Current Research (2006) Newfoundland and Labrador Department of Natural Resources
Geological Survey, Report 06-1, pages 161-176

REGIONAL ICE-FLOW MAPPING, SURFICIAL GEOLOGY AND TILL GEOCHEMISTRY OF THE NORTHERN BURIN PENINSULA AND ADJACENT PLACENTIA BAY

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ABSTRACT

A regional till geochemistry survey was recently completed on the northern Burin Peninsula where till was sampled, using a sample density ranging from 1 sample per 1 km^2 in areas of good access, to 1 sample per 4 km^2 where helicopter-support was required; 914 samples were collected during this survey. In addition, 178 newly recorded ice-flow indicators were mapped to reconstruct the paleo ice-flow history, supplemented by geomorphic data shown on the Shuttle Radar Topography Mission image for the area. Geomorphic and sedimentological data from the Geological Survey of Canada's Geoscience for Ocean Management program *in Placentia Bay was also incorporated into the ice-flow and surficial-mapping components of the project.*

The entire study area appears to have been covered by late Wisconsinan ice. Two major ice flows were identified; an early south-southeastward event from a source to the north crossed the entire area, followed by a westward flow in the southern half of the area and a southwestward flow into Fortune Bay in the central part; the early flow was likely main Newfoundland ice from a centre to the north. It is well defined in the striation record, in terrestrial landforms, and on the multibeam data from Placentia Bay, where southeastward-trending submerged drumlins are clearly evident. The westward flow was from an offshore source or from the Avalon Peninsula; this is suggested from the striation record but appears to have little geomorphic signature. The southwestward flow into Fortune Bay is likely a late-stage topographically controlled event.

Much of the northern part is covered by a blanket of locally derived granite-rich till; flutes are common. The remainder of the area has a thin, discontinuous veneer of till and numerous bedrock outcrops. Glaciofluvial sediments are confined to the larger valleys, commonly feeding into glaciomarine deposits. The effect of regional isostatic rebound was to produce raised marine features around much of the coastlines of Fortune and Placentia bays up to about 20 m asl. Material for radiocarbon dating has not been found in these areas to assist in the definition of a relative sea-level curve or to provide dates on regional deglaciation. Drift-exploration programs should carefully consider the affect the distribution of raised marine and glaciofluvial deposits will have on their sampling programs, or in interpreting data produced from such surveys.

INTRODUCTION

This report describes the progress of the eastern Newfoundland regional mapping and till geochemistry project that started on the Bonavista Peninsula (Batterson and Taylor, 2001a, b) and continued onto the western Avalon Peninsula and Isthmus (Batterson and Taylor, 2003a, b), and central Avalon/Bay de Verde peninsulas (Batterson and Taylor, 2004a, b). Similar projects have been completed in the Grand Falls–Mount Peyton (Batterson *et al*., 1998), Hodges Hill (Liverman *et al*., 2000), Roberts Arm (Liverman *et al*., 1996), and southern Labrador (McCuaig, 2002, 2005) areas. Open file releases of till geochemistry from these projects have been successful in generating exploration activity, with over 5000 claims staked following the release of the data.

These projects combine surficial mapping (a combination of airphoto analysis and field verification), paleo ice-

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flow mapping and sampling of till to be analyzed for geochemistry. The latter two components are complete for this project, although further surficial geology mapping is required.

The addition of data generated from the Geological Survey of Canada's *Geoscience for Ocean Management program* in Placentia is an important contribution because it provides a geomorphic and sedimentological link between the terrestrial and marine environments. The Placentia Bay project has the goal of mapping the entire bay and publishing maps of bathymetry, backscatter, and surficial geology. To this end, multibeam mapping surveys were undertaken in 2004 and 2005, which built on previous surveys in 1995 and 1999. In late October and early November of 2005, a survey was carried out using the CCGS Matthew to; 1) ground-truth multibeam imagery with Huntec DTS, sidescan sonar, bottom photographs, grab samples, and gravity cores; and 2) examine features that provide evidence of the pattern of glaciation and deglaciation that can be correlated with onshore features of a similar nature. These features include drumlins and de Geer moraines. Preliminary results of the CCGS Matthew cruise (#2005-051) are reported in Shaw *et al*. (2006). Here, selected results on ice-flow history and deglaciation from the western part of Placentia Bay are presented to complement the ice flow and preliminary geological mapping of the Newfoundland Geological Survey and illustrate the advantages of using an integrated database of offshore and onshore records.

LOCATION AND ACCESS

The study area includes all, or parts of, six 1:50 000 NTS map sheets (1M/7 Baine Harbour, 1M/8 Merasheen, 1M/9 Harbour Buffett, 1M/10 Terrenceville, 1M/15 Gisborne Lake, 1M/16 Sound Island) on the northern part of the Burin Peninsula (Figure 1). The area extends north to the Bay du Nord wilderness reserve, abutting the area sampled in 2000 and reported by Batterson and Taylor (2001b), east to the area sampled in 2002 and reported by Batterson and Taylor (2003b), and west to Gisborne Lake.

BEDROCK GEOLOGY AND MINERAL POTENTIAL

The area is within the Avalon Zone, and largely contains late Proterozoic submarine and non-marine volcanic and sedimentary rocks, overlain by late Proterozoic and early Paleozoic shallow-marine sediments (Colman-Sadd *et al*., 1990). The area has been partially mapped at 1:50 000 scale by O'Brien and Taylor (1983), O'Brien *et al.* (1984), O'Driscoll and Hussey (1978) and O'Driscoll and O'Brien (1990).

The oldest rocks are Neoproterozoic Connecting Point Group sediments exposed along the eastern part of the study area and underlying Long Island in Placentia Bay (Figures 1 and 2). Similar rocks are exposed northward to the Bonavista Peninsula and are found underlying much of eastern Avalon Peninsula. On the Burin Peninsula, these rocks are overlain by sediments (mostly sandstone and siltstone) and associated volcanic rocks (mostly basaltic flows and tuffs) of the Musgravetown Group and volcanic rocks (basaltic flows and tuffs) of the Marystown Group. These rocks comprise much of the central and eastern parts of the study area, including Merasheen Island. Higher in the sequence are late Neoproterozoic rocks of the Long Harbour Group (Rencontre, Mooring Cove, Andersons Cove, Snooks Tolt, English Harbour East and Southern Hills formations). These are mostly volcanic (rhyolite flows and tuffs) and associated sediments. These rocks are intruded by the Cross Hills Intrusive Suite, which outcrops north and west of Terrenceville. The Cross Hills Intrusive Suite was mapped by Tuach (1984) as including gabbro to diabase, granodiorite, biotite granite, peralkaline granite and minor syenite. Parts of the Long Harbour Group may represent the extrusive equivalent (Miller, 1989).

The area also is intruded by Devonian granites, of which the Ackley Granite is the most aerially extensive. This is a commonly pink, coarse-grained, massive, biotite granite (Dickson, 1983), which underlies much of the northern part of the study area (Figure 2). Various phases of the granite have been identified (O'Brien *et al.*, 1983). Several other granite plutons were mapped in the area, including the Red Island granite, Bar Haven granite and Ragged Islands Intrusive Suite, all of which outcrop around Placentia Bay.

The youngest rocks in the area are Carboniferous sediments of the Terrenceville Formation, which outcrops along the coast at Terrenceville.

The area has almost no history of mining, except for a small deposit at Rocky Cove, Placentia Bay, which was mined for copper (plus secondary gold and silver) in the early part of the 20th century. There are, however, numerous mineral occurrences in the area (Figure 2). Base-metal (mostly copper, and some lead and zinc) and precious-metal (gold) showings are found within the Marystown Group; molybdenum, tin and tungsten showings are found within the Ackley Granite; and the Cross Hills Intrusive Suite contains zirconium and associated REE mineralization (Miller, 1989; O'Driscoll *et al*., 1995).

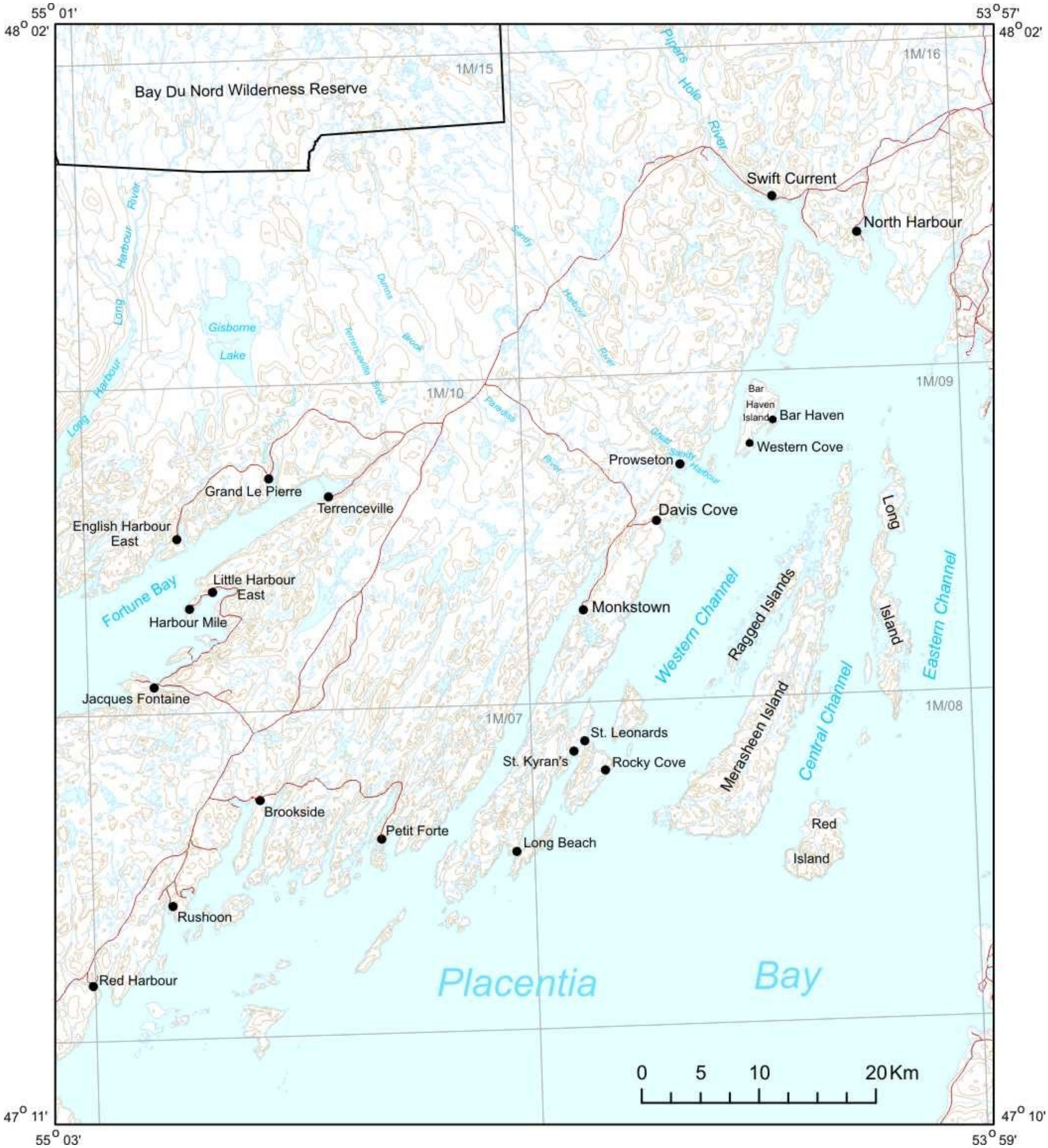


Figure 1. *Location map of the study area.*

OFFSHORE MAPPING IN PLACENTIA BAY

The Geological Survey of Canada's offshore mapping project in Placentia Bay provides important ice-flow and surficial geology data that may be integrated into discussions on the terrestrial mapping. For the purposes of this paper, descriptions of results from 2 areas, Western Channel and Central Channel, will be incorporated from the broader survey results reported in Shaw *et al.* (2006).

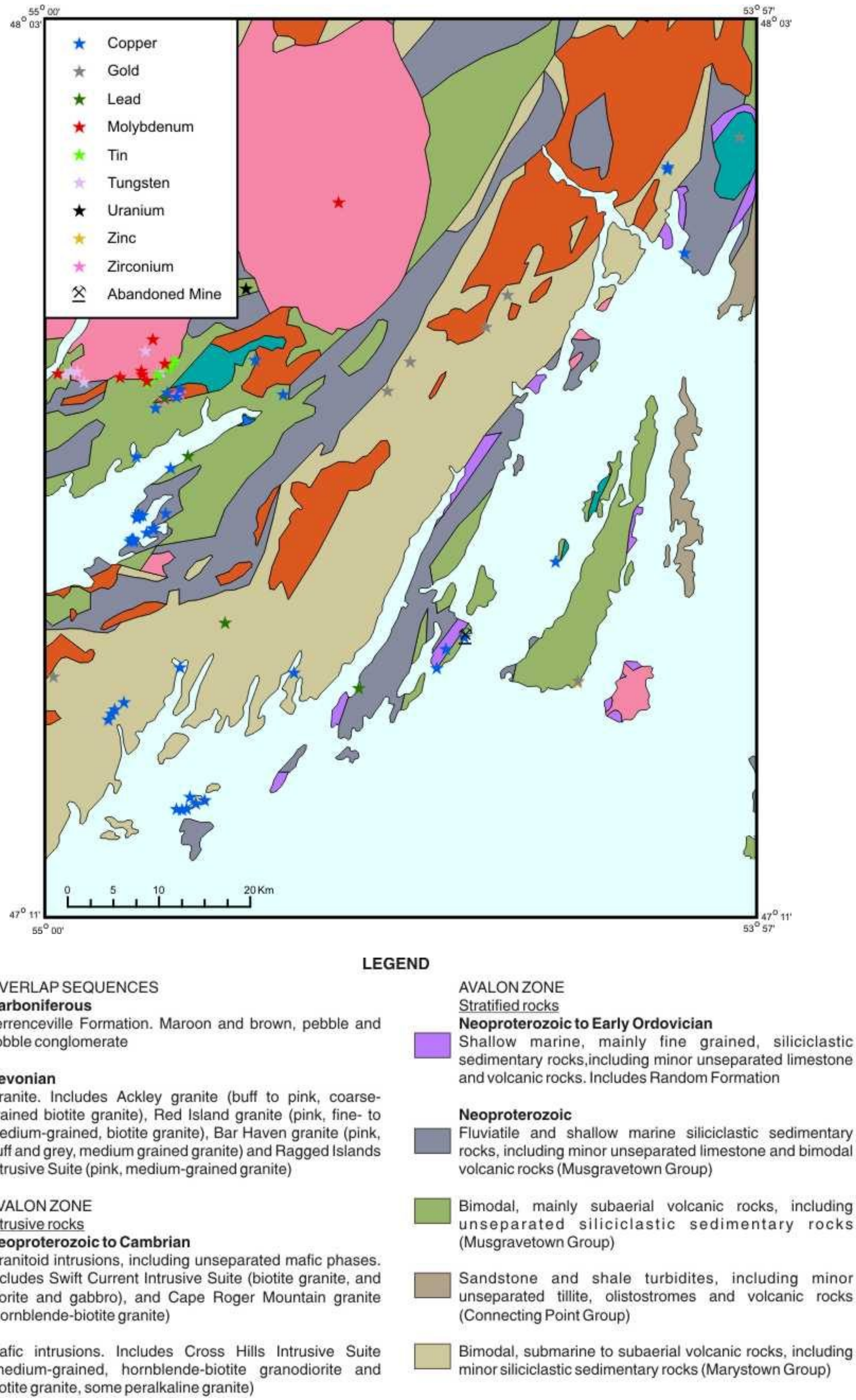


Figure 2. *Bedrock geology of the study area.*

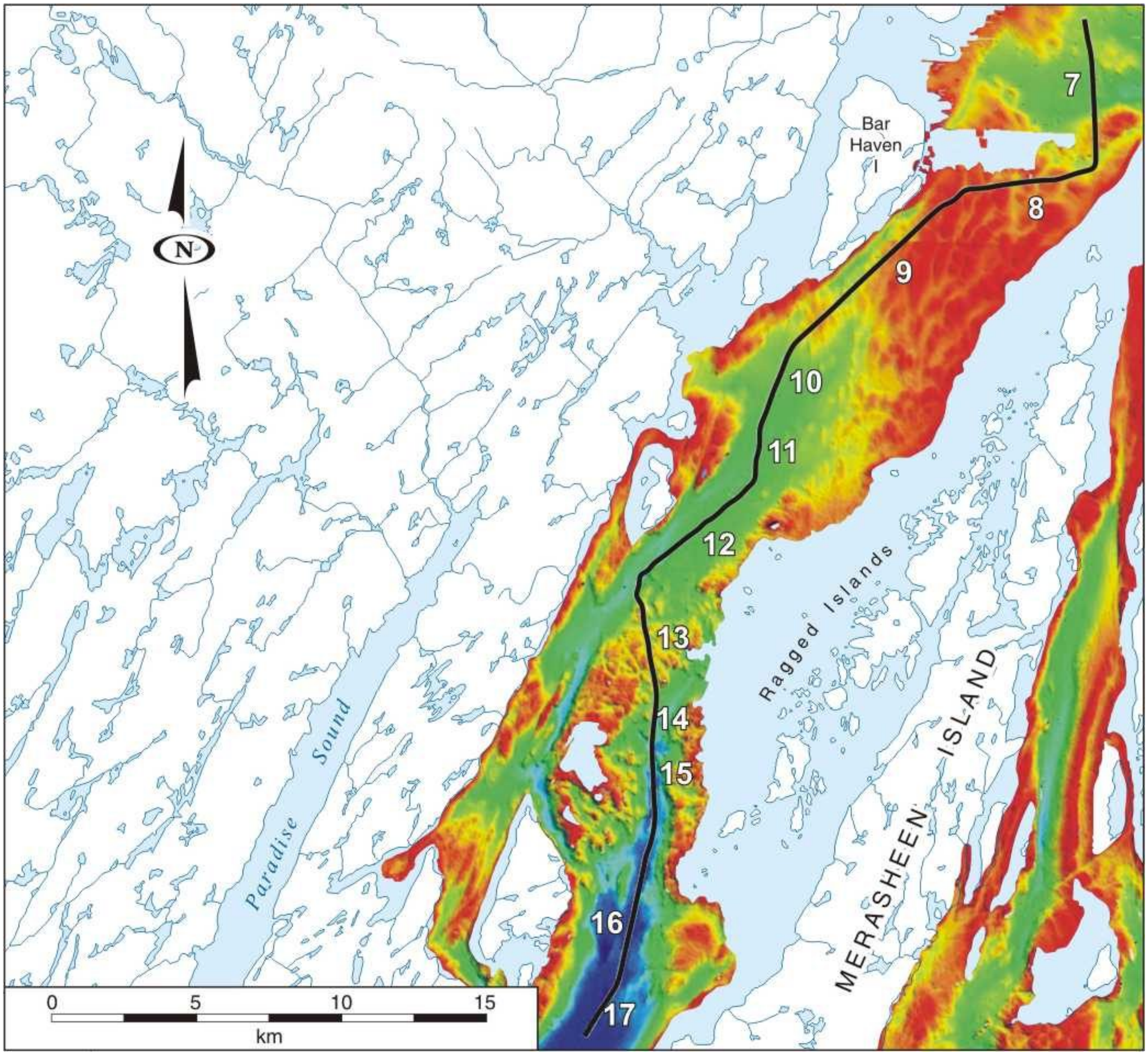


Figure 3. *Multibeam shaded relief image of seafloor morphology of northern Placentia Bay between Merasheen Island and the Burin Peninsula. Relief is indicated by colour ranging from shallow (red) and deep (blue). Numbers indicate location of Huntec DTS subbottom profile lines.*

Western Channel is a broad channel (10 km wide by 45 km long) separating Merasheen Island from the Burin Peninsula (Figure 3). It is relatively shallow along the western side of Merasheen Island, with numerous shoals in the vicinity of Ragged Islands. A multibeam survey of the channel reveals a small basin (up to 240 m water depth) enclosed by shallow seabed off Bar Haven Island to the north (90 m water depth) and an unnamed island to the south (54 m water depth).

The former shallow seabed was initially interpreted to consist of drumlinized till based on its ice-moulded appearance on the multibeam record. Although some boulders were observed on the sidescan imagery, and grab samples consisted of coarse sediments, the Huntec sub-bottom profile record reveals limited penetration of the surficial unit, suggesting bedrock at or near the surface. On the sidescan records, the boulders appear as linear clusters, also suggestive of bedrock outcrop. This region, therefore, may be an

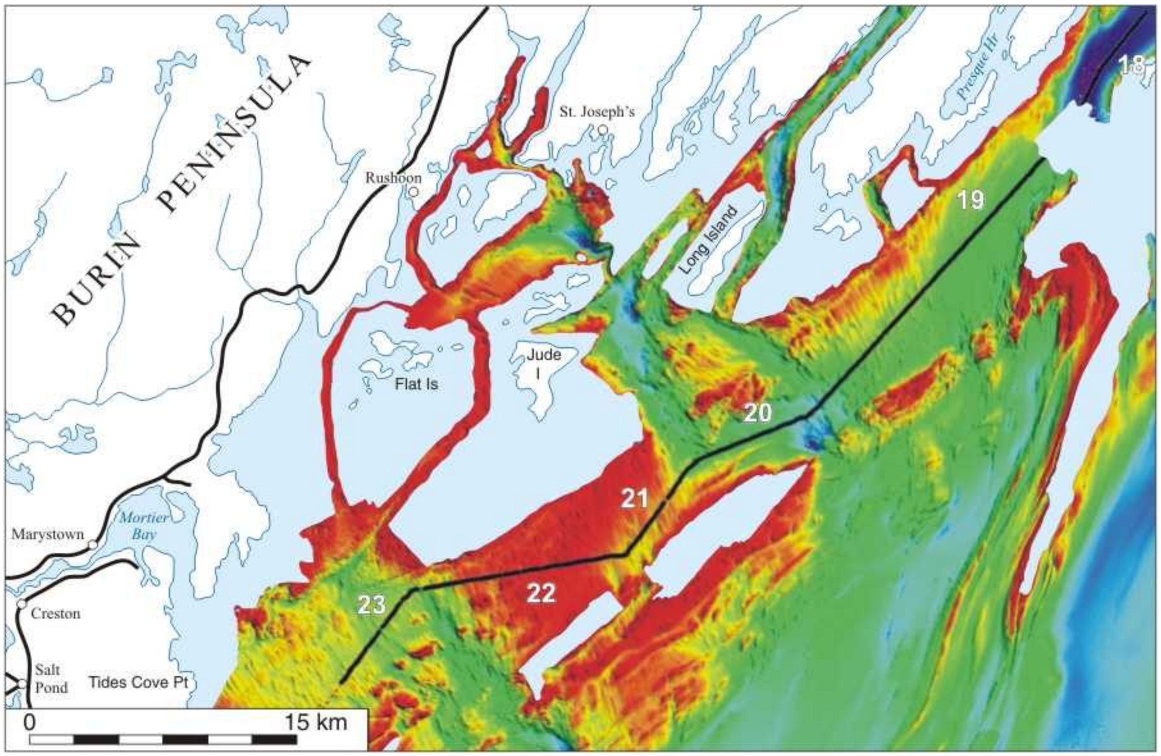


Figure 4. *Multibeam shaded relief image of seafloor morphology for western Placentia Bay, southwest of Merasheen Island.*

area of relatively soft bedrock that has been moulded by ice advancing southeast from the Burin Peninsula.

Farther south, along the margin of the basin, small ridges 2 to 3 ms high are superimposed on larger ridges up to 16 ms thick. The latter are made up of acoustically massive sediments interpreted to be till and are also aligned in a southeasterly direction. The smaller ridges are superimposed tangentially on the larger ridges and appear to follow the bathymetric contours. They are interpreted to represent de Geer moraines deposited during northeasterly retreat of a tidewater ice margin in the channel.

Huntec profiles across the shallow basin show considerable thickness of Quaternary sediments. Above bedrock, the combined thickness of glaciomarine and postglacial mud is up to 70 ms. Gas masking occurs in patches.

The Central Channel (5 km wide and 40 km long) contains a series of narrow, shallow basins (Figure 4) in which the maximum combined thickness of acoustically stratified glaciomarine and acoustically transparent postglacial sediments is 45 ms (34 m). Patches of shallow gas masking occur in areas of relatively thick postglacial mud. At the south end of the channel, a field of de Geer moraines transverse to the channel overlies a package of ice-contact sediment (till) that is tentatively up to 50 ms thick (Figure 5).

The marine surveys in the west of Placentia Bay consist of lines (19-23) that run in a southwesterly direction. Line 19 starts immediately southwest of the deep basin off the southwest tip of Merasheen Island; in the shallower water southwest of the basin, the line crosses fields of de Geer moraines that have mean heights of 2 to 8 ms and crest spacing of 215 m. The de Geer moraines are composed of acoustically incoherent material resting on bedrock. The material has a dark (reflective) tone on the sidescan sonograms, with scattered shadow-casting boulders, and is interpreted as glacial diamict (till).

The de Geer moraine field is superimposed on weakly developed streamlined ridges that extend to the south in a curvilinear pattern. South of about 47°20'N, the de Geer moraines are absent and the underlying streamlined ridges become larger and change orientation to a more southeasterly direction. They are part of a large field of streamlined ridges on the west side of Placentia Bay that extends as far as the extreme south of the multibeam coverage (Figure 4). The ridges exhibit a convergent pattern and are composed of acoustically incoherent sediment up to 20 ms thick that has a dark (reflective) tone on sidescan sonograms, scattered shadow-casting boulders, and is interpreted as glacial diamict (till). The streamlined ridges are suggestive of convergent flow of glacier ice into and down Placentia Bay.

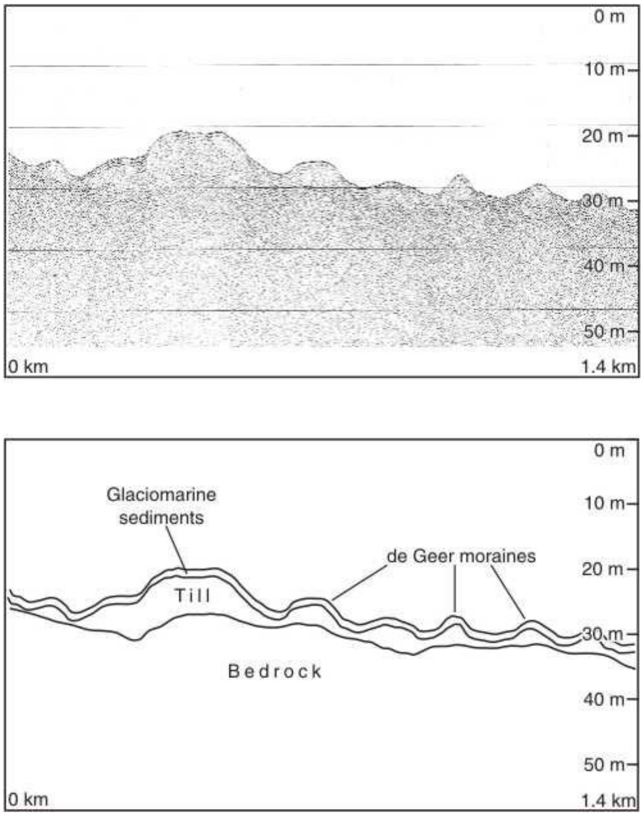


Figure 5. *Huntec DTS subbottom profile record (Line 18) across a field of ice-contact ridges interpreted as de Geer moraines in Western Channel.*

The convergent field of drumlin and megaflutes on the west side of Placentia Bay is mirrored by a field on the east side, off Placentia and extending over to Red Island. The field of large-scale sub-ice bedforms on the east side of the bay differs in several respects. Drumlins are present southwest of the Iona Islands. They are oriented northeast–southwest and become more elongated toward the south, being better described as megaflutes. Across Eastern Channel, the sub-ice bedforms are mostly crag-and-tail forms, and their orientation changes toward the west, to that south of Central Channel they indicate an ice flow from the north-northwest.

Preliminary analysis of the drumlins, megaflutes and crag-and-tail forms in Placentia Bay suggests a convergent flow into the bay from either side, and down the bay toward the south-southwest.

ICE-FLOW HISTORY

PREVIOUS WORK

There has been little research undertaken on the glacial history of the Burin Peninsula. The area escaped the attention of the early writers on the glaciation of the Province (e.g., Coleman, 1926; MacClintock and Twenhofel, 1940), likely due to poor access to the area. Reconnaissance mapping by Grant (1975) led to the definition of 4 main phases of glacial flow (Figure 6): A southward flow across the area south of about Terrenceville followed by an onshore northwestward flow from a source on the adjacent shelf (both of which were assigned a pre-Wisconsinan age); a southward Wisconsinan flow across much of the Burin Peninsula; and a late Wisconsinan radial flow from an ice-divide extending along the length of the peninsula. These were defined based on crossing striations, and weathering of older striation sets. Tucker (1979) and Tucker and McCann (1980) broadly concurred with Grant's sequence of events, although argued for considerably more restrictive late Wisconsinan ice extent. Tucker and McCann (1980) proposed a late Wisconsinan ice margin of main Newfoundland ice as only extending as far south as the Gisborne Lake basin, with limited local ice in the centre of the upper Burin Peninsula (Figure 6). The remainder of the peninsula was considered to be ice-free during the late Wisconsinan (Tucker and McCann, 1980). This margin conforms to the extensive end moraine identified by Jenness (1960) that separated his 'inner drift zone' characterized by numerous eskers and areas of hummocky moraine, from the 'outer drift zone' characterized by local till with little surface expression. The end moraine was interpreted to represent either a major stillstand in the retreat of Newfoundland ice or a readvance to that position (Jenness, 1960).

Ice-Flow Mapping

The favoured method of delineating ice flow in Newfoundland and Labrador is by mapping striations (Batterson and Liverman, 2001). Striations are excellent indicators of ice flow as they are formed by the direct action of moving ice. Data from individual striations should be treated with caution, as ice-flow patterns can show considerable local variation where ice flow was deflected by local topography (Liverman and St. Croix, 1989). Regional flow patterns can only be deduced after examining numerous striated outcrops. The orientation of ice flow can easily be determined from a striation by measuring its azimuth. Determination of the direction of flow can be made by noting the striation pattern over the outcrop; where areas in the lee of ice flow may not be striated; by the presence of such features as "nailhead" striations, miniature crag-and-tails (rat-tails), and by the morphology of the bedrock surface, which may show the effects of sculpturing by ice (Iverson, 1991). At many sites, the direction of ice flow is unclear, and only the orientation of ice flow (e.g., north or south) can be deduced. Where striations representing separate flow events are found, the age relationships are based on crosscutting of striation sets, and preservation of older striations in the lee of younger striations.

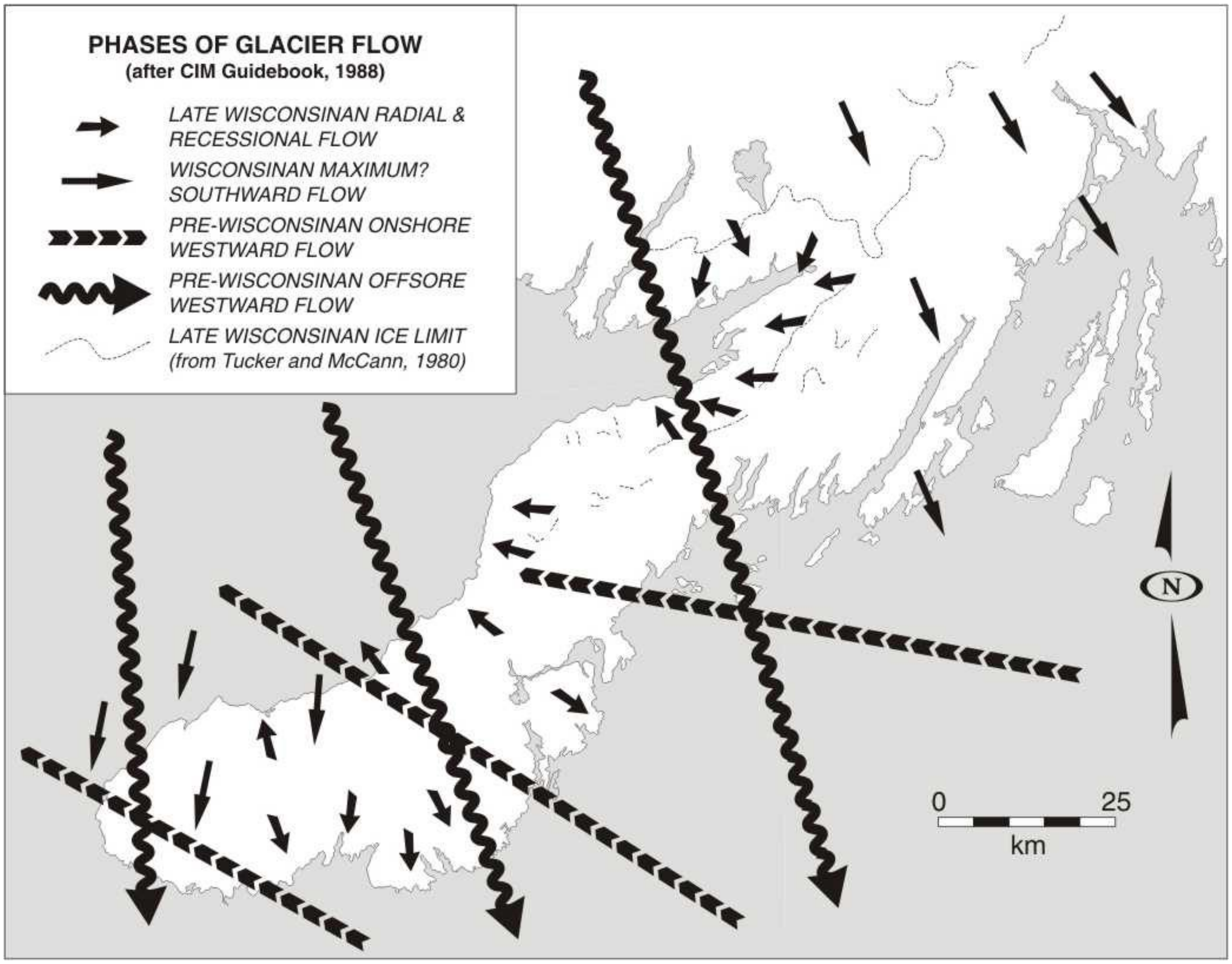


Figure 6. *Phases of glacial flow on the Burin Peninsula (after CIM Guidebook, 1988; Tucker and McCann, 1980).*

Striation data for Newfoundland and Labrador are compiled in a web-accessible database (Taylor, 2001), which currently contains over 10 900 observations. Ice flow is interpreted from striations, with additional data from large-scale landforms; either erosional rôche moutonée features or depositional features such as Rogen moraines. These features were identified from airphotos or from Shuttle Radar Topography Mission (SRTM) data (Figure 7). Clast provenance also helped confirm glacial source areas.

Results

Two-hundred and ninety-nine (299) observations have been made within the study area (Taylor, 2001), including 178 that were the result of field work in 2005. The data indicates two major paleo ice flows crossed the area (Figure 7).

The earliest flow was a regionally extensive southward to southeastward event from a source to the north of the study area. The flow is well expressed in the striation record and is evident on the SRTM image where streamlined landforms parallel the striation pattern. The direction of movement is generally consistent across the northern part of the peninsula and across Merasheen Island and Long Island into Placentia Bay, although trending more southward in the southern part of the study area. This event crossed the Ackley Granite, eroding and dispersing granite-rich diamicton across much of the northern part of the peninsula. This is the only flow recorded over the highlands east of the Burin Peninsula highway (Figures 1 and 7).

This southeastward event was followed by a westward flow that crossed Merasheen Island and, at least, the eastern part of the Burin Peninsula. It is well exposed in the southern part of the study area. This ice flow commonly removed evidence of the earlier southeastward ice flow from west-facing bedrock surfaces (Plate 1), and this relationship is shown in numerous locations along the Burin Peninsula

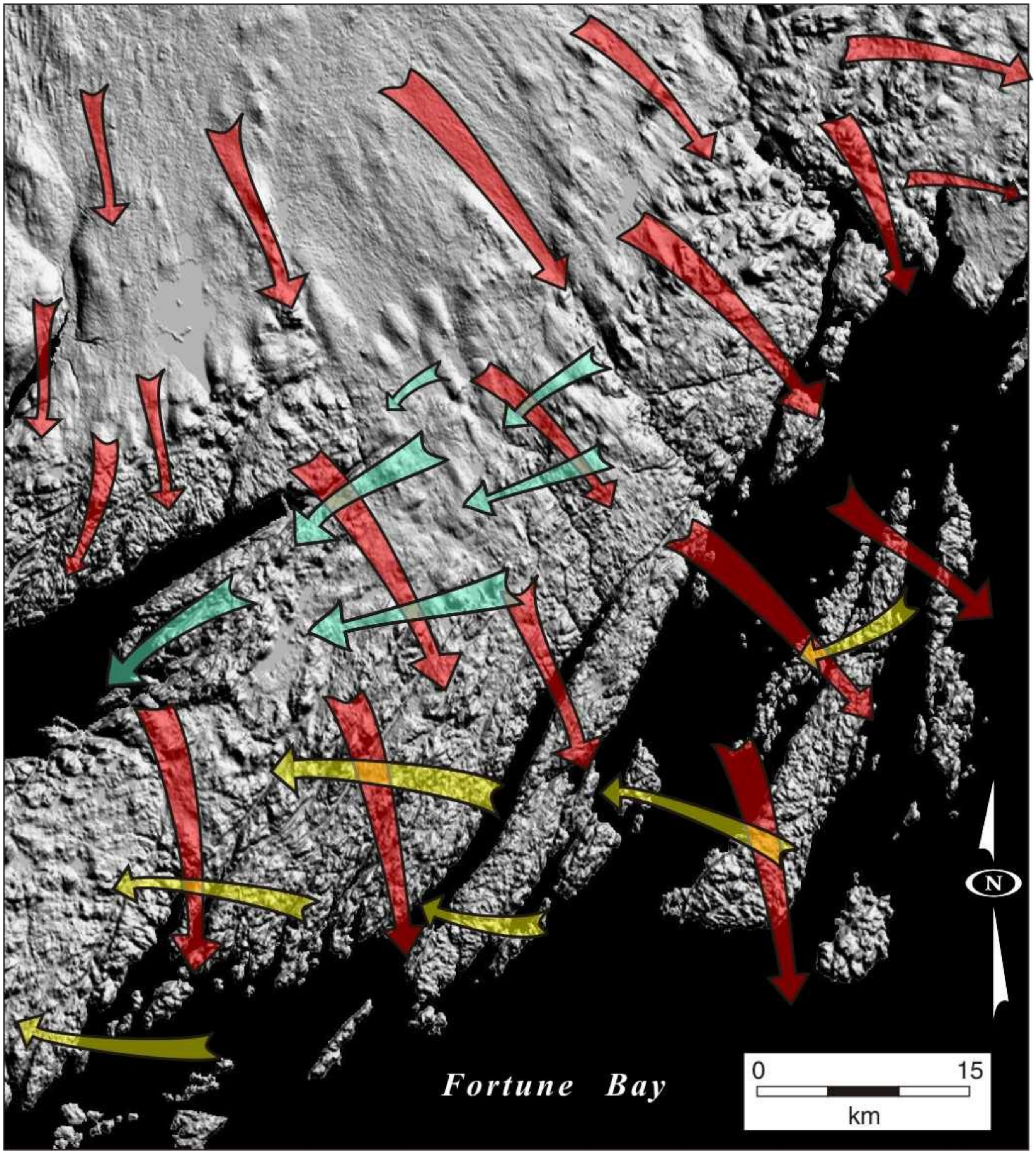


Figure 7. *Patterns of ice flow superimposed on SRTM image for the area. All flows are interpreted as late Wisconsinan. The earliest (red arrows) are likely from the main Newfoundland ice cap. The green arrows represent late topographically controlled flow into Fortune Bay, and the yellow arrows are onshore flow from a source to the east.*

highway and at a site on Merasheen Island (Plate 2). This westward event appeared to have little influence on sediment dispersal, and is not apparent on the SRTM image.

Farther north, the most recent flow is southwestward toward Fortune Bay. This direction is noted as far north as the Sandy Harbour River valley, although at this site the

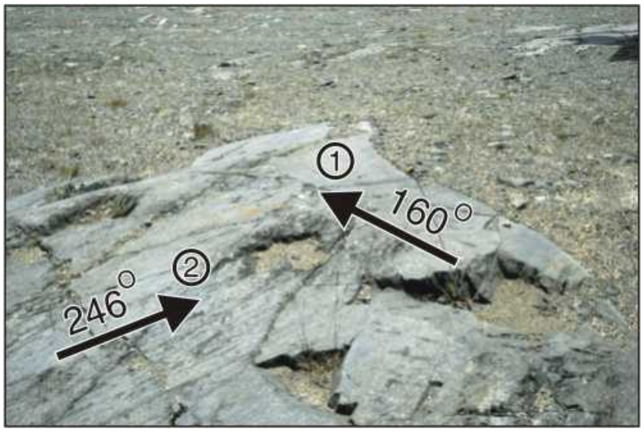


Plate 1. *Early southward (160°) ice flow crossed by more recent westward (246°) flow on a bedrock outcrop near Grandys Pond.*

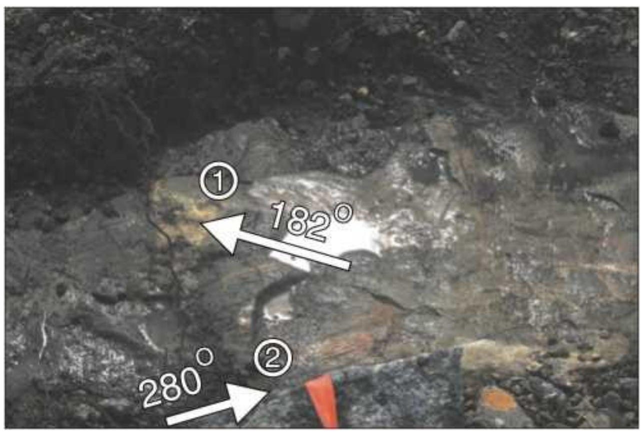


Plate 2. *Evidence for an early southward flow (182°) crossed by a later westward flow (280°) on a bedrock outcrop on Merasheen Island. The source for the later flow is uncertain but may have originated on the Avalon Peninsula.*

southwestward flow is interpreted as being the oldest flow. The southwestward flow is apparent between Harbour Mile and Terrenceville, eastward to the Burin Peninsula highway.

INTERPRETATION

It appears that all the ice-flow events identified are late Wisconsinan. Striations appear fresh and unweathered throughout the area. The regional ice-flow trend is consistent with dispersal from a dome of the main Newfoundland ice cap, north of the study area, likely in the Middle Ridge area. This flow was into Placentia Bay, crossing at least the northern end of Fortune Bay, and is clear from the multibeam images from Placentia Bay where southeast-oriented drumlins are well illustrated. The most recent flow event into Fortune Bay was likely a topographically controlled flow during retreat of the regional flow. This is suggested by its local distribution and prevalence at the northern end of Fortune Bay. The source of ice for the westward flow is uncertain. It is well developed on bedrock outcrop, but seemingly had little influence on depositional features, and is not clearly evident from the multibeam data. This may be the same event that was identified by Grant (1977, 1987) as a pre-late Wisconsinan flow from an ice divide extending from St. Pierre Bank to Green Bank to St. Mary's Bay, and which crossed the entire peninsula. It may result from a lobe of southward-flowing ice in Placentia Bay producing onshore flow on the west side of the bay. Alternatively, the source could be the Avalon Peninsula ice cap. All these suggestions require further investigation before either may be adopted as a working hypothesis.

SURFICIAL GEOLOGY

A brief description of the surficial geology is presented in advance of detailed airphoto interpretation. It is derived from field observations and the SRTM image of the area.

Bedrock outcrop is found over much of the study area, except in the north where it is underlain by the Ackley Granite. The SRTM image (Figure 7) shows a smooth surface in the north, indicating a thick sediment cover compared to the areas to the south and east, which have a rugged surface expression and is indicative of exposed bedrock. Bedrock exposed at the surface is commonly streamlined.

Till is common over the entire study area. It varies in thickness from a discontinuous veneer in bedrock-dominated terrain to a continuous blanket of several metres thickness where bedrock exposures are uncommon. The till composition commonly reflects the underlying bedrock geology, although in places, farther travelled sediment was identified. This took the form of a pink, sandy, granite-rich diamicton overlying grey volcanic bedrock. Fluted landforms are common in the northern part of the study area, and were derived from southeastward-flowing ice (Figure 7).

Small areas of glaciofluvial sand and gravel are exposed within the major valleys, several of which are being exploited for granular resources. The largest area is in the Swift Current valley (Ricketts, 1986). Deposits at the mouth of Pipers Hole River and opposite the community of Swift Current are both sand-dominated systems that have increasing amounts of pebble gravel toward the surface. A silt-clay deposit is found at the western extent of the deposit (Ricketts, 1986). The sediments were likely deposited as part of a prograding delta system that filled the valley, fed by meltwater from the Pipers Hole River valley. Other areas of glaciofluvial sediment include North Harbour, Sandy Harbour River, Grand Le Pierre Brook, Dunns River, Paradise River and Terrenceville Brook valleys (Kirby *et al.*, 1983).

Ricketts (1986) notes several eskers west of the mouth of Pipers Hole River, and eskers were also noted in the Gisborne Lake area.

The paleo sea-level history of the Burin Peninsula is poorly understood. Tucker (1979) argued that much of the Burin Peninsula was below the 20 m isobase, with the 0 m isopleth extending from the southern tip of the peninsula northeastward toward Red Island in Placentia Bay. Grant (1987) suggested that the 0 m isopleth crossed the southern Burin Peninsula, extending across Placentia Bay onto the Avalon Peninsula, similar to the model proposed by Jenness (1960). Much of the Burin Peninsula should therefore exhibit raised marine features, increasing in surface elevation toward the northwest.

Raised marine features were identified around the Fortune Bay and Placentia Bay coastlines. An ice-contact raised marine delta at Jacques Fontaine (Plate 3) has a surface elevation of 19 m asl, and similar features were identified at Terrenceville, Grand le Pierre and English Harbour East that have similar elevations. On Placentia Bay, a series of raised beaches with a maximum elevation of 20 m asl were identified at Great Sandy Harbour (Plate 4), and raised marine terraces were noted at St. Leonards, Bar Haven, and Prowseton, up to elevations of about 20 m asl. No dateable marine macro-fossils were found at any location and thus the age of the raised marine features remains speculative.

The postglacial relative sea-level lowstand in Placentia occurred at varying depths. Close to the study area, the lowering formed a delta at Marystown, in Mortier Bay (Shaw and Forbes, 1995). This feature, graded to -18 m, is clearly visible on images produced from recently collected multibeam bathymetry (Shaw *et al*., 2006).

Holocene sediments include fluvial sand, gravel and silt (alluvium) found adjacent to modern streams, colluvium at the base of steep hills, modern marine deposits such as beaches and tidal flats, and aeolian deposits. These sediment types are found in small areas across the study area. Many small stream valleys contain thin fluvial deposits over bedrock. Colluvium is common at the base of steep hills, particularly along the Fortune and Placentia bay coastlines. Most areas are removed from communities and infrastructure although the road between Jacques Fontaine and Little Bay East is susceptible to slope activity from overlying talus slopes. Much of the coastline in the study area is steep and bedrock dominated. Beaches are commonly restricted to small, gravel-dominated, high energy, pocket beaches. Barachois beaches occur at several localities, including Jacques Fontaine and Little Harbour East, Fortune Bay, and Western Cove, St. Kryan's and Long Beach on Placentia Bay (Figure 1). Tombolos were identified at Proweston and Bar Haven,

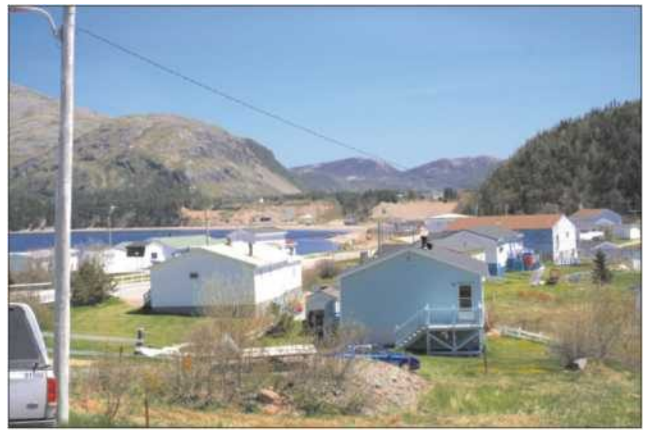


Plate 3. *Raised glaciomarine ice-contact delta at Jacques Fontaine. The delta has a surface elevation of ~19 m asl. The age of this feature, and other examples of raised marine/glaciomarine landforms along the Placentia and Fortune bay coastlines, remain uncertain due to the lack of dateable material contained within them.*

Plate 4. *Series of raised beaches found on the north shore of Great Sandy Harbour. Three levels are seen on the photographs, the highest at about 20 m asl. These are unusual features along the Placentia Bay coastline, and mark the progressive fall of sea level during the early part of the Holocene.*

Placentia Bay and Bay L'Argent and Little Bay East, Fortune Bay, and spits were noted in Fortune Bay at Grand Le Pierre and at Terrenceville. Most are gravel-dominated, have a variety of structures, including small- and large-scale cuspate features, and beach berms, with backbeach areas commonly exhibiting overwash fans, and are commonly less than 500 m long. The exception is the spit at Terrenceville, which is 1.8 km long.

Areas of organic accumulation are common across the entire area. Most are less than 50 cm thick, although pockets of bog are deeper than 3 m.

SUMMARY OF LATE GLACIAL EVENTS

Although surficial mapping and stratigraphic work have yet to be completed, a few observations can be made on the sequence of late glacial events on the northern Burin Peninsula. The study area was completely covered by southeastward-flowing ice from a centre to the north of the area. The suggestion that this was a pre-Wisconsinan event (Grant 1975, 1987; Tucker, 1979; Tucker and McCann, 1980) cannot be supported on the basis of current evidence. This flow is shown in striations and landforms, and is contiguous with events to the north. The multibeam and Huntec profile data from the floor of Placentia Bay shows distinct, linear features consistent with this southeastward flow. The striations appear fresh and unweathered in most places. In the north, this flow was followed by a southwestward flow into Fortune Bay, and in the south by a westward ice flow from a source to the east. These events scoured bedrock but apparently did little to modify or create surface landforms. The multibeam images from Placentia Bay also show little evidence of the later westward flow. This is the same relationship that was described by Tucker (1979) and Grant (1977), but evidence is lacking to support any but a late Wisconsinan age.

In the north of the study area, the few eskers suggest that ice retreated northward, across the Gisborne Lake basin where meltwater discharged down the major valleys, particularly the Long Harbour River and Pipers Hole River valleys. Remnant ice, likely existed at the pre-glacial outflow of Gisborne Lake. This is suggested by the well-defined channel (Plate 5) that extends from the western side of the lake into the Long Harbour River valley. This channel may represent a spillway from a higher level of the lake, although more detailed mapping will be required to confirm this. In the south, the lack of hummocky moraine suggests active glacial retreat in this area.

The pattern of raised marine features is generally consistent with previous descriptions of the area by Tucker (1979) and Grant (1980, 1987). Insufficient data exists to refine the isobase patterns previously presented. No dateable material has been found, thus far.

REGIONAL TILL SAMPLING

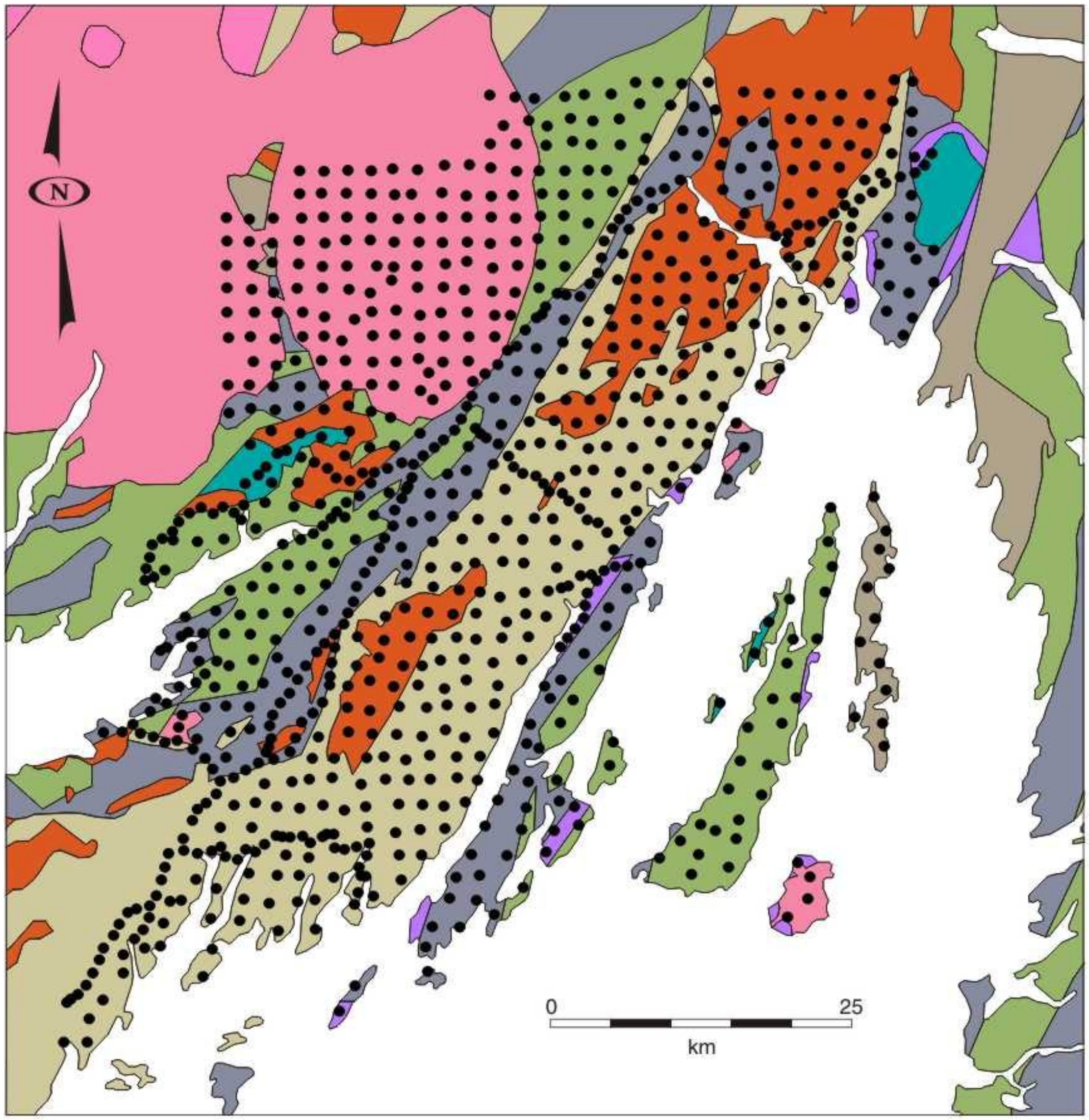
A regional till-sampling program was conducted across the entire study area. Glaciofluvial, fluvial, marine, and aeolian sediments were excluded as sampling media. Most samples were from the C- or BC- soil horizon, taken at about 0.5 m below surface from test pits, or 0.5 to 1.0 m depth from quarries or road cuts. In rare cases, the lack of surface sediment necessitated the sampling of bedrock detritus. Sample spacing was controlled by access, as well as surficial geology. In areas of good access, the sample density was about 1 sample per 1 km^2, increasing to about 1 sample per 4 km^2 in areas where helicopter support was required. Samples were sieved through a 5-mm-mesh sieve, and approximately 1 kg of sediment was placed in a paper bag.

Plate 5. *Series of meltwater channels extending from Gisborne Lake (background) into the Long Harbour River valley. Preglacial lake outlfow to the south was blocked by ice during deglaciation, producing a proglacial lake that eventually spilled over into the adjoining Long Harbour River valley to the west.*

A total of 914 samples were collected (Figure 8) and submitted to the Geological Survey's geochemical laboratory in St. John's for analyses, either internally by gravimetric analysis, and inductively coupled plasma emission spectrometry (ICP) using an aqua regia digestion; or externally by commercial laboratories using instrumental neutron activation analysis (INAA). These methods and the elements analyzed are summarized in Table 1. Data quality is monitored using field and laboratory duplicates (analytical precision only), and standard reference materials. In all cases, the silt/clay fraction (less than 0.063 mm) is analyzed. Data release is anticipated before summer 2006.

ACKNOWLEDGMENTS

The authors would like to thank the following for their contribution to the project. Gerry Hickey provided his usual high level of logistical support for the land-based component of the project. Till sampling was carried out with the excellent assistance of Chris Hicks and Pat Donovan, and the helicopter skills of Baxter Slade and Newfoundland Helicopters. Terry Sears produced the figures. The manuscript was improved through critical review by Dave Liverman.



LEGEND

OVERLAP SEQUENCES

Carboniferous

Terrenceville Formation. Maroon and brown, pebble and cobble conglomerate

Devonian

Granite. Includes Ackley granite (buff to pink, coarse-grained biotite granite), Red Island granite (pink, fine- to medium-grained, biotite granite), Bar Haven granite (pink, buff and grey, medium grained granite) and Ragged Islands Intrusive Suite (pink, medium-grained granite)

AVALON ZONE

Intrusive rocks

Neoproterozoic to Cambrian

Granitoid intrusions, including unseparated mafic phases. Includes Swift Current Intrusive Suite (biotite granite, and diorite and gabbro), and Cape Roger Mountain granite (hornblende-biotite granite)

Mafic intrusions. Includes Cross Hills Intrusive Suite (medium-grained, hornblende-biotite granodiorite and biotite granite, some peralkaline granite)

AVALON ZONE

Stratified rocks

Neoproterozoic to Early Ordovician

Shallow marine, mainly fine grained, siliciclastic sedimentary rocks,including minor unseparated limestone and volcanic rocks. Includes Random Formation

Neoproterozoic

Fluviatile and shallow marine siliciclastic sedimentary rocks, including minor unseparated limestone and bimodal volcanic rocks (Musgravetown Group)

Bimodal, mainly subaerial volcanic rocks, including unseparated siliciclastic sedimentary rocks (Musgravetown Group)

Sandstone and shale turbidites, including minor unseparated tillite, olistostromes and volcanic rocks (Connecting Point Group)

Bimodal, submarine to subaerial volcanic rocks, including minor siliciclastic sedimentary rocks (Marystown Group)

Figure 8. *Map showing location of till samples.*

Table 1. Elements (and LOI) analyzed by the GSNL and commercial laboratories

Method	Elements Analyzed
Gravimetric analysis	LOI
Inductively coupled plasma-emission spectrometry (ICP)	Ag, A1, Ba, Be, Ca, Ce, Co, Cr, Cu, Dy, Fe, Ga, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Sc, Sr, Ti, V, Y, Zn, Zr
Instrumental neutron activation analysis (INAA)	As, Au, Ba, Br, Ca, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Tb, U, Yb

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