybdenite and scheelite in till concentrates. Non-ore bearing MMSIM’s (e.g., apatite, red rutile) were also found. No KIM’s were observed. Gold grains were recovered from four of the IM samples, including two samples taken in till overlying or dispersed from known occurrences. The source of the gold in the other two samples is unknown; however, IM assemblages suggest that there may be unrecognized sources of Aucoin-type (orogenic) and porphyry or skarn Cu–Au–Mo mineralization up-ice of, or underlying, the locations of the till samples.

These results demonstrate the potential of using IM in tills to characterize bedrock mineral assemblages and detect the responses to known and unknown mineralization. In addition, the till IM results, coupled with the newly acquired airborne magnetic data, assisted in identifying prospective localities for the 2018 sampling program. Till IM sampling, in conjunction with traditional till geochemistry and pebble-lithology indicator studies, is suggested for future work in map area 13M.
INTRODUCTION

This surficial study was initiated in July 2017 under the Geological Survey of Canada’s Geomapping for Energy and Minerals (GEM) Program in collaboration with the Geological Survey of Newfoundland and Labrador (GSNL) and the Nunatsiavut Government. The objectives of the GEM project in Labrador are outlined by Corrigan et al. (2018). The goals of this reconnaissance surficial study are to test the efficacy of indicator mineral (IM) methods to identify mineral assemblages that are characteristic of mineralization and bedrock in the region.

Fieldwork for this study was conducted, concurrently with a bedrock-geological mapping, sampling and geochronology program. Sample sites were chosen for their bedrock geological significance. Till samples were collected from till veneer and mudboils, proximal to bedrock outcrop. Eight bulk till samples (15–21 kg) were collected for IM analysis, along with smaller 3–5 kg till samples for matrix geochemical analysis, and pebbles for coarse clast analysis. The samples were collected using GEM Program procedures (see Spirito et al., 2011 and McClenaghan et al., 2013). The IM results are published in Department of Natural Resources, Geological Survey of Newfoundland and Labrador, Open File LAB/1743 (Campbell and McClenaghan, 2019).

LOCATION

The study area is remote, accessible only by helicopter, and located west of the coastal community of Hopedale. Vale Canada Inc.’s Voisey’s Bay Ni–Cu–Co mine is located 110 km north of the study area, west of the community of Nain. The area of study encompasses Big Bay in the northeast (Figure 1), to Uğjoktok Bay to the southeast and extends to the Harp Lake Complex in the southwest and Pants Lake in the northwest.

PHYSIOGRAPHY

The northern part of the study area is characterized by bedrock ridges with moderate till cover, and broad, glacially sculpted valleys that drain toward the coast from a high plain west of Sarah Lake and Harp Lake (Figure 1). The highlands east of Sarah Lake and north of Hunt Lake are underlain by resistant plutonic bedrock of the Nain Plutonic Suite and the Flowers River intrusive suite. Southwest of Sarah Lake, the uplands of the Harp Lake Complex are characterized by sparse glacial cover and vegetation, and incised by deep valleys, with Harp Lake itself occupying the most prominent of these (Lopoukhine et al., 1977). South and west of Hunt Lake, forested ridges and lowlands have been burned over, exposing boulders, sand and till. Toward the coast, ridges have commonly been scoured by glacial erosion and washed by marine inundation and thus are only sparsely covered by drift. Valleys, particularly those that drain into Big Bay and Flowers Bay to the northeast of the study area, are filled with glaciofluvial and glaciomarine sediment. Modern fluvial systems, including the Hunt and Adlatok rivers, are incised through glacial fluvial and marine sediments, and drain into Big Bay and Uğjoktok Bay, respectively.

REGIONAL BEDROCK GEOLOGY AND MINERALIZATION

The following is a brief summary of the regional bedrock geology of the study area. For a more detailed overview of the regional geology, the reader is referred to: Kranck (1953); Christie et al. (1953); Douglas (1953); Jesseau (1976); Taylor (1971, 1977); Ermanovics (1979, 1980, 1981a, 1993); Ermanovics and Korstgard (1981); Ermanovics and Raudsepp (1979); Grant et al. (1983); Thomas and Morrison (1991); Hill (1982a, b, c); Bertrand et al. (1993); Miller (1994); Wasteneys et al. (1996); Connelly and Ryan (1996); James (1997a, b); James et al. (1996, 2002) and Ermanovics and van Kranendonk (1998). In addition, a more detailed account of the objectives and preliminary results of the bedrock part of the GEM II 2018 Hopedale study can be found in Corrigan et al. (2018). Figure 2 illustrates the simplified bedrock geology of the region (Wardle et al., 1997).

The Hopedale Block is part of the southwestern North Atlantic craton (James et al., 2002), and is located in the southern part of the Nain Province (Stockwell, 1963; Taylor, 1971). It is bounded by Paleoproterozoic orogens on three sides; Makkovik to the southeast, Torngat to the west and Nâgssugtoqidian to the northeast (James et al., 2002). The western part of the study area straddles the inferred boundary between the Saglek and Hopedale blocks of the Nain craton and the Nain–Churchill boundary, as marked by the Torngat orogeny (Connelly and Ryan, 1996; James et al., 2002). These boundaries are obscured by abundant Paleoproterozoic intrusions.

Bedrock geology from west to east across the Nain–Churchill boundary is summarized as follows. Paleoproterozoic gneisses of the southeastern Churchill Province (i.e., Tassiuyak gneiss: Wardle, 1983) outcrop to the west and are structurally interleaved along the western boundary of the study area with a sequence of presumed Paleoproterozoic mafic volcanic, volcaniclastic and clastic sedimentary rocks of the Ingrid group (Ermanovics, 1993). East of the Ingrid group, at Ingrid Lake and extending to the coast, Mesoproterozoic tonalitic to granodioritic, migmatic orthogneiss of the Hopedale Block (Maggo gneiss) contains...
widespread supracrustal remnants of the ca. 3.0 Ga Hunt River (volcanic) belt and Weekes amphibolite (Ermanovics, 1981b, 1993; James et al., 2002). Remnants of the Hunt River (volcanic belt) and Weekes amphibolite are collectively intruded by the Mesoarchean granodioritic Kanariktok intrusive suite. An unusual assemblage of late Neoarchean syenite, monzodiorite and monzogabbro is also recognized in the western part of the study area, immediately east of the Ingrid group and around the Aucoin Au–Ag–Pb–Te prospect (Sandeman and Rafuse, 2011; Sandeman and McNicoll, 2015).

In the northwest and north, the Archean rocks are cut by the Mesoproterozoic Nain Plutonic Suite (NPS; Ryan and James, 2004) and the Flowers River igneous suite (Hill, 1982a, b, c; Krogh, 1993). The Flowers River igneous suite occurs as a series of nested calderas in the north of the study area. Mesoproterozoic anorthositic rocks of the Harp Lake Complex (Emslie, 1980) outcrop to the south and southwest. The Paleoproterozoic Kikkertavik dykes and Mesoproterozoic Harp Lake and Kokkorvik dykes (Ermanovics, 1993; Cadman et al., 1993; Sparkes et al., 2010) are found throughout the study area.

Significant mineralization in the area includes (from west to east):

- magmatic Ni–Cu–Co sulphide mineralization related to the Mesoproterozoic Pants Lake intrusions (Kerr, 2012);
- Paleoproterozoic orogenic-style, quartz-vein-related gold mineralization hosted by Neoarchean alkaline rocks at the Aucoin prospect (Sandeman and Rafuse, 2011; Sandeman and McNicoll, 2015);

Figure 1. Shaded-elevation map of the study area. Lighter coloured areas indicate highlands, darker indicate lowlands. Large lakes in the west (Harp and Sarah lakes) drain into the Ugjoktok River, which drains into Ugjoktok Bay. Hunt Lake drains into Hunt River, which drains into Big Bay. Red dots mark the locations of 2017 sample sites.
rare-metal and rare-earth-element (RM-REE) mineralization in the Mesoproterozoic volcanic rocks of the Flowers River igneous suite (Kerr, 2011); and

• Ni–Cu and Au mineralization in the Hunt River and Florence Lake greenstone belts (James et al., 1996).

GLACIAL GEOLOGY

Glacial sediments and landforms of the Hopedale area were mapped as part of the Geological Survey of Canada’s 1:250 000 series maps, from airphotos and helicopter mapping traverses (Fulton et al., 1974); these data were later compiled and assimilated into GSC Map 1814A (Klassen et al., 1992). This map indicates areas of marine incursion in the Adlatok River valley, with terraces in Big Bay and Flowers Bay. Aggregate mapping by Ricketts (1984, 1988, 2011a, b) confirms the presence of marine terraces in the Big Bay area (Figure 2). Abundant glaciofluvial material was noted from Sarah Lake, toward Ugioktok Bay (ibid.) with almost 100% rock outcrop nearer the coast.

Glacial-flow indicator mapping and till sampling (Klassen and Bolduc, 1986), illustrate ice-flow trends of 055° over the Hunt River belt, changing to 085° west of the Flowers River igneous suite and generally eastward in the western part of the study area. Till samples from that study were collected at a density of 1 per 5 km² to 1 per 10 km², with sample density greatest in tills overlying the Flowers River Igneous Suite, the results of which are discussed by Klassen and Knight (1995).

More detailed mapping (1:50 000), based on aerial photographs with ground-checking, was undertaken by Batterson (1995, 1996, 1999, 2000a–d) of NTS map areas 13N/01/02/03 and 06/07 (Figure 3) as part of a till-geochemistry, boulder tracing and surficial mapping program in
LEGEND

MESOPROTEROZOIC
Grenville Province

- M1a Anorthosite and other, locally layered, mafic rocks

MIDDLE MESOPROTEROZOIC
Grenville, Southeastern Churchill and Nain provinces

- M2pg Peralkaline granite and syenite intrusions locally with ring structure
- M2pv Peralkaline felsic volcanic rocks
- M2g Granitoid rocks, including rapakivi varieties
- M2a Anorthositic rocks
- M2ma Intermediate rocks, chiefly ferrodiorite

EARLY MESOPROTEROZOIC
Grenville and Southeastern Churchill provinces

- M1g Granitoid rocks
- M1a Anorthosite and other, locally layered, mafic rocks

MIDDLE PALEOPROTEROZOIC
Southeastern Churchill, Makkovik, Nain and Grenville provinces

- P2mnv Basalt, andesite, dacite and conglomerate
- P2tv Rhyolite, ash-flow tuff, breccia and hypabyssal rhyolite intrusions; volcaniclastic siltstone and sandstone; minor basalt
- P2g Granite and granodiorite
- P2mv Schistose amphibolite derived from mafic volcanic rocks
- P2ga Gabbro and leucogabbro sills
- P2gpi Pelitic metasedimentary gneiss, minor marble and calc-silicate rock

ARCHEAN AND/OR PALEOPROTEROZOIC
Southeastern Churchill province

- A-Pggi Granitic gneiss
- A-Pgpp Tonalitic to granodioritic migmatitic gneisses containing abundant mafic to ultramafic inclusions and relict mafic dykes
- A-Pgpi Pelitic gneiss, minor marble and calc-silicate rock

ARCHEAN
Southeast Churchill and Makkovik provinces

- Aa Anorthosite and leucogabbro rocks

- Meso-Archean Southern Nain (Hopedale block) and Makkovik Provinces

- A-Mgpp Tonalitic and other gneisses reworked and retrograded during Makkovikian orogenesis
- A-Mgpl Granodiorite, tonalite and minor granite
- A-Mmrv Mafic volcanic and volcaniclastic rocks, lesser sedimentary and felsic volcanic rocks, and mafic-ultramafic sills; at greenschist to amphibolite facies
- A-Mgpi Tonalitic to granodioritic migmatitic orthogneiss containing abundant mafic to ultramafic inclusions and relict mafic dykes
- A-Mmgpi Mafic gneisses including rocks of intrusive and extrusive origin

Legend for Figure 2.
Figure 3. 1:50 000 surficial maps (Batterson, 1999, 2000a–d) of part of NTS map areas 13N/02, 03 and 13N/06, 07. The marine terrace referred to in the text is represented by a blue polygon in the south-central part of NTS 13N/06. Remnants of glaciofluvial material (tan) are noted west of the Adlatok River valley in NTS 13N/03, with major fluvial (mustard yellow) and minor aeolian (bright yellow) deposits noted in present-day river valleys. Bedrock (dark brown) and organically concealed bedrock (light brown) units comprise most of the map, with isolated till ridges (dark green) and till hummocks (lime green) and till veneer (light green) located in the northwestern corner of NTS 13N/06. Isostatic depression resulting from glaciation, and the subsequent melting of glaciers, resulted in marine incursion, and subsequent deposition of the marine terrace, 125 m asl and 50 km from the present-day coast.
the Florence Lake belt. The conclusions from the above studies include: 1) the southern Hopedale Block, south of the Adlatok River, was ice-covered through the late Wisconsinan, with ice-flow direction to the northeast to east-northeast (035–075°), and minor ice-flow deflection into valleys; 2) isostatically depressed areas underwent marine transgression and were covered by marine sediments up to a maximum of 125 m asl immediately following deglaciation (~8000 Ka), as observed in a marine delta 50 km west of the current coastline in the Adlatok River valley; and, 3) sediments were modified by fluvial processes during rapid relative sea-level fall, as observed by terraced sediments in the Adlatok River valley. This suggests that elevations below 125 m, with the exception of areas that remained ice-covered (i.e., Florence Lake, in the current study area), are unsuitable for geochemical and indicator mineral sampling, as any glacial material below this elevation would have been modified by marine processes (ibid.).

**INDICATOR MINERALS**

Indicator minerals (IM) are defined, in the current study, as those minerals that are specific to a certain mineral deposit type, alteration style, or bedrock lithology. They are ideal in identifying dispersion from mineralization, as mineral grain identification is independent of the bulk sample concentration, and is not diluted by non-IM material (Averill, 2001). In contrast, traditional geochemical methods, involving the digestion of mineralized and non-mineralized components of the silt and clay fraction of the surficial material, may cause the signature of minute particles of mineralized material to be diluted. Also, certain indicator mineral grains (e.g., garnite) are deposit-type characteristic and therefore, can assist in detecting dispersal patterns from the inferred bedrock source (ibid.).

Indicator mineral sampling has been shown to be effective across Canada in different terrains, including the mountains of the western Cordillera (e.g., Hashmi et al., 2015; Plouffe et al., 2016), the plains of the Western Canada Sedimentary Basin (Paulen et al., 2011; Oviatt et al., 2015), Arctic regions underlain by the Canadian Shield (e.g., McClenaghan et al., 2015), the boreal forest of the central Canadian Shield (e.g., Barnett and Averill, 2010) and the eastern Canadian Shield (e.g., McClenaghan et al., 2014, 2017a). Earlier IM work in Labrador includes a KIM study (Ryan and McConnell, 1995; McConnell and Ryan, 1996) focusing on assessing the potential for diamonds in the Saglek, Hopedale and Makkovik blocks. Two recent studies have been conducted in Newfoundland and Labrador by the GSNL, including a KIM study of eskers in western Labrador (Brushett and Amor, 2013) and a study in tills over and down-ice of the Pipestone Pond Complex in central Newfoundland (Brushett and Amor, 2016). The results of these studies demonstrate that IM sampling can detect dispersed bedrock and mineralization signatures in a variety of different glacial materials.

Common sulphide IM include base-metal-bearing minerals such as pyrite, chalcopyrite, galena and sphalerite, native precious metals and alloys, and more exotic, radioactive or rare earth element-bearing phases. Non-sulphide indicators include KIM such as Cr-diopside, Cr-pyrope, eclogitic garnet, Mg-ilmenite, Cr-spinel (chromite) and diamond itself, whereas other non-ore-bearing KIM include rutile, apatite, enstatite, and olivine (see McClenaghan and Paulen, 2017 and references therein for a more complete list of indicator minerals). Many of the non-sulphide indicator minerals listed above (e.g., apatite and rutile) can occur in a variety of geological environments and are not diagnostic of a specific deposit type. However, trace-element analysis of apatite, and subsequent discriminant analysis can indicate whether the source is barren or potentially represented by porphyry, skarn, or iron-ore–copper–gold-related mineralization (Mao et al., 2016). Similarly, rutile forms in a number of geological environments, but is a common alteration mineral in gold-mineralized rocks, and trace-element analysis can assist in identifying specific mineral sources (Clark and Williams-Jones, 2004).

**METHODS**

**MAPPING**

Preliminary mapping was conducted using helicopter traverses and satellite imagery. Twenty-two striation measurements were recorded from bedrock outcrops, to determine ice-flow directions. The results of these investigations, along with airphoto interpretation, detailed and targeted IM, till sampling and surficial materials, and bedrock observations will be integrated into a comprehensive contribution at a later date.

**INDICATOR MINERAL SAMPLING**

The sample sites were chosen to reflect the varied bedrock environments within the Hopedale Block. Eight bulk till samples were collected, along with smaller samples for till-geochemistry and pebble-lithology identification (Figure 2). Results of the till-geochemistry and pebble-lithology study are not yet available. Indicator mineral results of bulk till samples have been released in Open File LAB 1743 (Campbell and McClenaghan, 2019).

The till samples were collected from till veneer and mudboils, and placed in large (15–21 kg) bags, using GEM Program protocols (Spirito et al., 2011 and McClenaghan et al., 2013). The bags were taped, bagged again and re-taped
to prevent tearing and spillage during transport, and put into buckets for shipment to St. John’s and subsequently to Overburden Drilling Management Limited (ODM) in Ottawa, Ontario, for indicator mineral processing. Two GSC in-house heavy mineral “Bathurst blanks” (samples 17-4809 and 17-4810) were inserted in the analytical batch to monitor contamination. These blanks were collected from a weathered Silurian–Devonian granite “grus” from the South Nepisiguit River Plutonic Suite 66 km west of Bathurst, New Brunswick (Wilson, 2007), and consist of little to no indicator mineral or gold content (Plouffe et al., 2013). At ODM, the samples were processed using a combination of tabling, panning and heavy liquid separation in methylene iodide (SG 3.2). All samples were panned for gold, platinum-group minerals and fine-grained indicator minerals. The samples were processed following procedures described McClenaghan et al. (2017b) and Plouffe et al. (2013).

RESULTS

MAPPING

General glacial ice-flow patterns can be discerned from satellite imagery (Figure 4). The west–east orientation of streamlined land forms west of Sarah Lake changes to ~070° northeast of and ~120° southeast of Sarah Lake. A series of ridges (rogen moraine?) are discernible in satellite imagery, south of Sarah Lake (Figure 4).

Striation directions measured in 2017 range from 054–094°, and indicate similar trends of those reported by...

Figure 4. Satellite image (Source: ESRI, Digital Globe, GeoEye, Earthstar Geographics, CNES Airbus DS, USDA, USGS, AeroGRID) of the Sarah Lake region. Red striation indicators show measurements taken in 2017; yellow striation indicators show measurements taken in 1984–1986 by Klassen and Bolduc (1986). Ridged moraines are visible south of Sarah Lake, with glaciofluvial and fluvial sediments observed along the Adlatok river valley.
Klassen and Bolduc (1986). A striation measurement of 154° was recorded in a valley at the extreme west of the study area, and may reflect local deflection of ice toward lower elevations (see Batterson et al., 1987).

To the west, near the Québec–Labrador border and south of Mistastin Lake (Plate 1A), disintegration moraines, eskers and glaciofluvial material are abundant. Large-scale landforms northwest of Pants Lake indicate eastward flow (Figure 4; Plate 1B), whereas streamlined landforms and striation measurement west of Sarah Lake demonstrate that west- to east-flowing ice was redirected to the east-northeast and to the east-southeast.

Massive, hummocky boulder-strewn terrane (interpreted as moraine), boulder ridges, ribbed moraine, streamlined landforms, and minor glaciofluvial material are variably distributed in a ~200 km² area west of, and at, Sarah Lake, and to the south, toward the Adlatok River valley. Channels and boulders, and round potholes mark the surface of the boulder fields. South of Sarah Lake, two different sets of ridges (crescentic (flow till?) ridges overprinting southeast-oriented ribbed (Rogen moraine) are preserved (Plate 1C). Small (less than 1 km²) ice-contact glaciofluvial deposits and eskers occur between bedrock ridges to the north and east of Sarah Lake (not shown), with a larger, braided esker plain on the northwest shore of Sarah Lake (Plate 2). West-northwest to east-southeast and west–east flowing ice appears to have transposed ribbed till ridges (see Dunlop and Clark, 2006), into east-southeast and eastward-oriented streamlined landforms west of Sarah Lake (Figure 4, Plate 1D). Sinuous ridges, similar to those shown in Plate 1C, are present in the northwest and southwest corners of the lake, and overprint the streamlined ridges.

**Plate 1.** A) Disintegration moraine west of the study area, 60 km east of the Québec border; B) Looking southwest over a west–east-trending crag-and-tail landform north of Pants Lake; C) sinuous linear ridges (Rogen moraine) oriented 140° overprinted by crescentic ridges on the northwest shore of Sarah Lake; D) Crag-and-tail landform overprinting? ribbed moraine (red sinuous lines) 4 km west of Sarah Lake.
Glacially eroded valleys, interpreted to result from the onset of topographically confined glacial flow, begin at a plateau north of Ugjoktok River (Figure 4; Plate 3A), and continue eastward toward the coast (Plate 3B). These valleys have been locally covered by thick (>90 m) glaciofluvial, glaciomarine and fluvial deposits (Plate 3C). Glaciomarine deposits are also located at lower elevations (80 m asl) near the coast, 7 km east of Big Bay (Plate 3D).

In general, till is more abundant in the west of the study area, on hilltops and in valleys surrounding the Aucoin prospect and over the Ingrid Lake area, as well as near the Pants Lake Intrusive Suite (Figure 4). Local pockets of preserved till are located on hilltops south of Hunt Lake and southeast of Big Bay. Tills overlying the Hunt River belt consist of thin veneer (<2 m), giving way to exposed rock to the southeast.

INDICATOR MINERAL QA

In order to evaluate the quality of the data, the mineral grain counts for the two Bathurst blanks were examined and compared to published values (Plouffe, 2013; McClenaghan et al., 2017b). The samples contained the same mineral assemblage as their underlying source (South River Plutonic Suite; see Plouffe et al., 2007, page 308), containing no gold or indicator minerals, satisfactorily demonstrating that no cross-contamination occurred during the processing of the minerals.

SITE RESULTS

Site observations, from northwest of the study area to the southeast, with details of the local glacial environment and the IM summaries for the individual sites are described and tabulated below. Figures 1 and 2 show the location for each of the described sites.

Sample 17-4805: 10 km West of Pants Lake:
62°15’37”W, 55°30’17” (NAD27), Elevation = 539 m (Table 1)

Sample 17-4805 was collected from a light, brownish-grey till veneer (<2 m) on the edge of a cirque basin (Plates 3A and 4E). Till is thick (>2 m) in places, and is cut by east–west-trending glacially scoured valleys. Small (<500 m long, 2–3 m wide) glaciofluvial channels are locally observed, cutting through bedrock and till. Striation measurements of 102 and 155° were recorded on the side and top respectively of an outcrop of coarse-grained garnetiferous gneiss, in a valley 6.3 km east-southeast of the sample site at an elevation of 517 m.

Plate 2. Looking west over Sarah Lake at a glaciofluvial plain with braided eskers (foreground), ice-contact deposits, including ridges, and massive hummocky moraine (area between the dotted yellow lines), that overprint ribbed moraine (ridges in background).
Gneissic Bedrock (SECP) (Thomas and Morrison, 1988; Hill 1982a, c; Wardle et al., 1997)

Nearest bedrock outcrop: granitic gneiss intermixed with tonalite gneiss and quartz syenite (7: Thomas and Morrison, 1988; 10b: Hill, 1982a and c) Also mapped as P2g (Wardle et al., 1997)

Constituent bedrock mineral assemblage: orthopyroxene, clinopyroxene, amphibole, garnet, sillimanite, chlorite

Mineralization: pyrite, pyrrhotite

Summary-Indicator Mineral Sample 17-4805

Munsell Colour: 10YR 6/2

Clasts >2 mm Total: 22% %

Volcanic rocks/sediments 10

Granites 90

Table 1. Table summarizing the results for sample 17-4805

Plate 3. A) Looking west-northwest over a minor cirque basin (left) perched above a west–east trending glacially scoured valley (right) that leads to the coast; B) The valley begins in the Harp Lake uplands, continuing east; C) A relict marine ridge (90 m asl) and an incised fluvial terrace, in a valley south of Hunt River; D) Marine ridges (uppermost ridge is 80 m asl) 7 km west of Big Bay.
Sample 17-4806: Southwest Flowers River, 19 km
East of Sarah Lake: 61°28’47"W, 55°28’46"N (NAD27), Elevation = 573 m (Table 2)

Sample 17-4806 was collected from a light, brownish-grey till veneer proximal to an outcrop of gabbro. The local area to the sample site is characterized by ridges of till veneer, with exposed bedrock at high elevations, interspersed with spruce and moss-covered rock ridges, minor east-northeast streamlined ridges 800–900 m long, and bogs at lower elevations. Small glaciofluvial channels (<500 m long, 2–3 m wide) were noted. Striation orientations recorded on coarse-grained granitoid outcrop west and north of the sample site range from 66–75°. Striation measurements 11 km to the south of this site are mentioned in the description of sites at Ingrid Lake.

Samples 17-4800: 61°31’40”W, 55°22’45”N (NAD27), Elevation = 472 m, and 4801: 61°31’14”W, 55°20’56”N (NAD27), Elevation = 387 m (Tables 3 and 4)

Sample 17-4800 was collected from a light yellowish-brown till veneer overlying green basalt. Locally, till veneer and rock outcrop dominate the hilltops with minor (ice-contact?) glaciofluvial material in valleys. Exposed bedrock is locally polished, particularly over fine-grained rock units, and stossed to the east. A single striation measurement of 104° was recorded on fine-grained basaltic rock at this site.

Sample 17-4801 was collected in a light yellowish-brown mudboil overlying interbedded polymictic conglomerate and greywacke, with isolated felsic rocks. Two ice-flow directions were observed at the site, at a lower elevation, in polymictic conglomerate (Plate 4A): an east-south-eastward (094°) striation cut by what appears to be a later east-northeastward striation (075°). Similar orientations (080–110°) were also noted by Klassen and Bolduc (1986), but with opposite relative ages (i.e., a 080° striation crosscut by a 110°) and, at a location 9 km to the south, closer to the Adlatok River valley (see striation database, Taylor, 2001).

Sample 17-4802 Aucoin Prospect Area: 61°23’07”W, 55°21’34”N (NAD27), Elevation = 334 m (Table 5)

Sample 17-4802 was collected from a pale-brown mudboil overlying a fine-grained monzodiorite outcrop, 300 m south-southeast of MODS 013N/06/Au001. Ridgetops and valleys proximal to the Aucoin prospect are covered by a thin (<2 m) till veneer, with commonly scoured and polished bedrock exposures outcropping throughout. To the northeast, small eskers (<2 km-long) and sporadically preserved glaciofluvial deposits were noted, along with minor ridges and drumlinoid landforms. Thick (>2 m) till is abundant south of Aucoin (Plate 4B). No striation measurements were made at this site.

Sample 17-4808: Flowers River Intrusive Suite: 61°02’21”W, 55°33’13”N (NAD27), Elevation = 511 m (Table 6)

Sample 17-4808 was collected from a light brownish-grey till veneer overlying disintegrated bedrock (grus). Till in this region is thin (<1 m) but extensive, leaving moderate bedrock exposure on the hilltops (Plate 4F). Striation measurements on the up-ice side (stoss) of a quartz–feldspar-porphyry unit in outcrop include a set oriented at 060°, and another set at 076° on the down-ice (lee) side of the outcrop.

Sample 17-4803: Hunt River Belt: 60°49’08”W, 55°16’48”N (NAD27), Elevation = 372 m (Table 7)

Sample 17-4803 was collected from a light yellowish-brown mudboil overlying amphibolite. Locally, till overlying rocks of the Hunt River belt is thin (<1 m), and preserved in shallow pockets between rock outcrops. Directly north of the sample site, terraced moss and tree-covered rock outcrops lead to a broad, flat (glacially scoured) valley devoid of glacial deposits. Polished surfaces are not common in the immediate sample area, possibly owing to the strongly foliated nature of the bedrock (Plate 4D). A striation measurement of 054°, taken at an elevation of 295 m, was noted 3 km north of the sample site, on an outcrop of pelitic metasedimentary rock.

Sample 17-4804: Florence Lake Belt: 60°30’48”W, 55°08’55”N (NAD27), Elevation = 173 m (Table 8)

Sample 17-4804 was collected in a light olive-brown mudboil, 4 km northeast and in the inferred down-ice direction of MODS 13N/02/Au001. Much like the Hunt River belt, till in the vicinity of the sample site in the central Florence Lake belt, is thin (<1 m), large bedrock ridges and

Plate 4. (Plate on page 199). A) Striated (075/094°) polymictic conglomerate with minor mafic dyke (photo facing northeast); B) Looking north over a small (<1 km) esker (foreground), ridged till (on bedrock knob in background) and streamlined landforms (background, behind bedrock knob), 3.3 km north of the sample 17-4802; C) Epidote alteration in monzogabbro bedrock outcrop (top picture) in the same location as plate 4B, and medium-grained hornblende ± clinopyroxene syenite with hornblende ± clinopyroxene ± magnetite rich lenses (bottom picture – Sandeman and Rafuse, 2011). 1.4 km southwest of the Aucoin prospect; D) Looking northwest across the Hunt River Belt, toward a glacially scoured valley; E) Site of westernmost sample (17-4805) taken on the edge of a cirque basin over gneissic bedrock west of Pants Lake; F) Looking northwest over the innermost caldera complex of the Flowers River igneous suite.
Flowers River Igneous Suite/Nain Plutonic Suite Bedrock (Thomas and Morrison, 1991; Hill, 1982a, c; Wardle et al., 1997)

Nearest bedrock outcrop: contact of peralkaline granite and gabbro of the Nain Plutonic Suite (21: Thomas and Morrison, 1991). Mapped in other areas as medium grained quartz-syenite, quartz monzonite (16b: Hill, 1982a, c) and peralkaline coarse-grained granite (19a,b: Hill, ibid.) and plagioclase-phyric olivine gabbro, gabbroronite and monzogabbro (14a: Hill, ibid.). Also mapped as granite, monzantine and charnockite (M2g: Wardle et al., 1997)

Constituent bedrock mineral assemblage: peralkaline granite: quartz, perthite, plagioclase, aegerine, arfvedsonite and reibekite; gabbro: pyroxene, amphibole, epidote, amphiboles, clinopyroxene, olivine

Mineralization: pyrite, pyrrhotite (Wares and Leriche, 1996)

<table>
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<tr>
<th>Summary-Indicator Mineral Sample 17-4806 Matrix: Coarse Silty Very Fine Sand. Munsell Colour: 2.5Y 6/2</th>
<th>Clasts &gt;2 mm Total: 23%</th>
</tr>
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<tbody>
<tr>
<td>Indicator minerals present: chalcopyrite (1 grain), red rutile (2 grains), apatite (20 grains)</td>
<td>Volcanic rocks/sediments 5</td>
</tr>
</tbody>
</table>

Mineral assemblage: augite–hornblende–fayalite/diopside–apatite

Granites 95

<table>
<thead>
<tr>
<th>Summary-Indicator Mineral Sample 17-4800 Matrix: Coarse-Silty Very Fine Sand. Munsell Colour: 10YR 6/4</th>
<th>Clasts &gt;2 mm Total: 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator minerals present: native gold (1 grain modified, 25 µm, 1 reshaped 50 µm, calculated ppb = 1), red rutile, apatite (2 grains), Cr-grossular (1 grain), leucoxene (1 grain)</td>
<td>Volcanic rocks/sediments 30</td>
</tr>
</tbody>
</table>

Mineral assemblage: augite–almandine/epidote–diopside–leucoxene

Granites 70
shrub and spruce-covered low ground. The bedrock is locally polished, outcropping on ridges, between shrubs and trees. Till is preserved in shallow (30–40 cm) pockets between rock outcrops.

**DISCUSSION**

**GLACIAL ENVIRONMENT**

The glacial sediment varies from the northwest to the southeast of the study area. Ice-contact glaciofluvial material in valleys, streamlined rock outcrops, ridged-moraines and continuous till units characterize the higher elevation, northwestern and northern parts of the study area, whereas fluvial material, discontinuous till veneer and organic material characterize the lower elevation, southern and southeastern areas. Striation measurements obtained during the 2017 field season indicate eastward and northeastward flow; however, they are limited to a few places, and not sufficiently widespread to conclusively determine individual and crosscutting flow sets.

Striation sets recorded on the west side of Sarah Lake, south of Ingrid Lake and north of the Adlatok River valley (Klassen and Bolduc, 1986), appear to indicate multidirectional flow. The northwest–southeast-oriented striations...
(100–110°) of these sets may indicate a later shift in ice flow, related to ice drawdown resulting from the melting of glacial ice initiated by marine incursion into this region (Batterson, 1996). The crosscutting striation set, measured at Ingrid Lake (this study), indicates east-southeast flow (094°) crosscutting east-northeast flow (075°). This relative age relationship is opposite to those noted by Klassen and Bolduc (1986), and may represent: 1) locally deflected, topographically controlled ice flow at lower elevations unrelated to the larger regional trends, 2) localized east-southeast flow related to the glacial dynamics at Sarah Lake that were subsequently overprinted by east-northeast ice flow, or 3) a misinterpreted age relationship. Clearly, more data are needed to determine the ice-flow sequence in this and other localities, and to relate the local ice-flow events to regional ice-flow trends.

The glacial dynamics west of, and at, Sarah Lake are important to constrain, as there are a number of Ni–Cu ± Co mineral occurrences associated with the Pants Lake intrusions (Kerr, 2012), and these are located up-ice (west) of this region. The following sequence of events at Sarah Lake is proposed:

1) Cessation of west- to east-directed movement of an ice mass by a granite ridge, and deposition of ribbed moraine immediately west and south of Sarah Lake (Figure 4, Plates 1C and 2);
2) Melting of ice and deposition of glaciofluvial material, including braided esker plains to the northwest of Sarah Lake (Plate 2);

3) Onset of high-velocity, east-southeast-directed ice flow on the southern margin of the ice mass south of Sarah Lake and east-northeast-directed ice flow on the northeastern margin of the ice mass northeast of Sarah Lake, thereby producing streamlined landforms from previously deposited ribbed moraine and rocks to the north (Plate 1D), and forming drumlin fields to the southwest;

4) In-situ melting of an ice mass and deposition of massive, boulder-strewn melt-out tills and till ridges (flow till from down-wasting ice margins?) over ribbed moraine (Plates 1C and 2).

In order to solidify this preliminary interpretation of the dynamics of ice flow in the region, further mapping and examination of the surficial materials has to be undertaken. It is emphasized that care and caution must be applied when conducting drift prospecting or surficial materials geochemical sampling in this part of Labrador, as material from ribbed moraines has clearly been re-entrained and transported farther down ice from inferred sources by the later, high-velocity ice. In addition, in-situ melting of a remnant ice mass in the west to east valley leading to Sarah Lake, may have deposited material entrained and transported on the top of the glacier from a source farther west (englacial material). Meltwater will have eroded basally deposited material into a coarser grained, sorted glaciofluvial material making it harder to trace to the source. This glaciofluvial material is readily identifiable and should be avoided during sampling campaigns. Material sampled from these landforms must be sourced up-stream rather than up-ice, and paleo-stream directions are often difficult to determine.

Geochemical responses to mineralization in these areas may be diluted, either through the removal of the silt and clay fraction of till, where base-metal sulphides commonly reside (see McClenaghan and Paulen, 2017 and references therein), or by the addition of non-mineralized material.

Glacial deposits overlying the Hunt River and Florence Lake greenstone belts are scarce, and limited to shallow (<1 m) till pockets preserved between bedrock outcrops on ridges; with isolated glaciomarine deposits in valleys. In general, erosion of glacial material and deposition of marine sediments are expected at elevations below the marine limit of 125 m asl. The lack of marine sediments in the valley directly north of the Hunt River belt (Plate 4D) suggests that this area may have been ice covered during marine incursion, similar to Florence Lake (Batterson, 1996). In addition, the lack of till deposits on the ridgetops suggests a locally colder based, less-erosive ice environment (Benn and Evans, 2010).

**INDICATOR MINERAL**

The IM samples contain mineral assemblages that are found in the rock units from which they are presumably derived. Sulphides or gold are noted in five of the seven samples. Sample 17-4802, with a calculated value of 11 ppb and containing one pristine and one modified grain, and sample 17-4804, with a calculated value of 8 ppb and containing one pristine grain, were collected near or immediately down-ice of known gold occurrences. The occurrence of gold in these samples lends support to the veracity of the IM sampling process, although the overall grain count is low. The paucity of gold grains in sample 17-4802, may reflect that the sample was taken 300 m south-southeast of the Aucoin prospect, not in the inferred down-ice direction. In addition, the gold in the Aucoin prospect is hosted in anastomosing and discontinuous <60-cm-wide quartz veins (Sandeman and McNicoll, 2015), the distribution and erosion of which may contribute to variable amounts of gold grains in tills. The pristine grain collected from Sample 17-4804 is suspected to be from a source less than 100 m southwest of the sample site, and not from the Thurber Dog Lake #1 showing, which is 4 km in the inferred up-ice direction.

Galena and pyrite were also noted in sample 17-4802; again, these minerals are constituents of the mineralized zones at the Aucoin prospect (Sandeman and McNicoll, 2015). There are no known gold occurrences in the Ingrid group or in the gneisses west of Pants Lake. Thus, the two gold grains (reshaped and modified) from till overlying the Ingrid group, and one pristine grain from the till sample west of Pants Lake (samples 17-4800 and 17-4805) either suggest the unrealized presence of auriferous mineralization, or alternatively they may simply represent background levels of gold-in-tills in these areas. Molybdenite was noted in till sample 17-4805. Scheelite is noted in the sample from the Hunt River belt (17-4803) and chalcopyrite is noted in the southwest Flowers River region (17-4806). The significance of the abundance (or lack thereof) of these minerals in till is not clear, as the sample density is not sufficient to establish a background grain content.

Apatite is noted in all samples with the exception of the two samples obtained from tills overlying the Archean Hunt River and Florence Lake greenstone belts. As discussed previously, apatite can be formed in a number of different geological environments, so the presence of the mineral alone in till is not diagnostic. Leucoxene, a common alteration phase
derived from primary titanium-bearing minerals (e.g., ilmenite or titanite: Deer et al., 1978), is present in samples 17-4800 and 17-4801 obtained from till overlying the Ingrid group. Stillmanite, a high-temperature metamorphic mineral (ibid.), is found in samples 17-4805 and 17-4806 and chondrodite, a mineral normally associated with calc-silicate skarns and hydrothermal alteration of carbonate and ultramafic rocks (e.g., Zhao et al., 1999), was recovered from sample 17-4805. Almandine garnet, another high-temperature metamorphic mineral (Deer et al., 1978), occurs in sample 17-4800, overlying the Ingrid group and in sample 17-4805, overlying the gneisses complex; zircon, a mineral associated with alkaline plutonic rocks (ibid.), occurs in sample 17-4808. Epidote, hornblende and diopside grains are found in all of the samples.

The combination of molybdenite, gold and rutile in sample 17-4805, obtained from till overlying granitic and tonalite gneiss, 10 km west of Pants Lake, may suggest a Cu–Au–Mo porphyry or skarn association (e.g., McClanaghan and Paulen, 2017) for their source. The inferred source is expected to be less than 100 m to the west of the sample site, as the gold grain is pristine (Averill, 2001). The chondrodite grain may be derived from tonalitic gneiss of Unit 8b of Hill (1982c), which was reported to contain a number of metre-scale lenses of coarse-grained marble associated with garnetiferous granitic migmatite.

Scheelite, of which one grain was extracted from sample 17-4803, is commonly associated with greenstone belt-hosted gold, and is typical of skarns, hydrothermal veins, greisens and pegmatites. It is not understood whether this mineral reflects possible mineralization in the Hunt River belt or whether it is related to a granitic pegmatite (Unit H’pe, Ermanovics, 1993) 840 m in the inferred up-ice direction (southwest) of the sample site, or from a local, unknown pegmatitic source.

The source for the gold in sample 17-4800 is unknown, but the combination of the rutile, gold and leucoxene may indicate a prospective mineralized system. Gold, leucoxene and pyrite occur in gold deposits elsewhere (e.g., Hemlo deposit; Corfu and Muir, 1989; Stog‘r Tight deposit; Ramezani et al., 2002). These deposits were interpreted to have formed via the interaction of hydrothermal, gold- and sulphur-bearing fluids with primary Fe—Ti oxides; the oxidation of this fluid causing the co-precipitation of gold and pyrite (Pochon et al., 2017). Rutile replacing ilmenite is associated with gold mineralization at the Aucoin prospect (Sandman and McNicoll, 2015). The mineral assemblages observed in sample 17-4800 may be derived from as yet unrecognized Aucoin-like mineralization, east (up-ice) of the sample site.

CONCLUSIONS AND FUTURE WORK

Preliminary glacial mapping has identified two flow-set directions, as evidenced by striation measurements and in landforms. The formation of ribbed moraine in close proximity to a glaciofluvial system at Sarah Lake, with marginal streamlined ice-forms, and the subsequent deposition of massive, poorly sorted, sandy till (interpreted as disintegration moraine), suggest that an ice mass was initially blocked, with flow on the north and south margins of the ice mass redirected to the east-northeast and east-southeast, and that the remaining ice mass melted in situ. However, the mapping and striation data are limited, and not yet conclusive. Further measurements are needed to understand ice flow, and the paleo-glacial environment within the study area and these will be obtained during future field seasons.

Till is continuous on ridges in the northwestern part of the study area, with moraine ridges and minor ice-contact glaciofluvial material in valleys. Discontinuous till cover, with bedrock and organic materials, dominate the southern part of the study area, along with evidence of glaciofluvial, glaciomarine and fluvial deposition in valleys. Further mapping will clarify the nature of the paleo-ice environment, particularly in the Sarah Lake area, and allow for more conclusive insights into glacial erosion and deposition.

Indicator mineral results demonstrate that many minerals derived from local bedrock have been entrained in till. Two of the till samples (17-4802 and 17-4804), proximal to and perhaps dispersed from known mineralization, contained gold, galena and pyrite. In addition, gold, rutile and leucoxene were noted in sample 17-4800 and gold, molybdenite and rutile in sample 17-4805. The presence of sulphide minerals and gold in these two samples is promising. Furthermore, the mineral assemblages noted in sample 17-4800 may be indicative of unrecognized Aucoin-type orogenic gold, immediately up-ice of that locality. Similarly, the mineral assemblage of molybdenite + gold + rutile in sample 17-4805 may suggest proximal, unrecognized Cu–Au–Mo porphyry or skarn mineralization. These preliminary results underscore the necessity for continued till indicator mineral studies, reconnaissance and locally focused geochemical studies, along with detailed geological and surficial materials mapping to further evaluate the potential for Hopedale Block bedrock sources to contain more extensive, Aucoin-type orogenic as well as Cu–Au–Mo porphyry or skarn mineralization.

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