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# TILL GEOCHEMICAL SURVEYS AND PRELIMINARY QUATERNARY MAPPING OF THE BURIN PENINSULA AND ADJACENT AREAS

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## ABSTRACT

*A regional till geochemistry survey was completed on the Burin Peninsula. Till was sampled at a 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; 748 samples were collected during this survey to supplement 914 samples collected in adjacent areas in 2005. In addition, 135 newly recorded ice-flow indicators were recorded and mapped to reconstruct the palaeo ice-flow history of the survey area; the reconstruction was supplemented by geomorphic data shown on the Shuttle Radar Topography Mission (SRTM) image for the area.*

*Striation and landform evidence confirm that a regional southward (south to southeastward) ice-flow event, which covered the entire study area, crossed the Burin Peninsula. The striations are generally fresh and unweathered, although some weathered facets were noted. The consistency of flow patterns across the area suggests that they are of the same age as those interpreted as late Wisconsinan in central and eastern Newfoundland; this ice flow produced most of the glacial streamlined landforms in the area. The southward ice flow was followed by a regionally extensive westward (southwest to northwest) ice flow that crossed the Burin Peninsula from Placentia Bay to Fortune Bay. The evidence for this event is crossing striations; however, the source of this ice flow remains uncertain. Striations produced by a westward to northwestward ice flow are found at the southern tip of the peninsula. This ice flow may be the same event as the westward flow found farther north, but the lack of striated bedrock in intervening areas means that a link between the two cannot be established.*

*The northern part of the Burin Peninsula is covered by a blanket of locally derived granite-rich till. Flutes are common in this area. The central part of the peninsula is bedrock-dominated, whereas the area south of Marystown has a thicker sediment cover, commonly exceeding 5 m. Deglaciation led to the production of extensive glaciofluvial deposits in many of the major valleys, which are commonly graded to the postglacial sea level. Raised marine features (mostly deltas and terraces) suggest that the marine limit was about 20 m asl on both the Fortune Bay and Placentia Bay coasts. There is no evidence for raised postglacial seas in the southern part of the peninsula, suggesting that the area has experienced continual submergence during the Holocene (*i.e.*, south of the 0 m isobase) or that the area was ice covered at a time when the areas to the north were ice free. During deglaciation, proglacial lakes formed at Gisborne Lake, and to the south of Fortune. The lack of shoreline features and thin glaciolacustrine sediments suggest that these were short-lived features. Sea level has been rising through much of the Holocene following the postglacial lowstand. Rising sea levels, as a combined result of isostatic rebound and global sea-level changes, will continue to be a major influence on coastal change on the Burin Peninsula.*

## INTRODUCTION

This report describes the progress of a regional Quaternary mapping and till geochemistry project that started on the Bonavista Peninsula (Batterson and Taylor, 2001a, b) – continued onto the western Avalon Peninsula and Isthmus (Batterson and Taylor, 2003a, b), the central Avalon and Bay de Verde peninsulas (Batterson and Taylor, 2004a, b), and the northern Burin Peninsula (Batterson *et al.,* 2006; Batterson and Taylor, 2006). This, and similar projects elsewhere (*e.g.,* Batterson *et al.,* 1998; Liverman *et al.,* 1996, 2000; McCuaig, 2002, 2004), were successful in generating exploration activity, with over 5,000 claims staked following the open-file release of the data.

In 2006, the project was a continuation of the earlier northern Burin Peninsula project, initiated in 2005 and reported on by Batterson and Taylor (2006). Based on promising analytical results, particularly for uranium, some rare-earth-elements (REE's) and base metals, the survey was extended westward through the volcanic rocks of the Musgravetown Group exposed between Fortune Bay and the Ackley Granite, and southward across the remainder of the Burin Peninsula not covered during the 2005 survey.

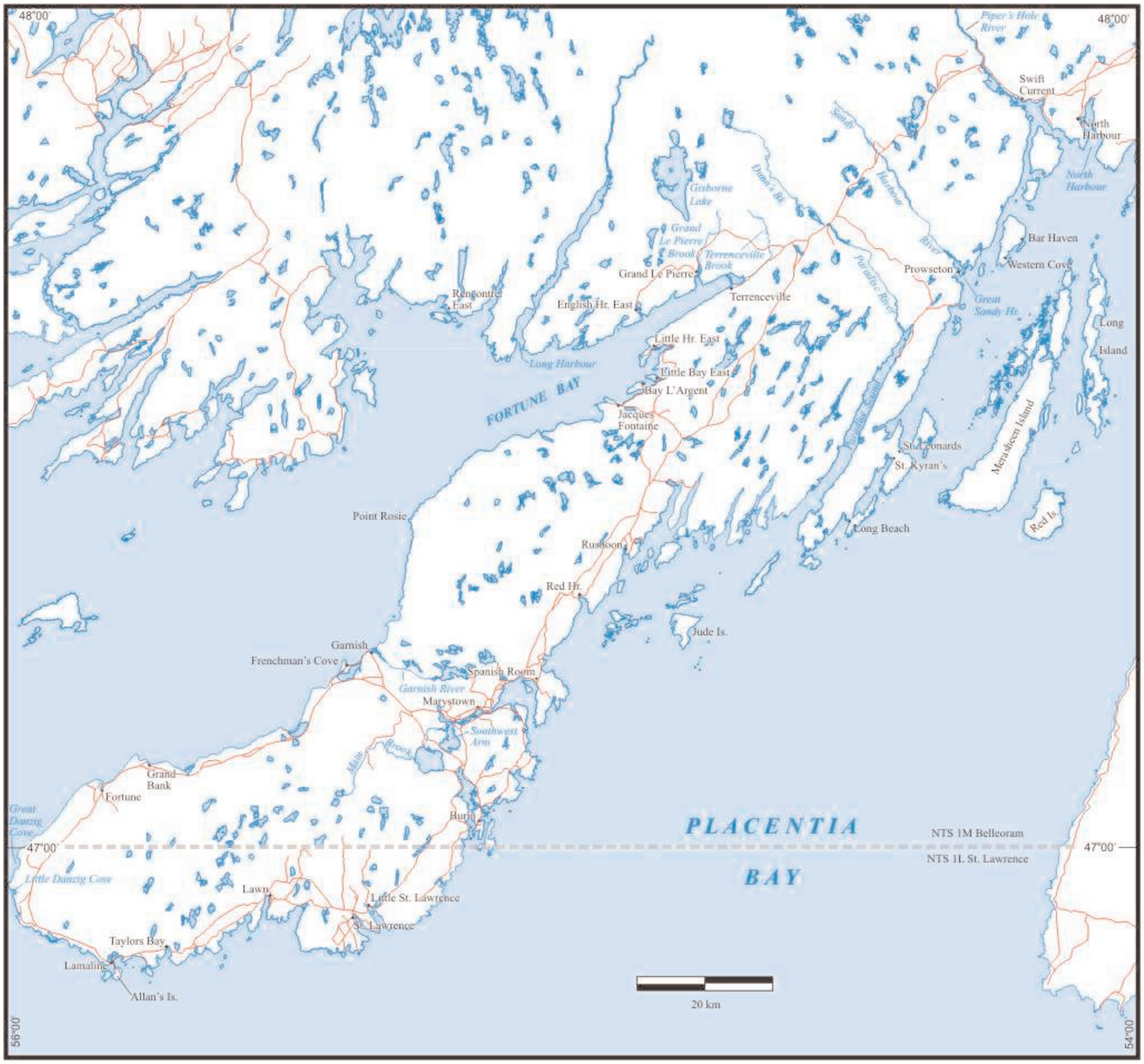



**Figure 1.** *Location map and places mentioned in text.*

These projects combine surficial mapping (a combination of aerial photograph analyses and field verification), palaeo ice-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.

## LOCATION AND ACCESS

The study area includes all, or parts of, ten 1:50,000 NTS map areas (1L/13 Lamaline, 1L/14 St. Lawrence, 1M/2 Jude Island, 1M/3 Marystown, 1M/4 Grand Bank, 1M/6 Point Enragée, 1M/7 Baine Harbour, 1M/10 Terrenceville, 1M/11 Belleoram and 1M/15 Gisborne Lake) on the Burin Peninsula and adjacent areas (Figure 1). Access to the area was mostly by paved or gravel roads that service the communities on the Burin Peninsula. Some Provincial Government-designated ATV trails exist in the area, *e.g.,* to Gisborne Lake and Point Rosie. Some are well maintained but most are not, and provide no access to the interior of the peninsula. Large areas of the study area were only accessible by foot or by helicopter, the latter mode being preferred.

## BEDROCK GEOLOGY AND MINERAL POTENTIAL

The study area is within the Avalon Zone, and largely contains Neoproterozoic submarine and non-marine volcanic and sedimentary rocks, overlain by Neoproterozoic and early Palaeozoic shallow-marine sediments, the details of which are summarized by Colman-Sadd *et al.* (1990; Figure 2). O'Driscoll *et al.* (1995) provides a more detailed map, largely based on 1:50,000-scale mapping by O'Brien and Taylor (1983), O'Brien *et al.* (1977, 1984), O'Driscoll and Hussey (1978), O'Driscoll and O'Brien (1990), and Strong *et al.* (1977).

The oldest rocks are the Neoproterozoic Connecting Point Group sediments exposed along the eastern part of the study area and underlying Long Island in Placentia Bay. Similar rocks are exposed northward, to the Bonavista Peninsula, and are found underlying much of the 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 compose much 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 its extrusive equivalent (Miller, 1989). Late Neoproterozoic to Early Cambrian sedimentary rocks of the Chapel Island Formation are exposed in the southwest Burin Peninsula (Figure 2) and the global stratotype for the Precambrian-Cambrian boundary is located in this area.

The area is intruded by Devonian granites, of which the Ackley Granite is the most extensive. This is a commonly pink, coarse-grained, massive, biotite granite (Dickson, 1983) that underlies much of the northern part of the study area and 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, Ragged Islands intrusive suite, and the St. Lawrence Granite, all of which outcrop around Placentia Bay. The youngest rocks in the area are Carboniferous sediments of the Terrenceville Formation (not shown on map), which outcrop as a small exposure along the coast at Terrenceville.

A fluorspar mine operated successfully in St. Lawrence between 1933 and 1978, but eventually closed due mostly to economic considerations, although it did re-open briefly between 1984 and 1990. The rest of the area has a limited mining history, except for a small copper deposit (plus secondary gold and silver) at Rocky Cove, Placentia Bay, which was mined in the early part of the 20th century. There are, however, numerous mineral occurrences in the area. 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; the Cross Hills intrusive suite contains zirconium and associated REE mineralization (Miller, 1989; O'Driscoll *et al.,* 1995); and the Grand Beach complex contains several uranium anomalies (MODS, 2006).

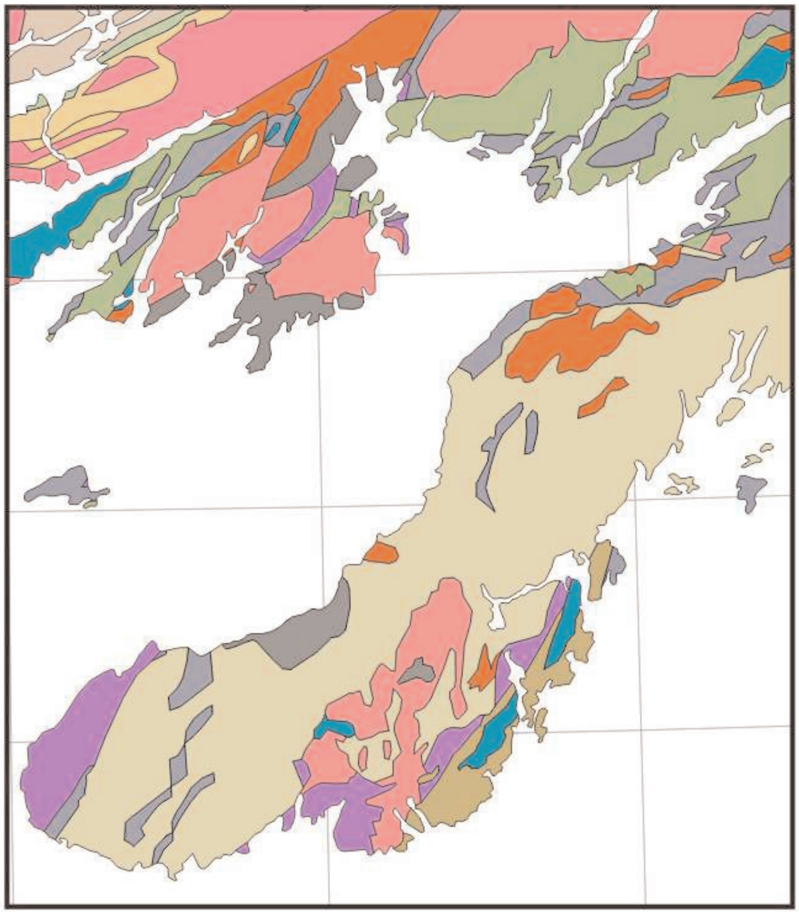
## QUATERNARY GEOLOGY

### ICE-FLOW MAPPING

The favoured method of delineating ice flow in the province 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 on bedrock. Data from individual striations should be treated with caution because ice-flow patterns can show considerable local variation where ice flow has been 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 ice 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 "nail-head" striations, and miniature crag-and-tails (rat-tails), and by the morphology of the bedrock surface, which may show the affects of sculpting by ice (Iverson, 1991). At many sites, the direction of ice flow is unclear, and only the orientation of ice flow (*e.g.,* northward or southward) can be deduced. Where striations representing separate flow events are found, the age relationships are based on crosscutting of striation sets, and the preservation of older striations in the lee of the younger striations.

Striation data for the province are compiled in a web-accessible database (http://gis.geosurv.gov.nl.ca; Taylor, 2001) that 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 aerial photographs or from Shuttle Radar Topography Mission (SRTM) data (Figure 3). Clast provenance also helped confirm glacial source areas.

Palaeo ice-flow indicators show that the Burin Peninsula has been covered by possibly 3 separate ice-flow events (Figure 3).



OVERLAP SEQUENCES

***Carboniferous***

Terrenceville Formation. Maroon and brown, pebble and cobble conglomerate

***Devonian and Carboniferous***

Non-marine sedimentary and volcanic rocks. Includes Grand Beach complex, Rocky Ridge Formation

***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), Ragged Islands Intrusive Suite (pink, medium-grained granite) and St. Lawrence granite (pink to red, medium- to fine-grained riebeckite-aegirine granite)

DUNNAGE ZONE

Cambrian to Middle Ordovician

Marine siliclastic submarine rocks, including shale, argillite, sandstone with minor volcanic rocks

Submarine mafic, intermediate and felsic volcanic rocks, including rocks from ophiolite complexes

GANDER ZONE

Cambrian (?) and Ordovician

Quartzite, psammite, semipelite and pelite, including minor black shale, conglomerate, limestone, mafic and felsic volcanic rocks

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)

Stratified rocks

***Neoproterozoic to Early Ordovician***

Shallow-marine, mainly fine-grained, siliciclastic sedimentary rocks, including minor unseparated limestone and volcanic rocks. Includes Random Formation, Chapel Island 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 2.** *Bedrock geology (after Colman-Sadd* et al., *1990).*

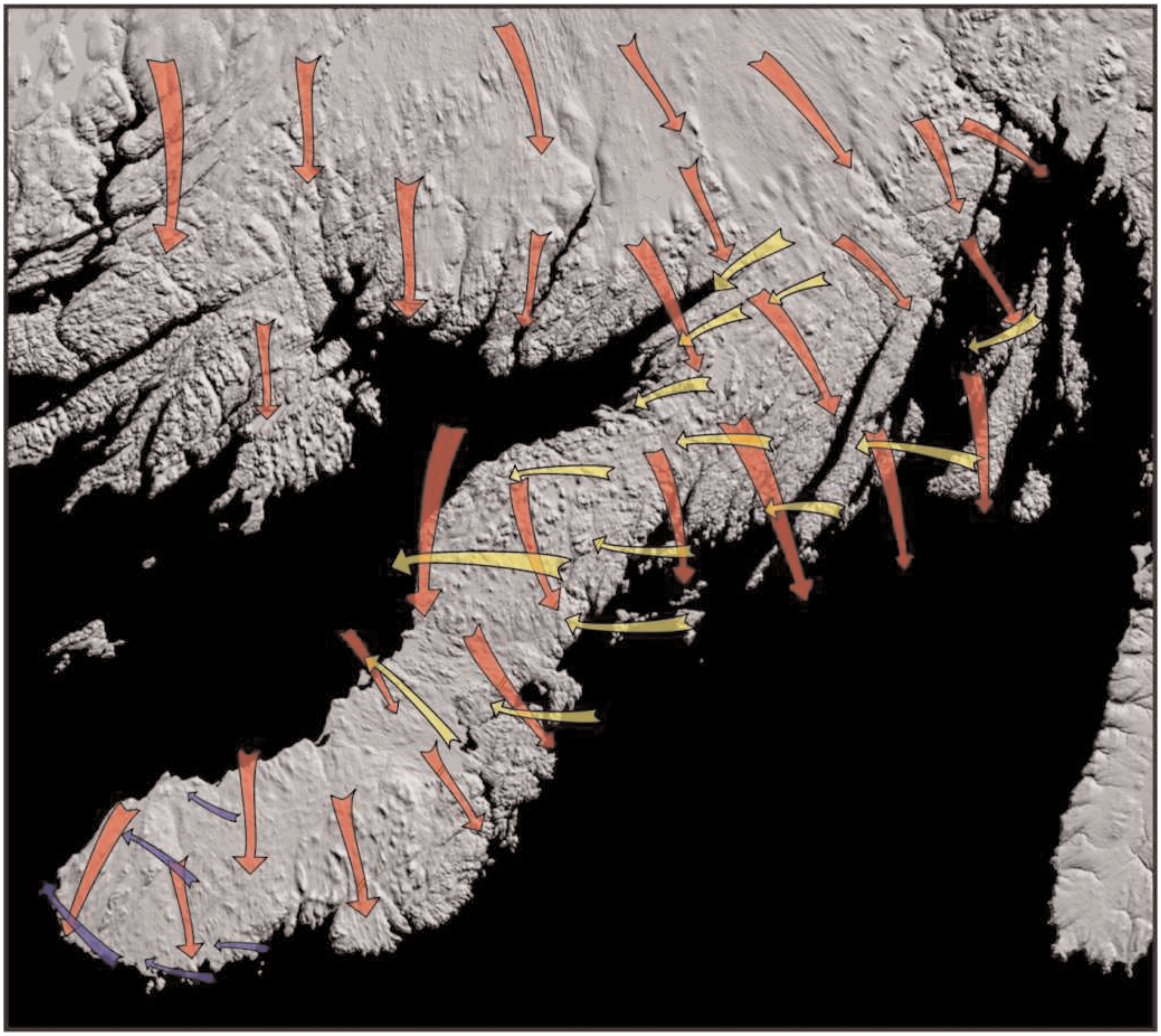


**Figure 3.** *Palaeo ice flow on the Burin Peninsula and adjacent areas, interpreted from data compiled from various sources. Red arrows are relatively older than the yellow and purple arrows, which have the same relative age. All striations are interpreted to have been formed during the last, late Wisconsinian glacial period.*

**Flow Phase 1**

The earliest ice flow was a generally southward event (Figure 3), evidence for which is found across the entire study area. It is the only flow direction recorded north of Fortune Bay, and it is consistently the oldest flow when two or more flow directions are recorded. Striations are fresh and unweathered, although minor iron-staining was found in some locations. The southward ice flow is responsible for most of the glacial landforms in the area. The SRTM data shows southward-oriented landforms (mostly flutes) extending south of the Ackley Granite, and across the north part of the Burin Peninsula. These landforms are parallel to striations found in the same area, and although no temporal link can be established between the two, the coincidence of direction is perhaps significant. The southward ice flow is also shown by the distribution of clasts from bedrock sources to the north. In particular, the southward displacement of Ackley Granite clasts is consistent with southward-directed ice flow. Insufficient clast provenance work has been completed on the southern part of the Burin Peninsula, although Tucker and McCann (1980) reported vesicular basalt clasts at Little Danzig Cove, that they consider were derived from the Hermitage Peninsula.

The source of the southward flow is from north of the study area. No divergent ice-flow patterns were found within the study area, confirming that any ice divide is north of the area. The source was likely the central Newfoundland ice divide (Shaw *et al.,* 2006). The continuity of striations and glacial features related to the southward flow across the Burin Peninsula strongly suggests that all are of the same age. No moraines or change in surface weathering to suggest a period of ice-free conditions, were recognized. The southward ice-flow event is therefore interpreted as late Wisconsinan.

### Flow Phase 2

The southward ice flow was succeeded by a southwestward (in the north) to northwestward (in the south) ice flow (Figure 3). Evidence for this flow is found south of the head of Fortune Bay to a line extending between Marystown and Frenchman's Cove. Westward ice flow is found on Merasheen Island, and Jude Island in Placentia Bay. Although the westward flow moulded bedrock outcrops (Plate 1), glacial depositional landforms were not found associated with this flow event. Batterson and Taylor (2006) suggested that the southwestward flow, near Fortune Bay, was distinct from the westward flow seen elsewhere in the area. The distribution of striations and the consistent relationships found now suggest that the two flows cannot be separated.

The source of the westward flow is problematic, although there are two possibilities: an offshore Placentia Bay ice centre or an Avalon Peninsula ice centre. An offshore source would require either that a lobe of ice extended into Placentia Bay from the north, or that an offshore bank was occupied by ice. Shaw *et al.* (2006) suggested that an ice stream occupied Placentia Bay during the glacial maximum, supported by submarine glacial bedforms (drumlins) that showed convergent flow from the main part of the Island and the Avalon Peninsula. It is possible that during the waning stages, a lobe of ice was pinned by the islands, in the north part of the bay, producing onshore flow on the Burin Peninsula. However, no onshore striations have been identified on the Avalon Peninsula (Catto, 1998), and any lobe would require sufficient thickness to cross the entire peninsula, which is over 170 m asl in the centre of the peninsula and a maximum elevation of ~320 m asl. Grant (1975, 1987) considered onshore ice flow on the southern Burin Peninsula was from 'a source centred in Placentia Bay or on the banks beyond' (Grant 1975, p. 55), likely St. Pierre, Green or Whale banks (Figure 4).

The Avalon Peninsula has long been recognized as maintaining an independent ice cap during the late Wisconsinan (*e.g.,* Chamberlin, 1895; Coleman, 1926, Henderson, 1959). This ice cap, which was of a sufficient thickness to

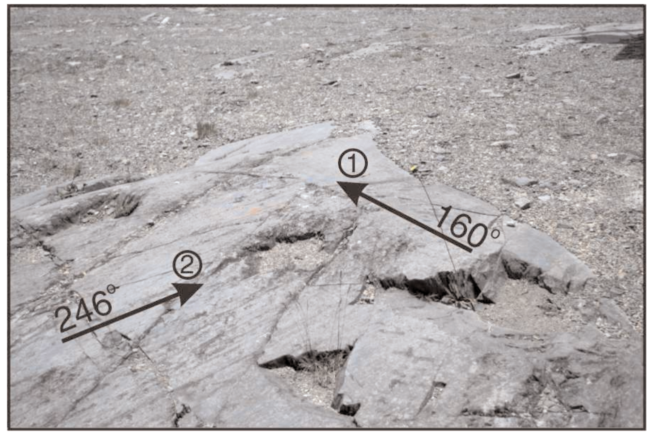



**Plate 1.** *Early southward (160) ice flow crossed by more recent westward (246) flow on a bedrock outcrop near Grandy's Pond.*


**Figure 4.** *Map showing major submarine banks off the south coast.*

block eastward-flowing ice from the main part of Newfoundland, maintained ice until about 10 ka BP, a date supported by the lack of evidence for the Younger Dryas in pollen records (Macpherson, 1996). The ice-flow reconstructions of Catto (1998) suggested that westward ice flow from the Avalon Peninsula during the late Wisconsinan was confluent with Newfoundland ice in flowing southward down Placentia Bay. The possibility remains that during deglaciation and following retreat of Newfoundland ice, Avalon ice crossed Placentia Bay and the Burin Peninsula.

Whether this configuration would be unsupportable glaciologically (*e.g.,* the ice cap would be too asymmetric to be viable) requires further examination.

Regardless of the source, the westward flow must be late Wisconsinan (deglacial?) because it postdates the southward ice-flow event, which has already been interpreted as late Wisconsinan (maximum?).

**Flow Phase 3 (?)**

A possible third flow event is recorded at the southern tip of the Burin Peninsula (Figure 3). This flow was westward to northwestward, and in all cases it postdates the southward ice flow, where evidence for the two ice-flow directions are found on the same bedrock outcrop. It is possible that this flow is equivalent to the westward ice flow recorded to the north, but no evidence was found to support the connection between the two areas. The Fortune Bay coast between Frenchman's Cove and Fortune revealed no striation sites, and the Placentia Bay coast between Burin and St. Lawrence had few sites, none of which recorded the westward ice flow. The interior area was not examined because of the lack of access.

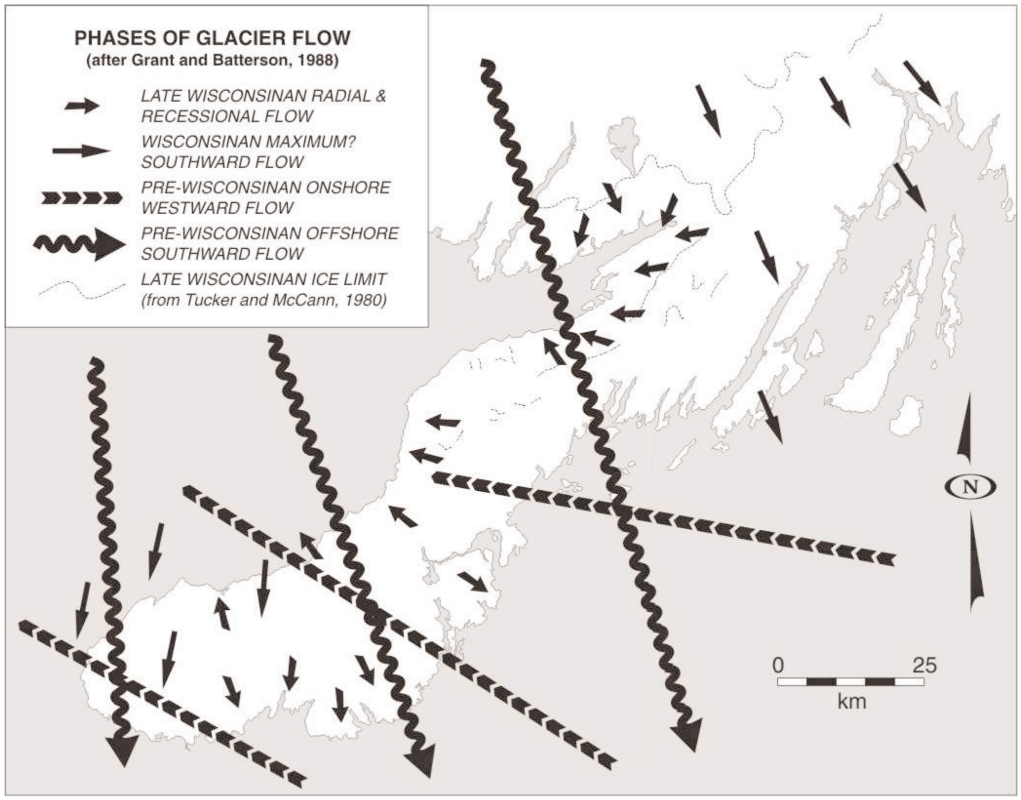



**Figure 5.** *Phases of glacial flow on the Burin Peninsula (after Grant and Batterson, 1988; Tucker and McCann, 1980).*

## Discussion

Evidence for two, possibly, three late Wisconsinan ice-flow events were found on the Burin Peninsula. An early, regionally extensive southward ice flow was superseded by westward ice flow from the Avalon Peninsula or an offshore source. A remnant ice cap on the southern part of the Burin Peninsula may explain the ice-flow patterns in this area, as noted by Vanderveer (1975) and later by Tucker and McCann (1980).

The general sequence of events determined from striation mapping is similar to earlier reconstructions (Figure 5). Alstine (1948), Walthier (1948), Grant (1975) and Tucker and McCann (1980) identified northwestward striations on the southern part of the Burin Peninsula, which post-dated southward flow. Grant (1975) and Tucker and McCann (1980) argued that the ice-flow events were likely early Wisconsinan, based on the reported weathering of striations and the relationship of separate ice-flow events to stratigraphy along the Fortune Bay coastline. At Dantzic (Danzig) Cove, Tucker and McCann (1980) reported coastal exposures up to 45 m high and 1.4 km long (Plate 2) that reveal a 'lower very compact, pink-grey, silty-sandy till; a middle unit of faulted, cross-bedded, very fine sands and silts, containing benthic foraminifera; and an upper light brown, substratified till'. They argued that the stratigraphy and foraminiferal assemblage of the sand/silt unit at Danzig Cove is similar to that exposed at Salmon River in Nova Scotia, where a sand unit was dated at 38,600 ± 1300 radiocarbon years BP (Nielsen, 1974). Therefore, the two exposures were considered to be correlative. The lower till (Plate 3), lying below the sands, was argued to have been deposited by southward- flowing ice based on clast provenance and clast fabrics and was thus assigned an early Wisconsinan age. However, the exposures at Danzig Cove remain undated, and the foraminiferal content is suggestive only of generally shallow-water, low saline conditions. Exposures of diamicton separated by sand, although they may indicate a readvance of ice, have also been interpreted as being deposited from tidewater glaciers (*cf.,* Bell *et al.,* 2001). The inherent complications of long-distance correlations must place into doubt the chronology interpreted from the Danzig Cove exposures by

**Plate 2.** *Extensive exposure of Quaternary sediment at Great Danzig Cove, Fortune Bay. Several diamicton units are exposed in these sections, which have a lateral extent of over 1500 m and a height of over 25 m.*

**Plate 3.** *Exposure of glacial sediment at Great Danzig Cove. The basal unit is a pink, silty clay diamicton. It is overlain by 10m+ of grey diamicton. The lower unit may have been deposited by southward flowing ice that crossed Fortune Bay. Clast provenance studies should assist in the differentiation of the source of these diamicton units.*

Tucker and McCann (1980). A more detailed examination of the stratigraphy will be required to resolve this issue.

## GLACIAL LANDFORMS

Although airphoto interpretation of the Burin Peninsula is incomplete, comments on the surficial geology can be made based on ground observations and the use of the Shuttle Radar Topography Mission (SRTM) image for the area. The SRTM, flown in 2000, aimed to map the Earth's surface topography using synthetic aperture radar. Data from the mission are freely available on-line, and have been used for interpreting glacial landforms (*e.g.,* Campbell, 2005). Liverman *et al.* (2006) provided a preliminary interpretation of a digital elevation model (DEM) from the SRTM data that provides a new insight into the ice-flow and glacial history of the Island.

Streamlined glacial landforms are clearly evident from the SRTM image (Figure 6), particularly in the Gisborne Lake area (Figure 6a), between Marystown and Garnish (Figure 6b), and near St. Lawrence (Figure 6c). A blanket of thicker sediment is shown on the SRTM image by the smooth surface. Streamlined landforms are southward- to southeastward-oriented lineations that extend from the top of the image to east of Terrenceville. These features have an orientation consistent with the ice-flow record, and are interpreted as having been deposited by ice from the main Newfoundland ice divide. There appears to be no large-scale landform evidence of the subsequent westward ice flow. South to the Marystown-Garnish area, the landscape is dominated by bedrock outcrop, indicated by the rough surface topography on the SRTM image. Few glacial depositional landforms are found in this area. The lowlands between Marystown and Garnish contain thicker sediment cover, including southeast–northwest-oriented landforms (Figure 6b). The orientation of these landforms is parallel to the striations from the early phase of ice movement, and on this basis the landforms are tentatively assigned to that flow direction. In the St. Lawrence area, southward-oriented landforms are common (Figure 6c), although the area differs from the Marystown–Garnish and Gisborne Lake areas because more bedrock is exposed. The orientations of landforms are parallel to striations interpreted to represent the first phase of ice flow, and the landforms are tentatively assigned to that ice flow. Elsewhere on the Burin Peninsula, blankets of sediment are found at the southwestern tip (Plate 4), although glacial depositional landforms are uncommon.

Deglacial landforms, and those deposited during the Holocene, are mostly associated with glaciomarine and marine environments. Batterson *et al.* (2006) reported on small areas of glaciofluvial sand and gravel that are exposed within the major valleys, several of which are being exploited for granular aggregate; 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 with 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, Terrenceville Brook, Garnish River, Main Brook and Southwest Arm valleys (Kirby *et al.,* 1983). Ricketts (1986) noted several eskers west of the mouth of Pipers Hole River, and eskers were also noted in the Gisborne Lake area.

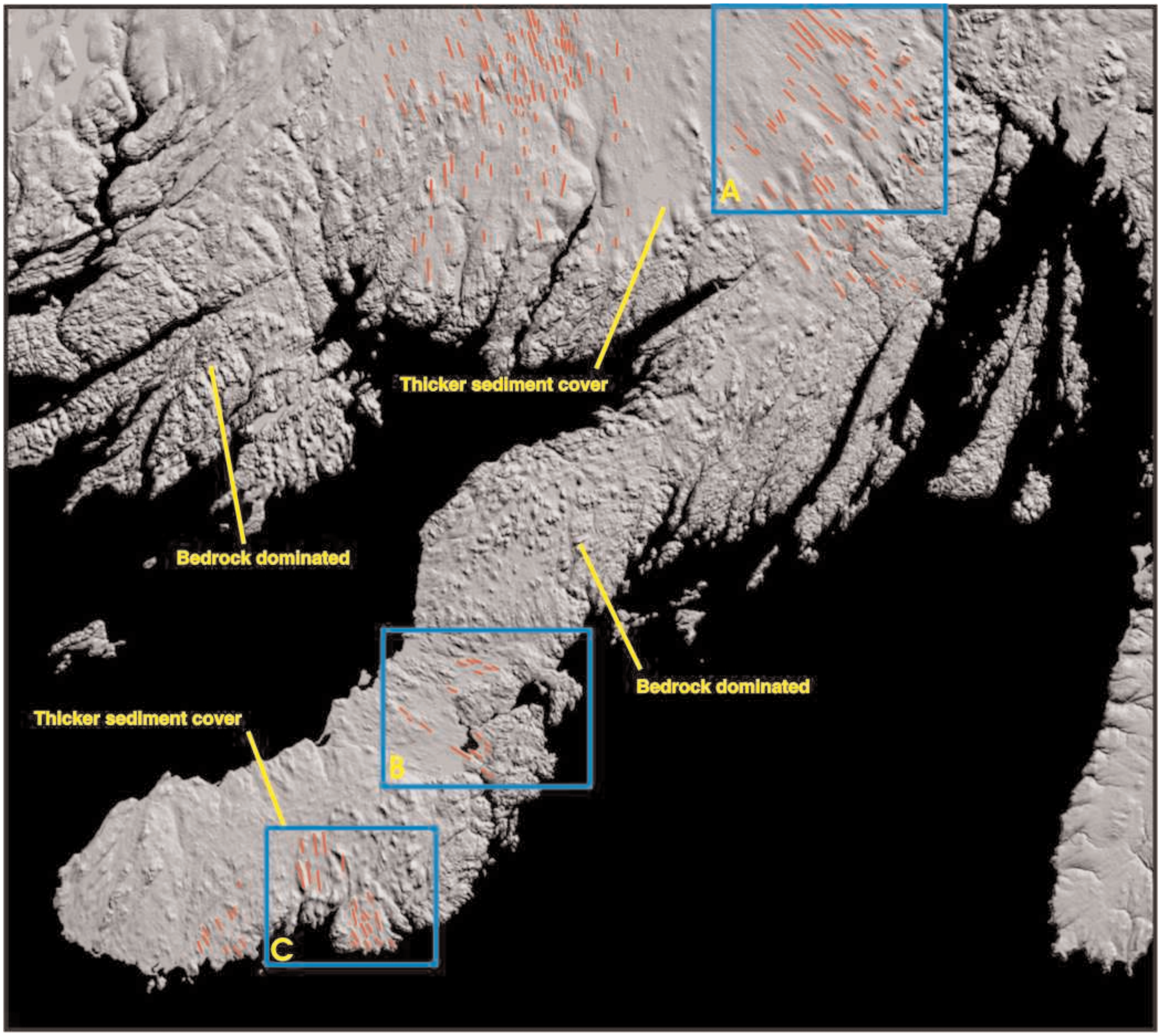



**Figure 6.** *Landforms on the Burin Peninsula and adjacent areas as seen on the SRTM image.*

Several proglacial lakes were formed during the last deglaciation. Batterson *et al.* (2006) reported evidence for a proglacial lake in the Gisborne Lake valley. Evidence for a smaller proglacial lake was found in the valley south of Fortune. Fine-grained sediments (mostly interbedded silts and fine sands) and interbedded diamicton are exposed in several road cuts (elevation ~45 m asl; Plate 5) located 2 km south of Fortune. The lake may have been ponded by ice at the mouth of Fortune Harbour, where a bank of compact pink diamicton is exposed (Plate 6). The morphology of the exposure, banked against the hillside, may suggest it is the remnants of a moraine, although further analyses will be required to confirm this. No lacustrine beaches or terraces were found, and this, coupled with the small exposures of sediment, may suggest that the lake was short-lived. This proglacial lake was previously described by Grant and Batterson (1988), who suggested that the lake drained to the south through a channel at about 100 m asl.

## SEA-LEVEL HISTORY

Evidence for raised sea levels is common along the coast of the Burin Peninsula, mostly in the form of raised marine terraces and deltas. All remain undated, and no dateable material has been found to constrain a late glacial chronology on the peninsula.

**Plate 4.** *Coastline south of Fortune. About 4-6 m of diamicton is exposed overlying Precambrian to Cambrian micaceous sandstone.*

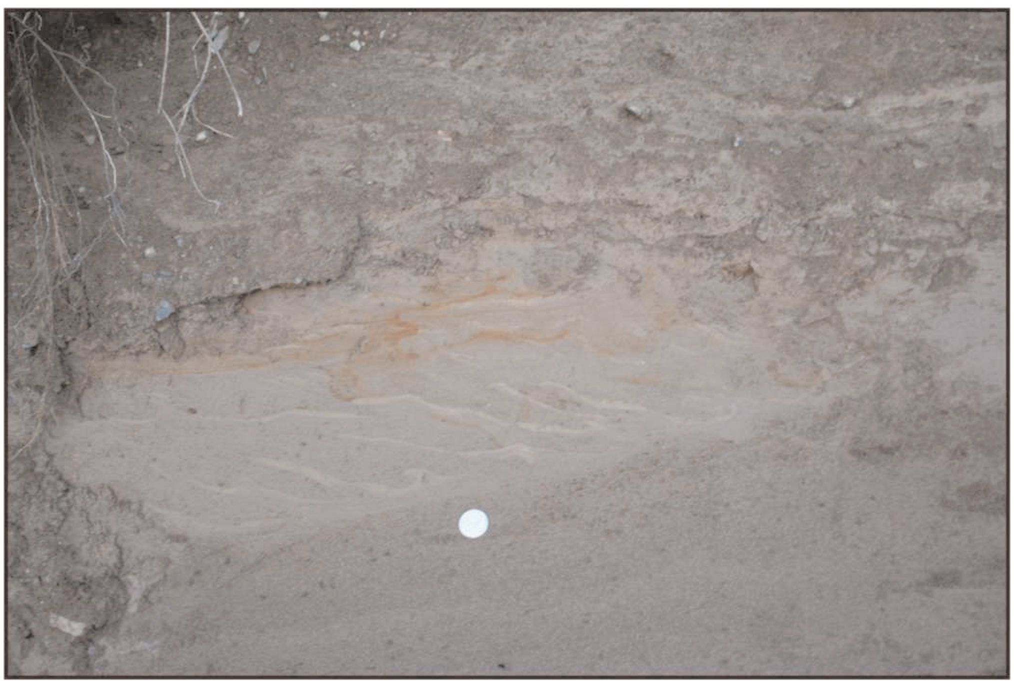


**Plate 5.** *Fine-grained sands, silts and diamicton in roadside exposure south of Fortune. These sediments are interpreted as having been deposited in a glaciolacustrine envirnoment.*

Along the Fortune Bay coastline, an ice-contact glaciomarine delta having a surface elevation of ~19 m asl is found at Jacques Fontaine (Plate 7). It was likely formed by a tongue of ice that occupied the valley east of the community. Bedding of interbedded sands and sandy gravels exposed in a small aggregate pit at the coastward side of the delta dips toward Fortune Bay. Similar features are found on the north shore of Fortune Bay, on the east side of Grand le Pierre Harbour, at Tickle Head in Long Harbour (Plate 8), and at Terrenceville, all with surface elevations estimated between 17 and 20 m asl. Features are flat topped, with steep upstream and downstream faces.

Raised marine sediments and features are common along the Fortune Bay coastline between the now-abandoned community of Point Rosie (Point Enragée) and Grand Bank. The coastline is largely bedrock dominated north of Point Rosie. Sediments are commonly poorly sorted sand and gravel, and likely reflect a nearshore depositional environment. Fine-grained sediments were largely absent. Marine terraces were identified at Rencontre East and north of Garnish, where surface elevations are estimated to be between ~ 15 and 20 m asl.

The bedrock-dominated Placentia Bay coast has less evidence for raised marine features than the Fortune Bay side. A series of three raised beaches with a maximum elevation of ~20 m asl were identified on the east shore of Great Sandy Harbour (Plate 4 in Batterson *et al.,* 2006), and raised marine terraces were found at St. Leonards, Bar Haven, and Prowseton, all at elevations of about 20 m asl.

**Plate 6.** *Compact, pink diamicton exposed in cliffs east of Fortune Harbour. This diamicton may represent a moraine at the mouth of the harbour that impounded a small proglacial lake in the valley south of Fortune.*

**Plate 7.** *Raised glaciomarine ice-contact delta at Jacques Fontaine. The delta has a surface elevation of ~19m asl. The age of this feature, and other examples of raised marine/glaciomarine landforms along the Placentia and Fortune bay coastline, remain uncertain due to the lack of dateable material contained within them.*

Raised marine features and sediments are found as far south as Grand Bank on Fortune Bay, and St. Lawrence on Placentia Bay. Glacial diamicton is exposed along the coast between these areas, indicating that no marine overlap has occurred.

The broad pattern of observations was reported by Jenness (1960), Tucker (1979), Grant (1989), and Grant and Batterson (1988), although different interpretations of their significance have been reached. Jenness (1960) and Grant (1989) argued for west–east-trending isobases crossing the Burin Peninsula, with the 0 m isobase extending across the southern part of the peninsula (Figure 7). Tucker (1979) preferred a more southwest–northeast trend to the isobases,

**Plate 8.** *Raised glaciomarine delta at Tickle Head, Long Harbour. This feature has a surface elevation estimated about 17m asl.*

with the 0 m isobase only impinging on the southeast part of the peninsula (Figure 7). However, no evidence of raised marine features was found west of Grand Bank. Assuming the entire peninsula was deglaciated, areas south of the 0 m isobase would have been continuously submerged following deglaciation. Alternatively, the absence of raised marine features may imply that the southern part of the peninsula was ice covered while areas to the north were ice free. This latter argument may lend support to the existence of remnant ice at the southeastern tip of the Burin Peninsula during regional deglaciation.

The early Holocene sea-level history shows a lowering of sea level to the postglacial lowstand that occurred in eastern Newfoundland between 6.5 and 8.0 ka (Shaw and Forbes, 1995). The lowstand reached depths of between 8 and 18 m below present sea level, deepening to the south. Submerged terraces (deltas) were recorded at Long Harbour, Fortune Bay (-12 m), Piper's Hole (-8 m), Paradise Sound (-13 m) and Marystown Harbour (-18 m). Following the lowstand, the pattern of sea-level change has been one of gradual submergence. Evidence of submergence is found at Frenchman's Cove where a series of prograded beach ridges are being successively inundated by the sea (Plate 9). Grant and Batterson (1988) cite drowned peat bogs and salt marsh development in the Little St. Lawrence/Lawn area. Radiocarbon dates on peat and wood 1.7 m below the high tide level are ~1000 radiocarbon years BP, suggesting a submergence rate of 17 cm per century. However, the peat must have accumulated above sea level and thus before inundation, and so the rate of submergence may be significantly lower. In comparison, Catto *et al.* (2000) suggest rates of submergence of between 10 and 65 cm per century for several sites on the Avalon Peninsula, whereas Daly (2002) reports a submergence rate of 7 cm per century from salt marsh deposits at Placentia. D. Liverman (GSNL, unpub-

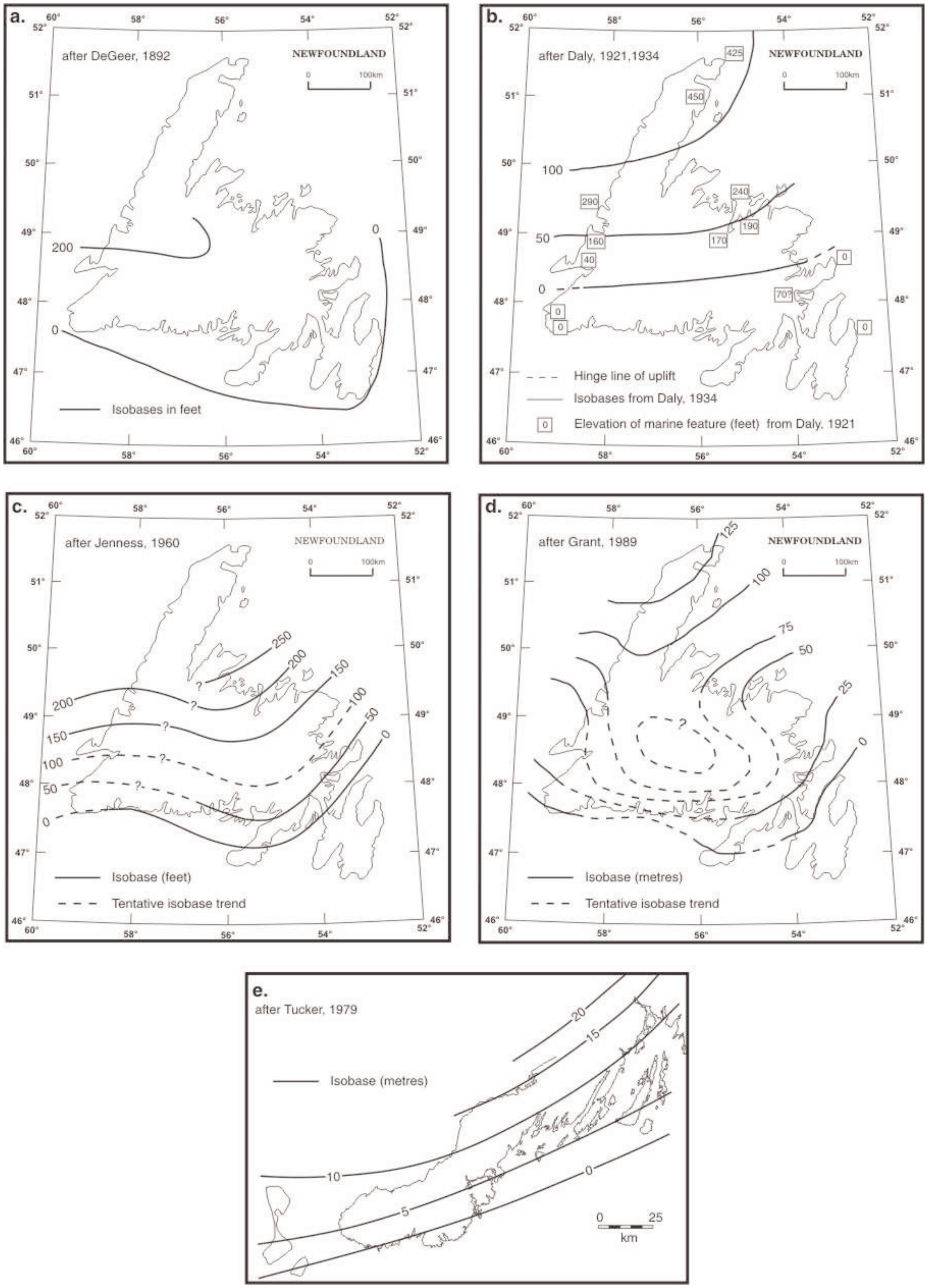



**Figure 7.** *Previously published isobase maps of Newfoundland.*

**Plate 9.** *Raised beaches at Frenchman's Cove, looking north. This part of the Fortune Bay coastline is under threat from rising sea level.*

lished data, 2006) records several dates, the oldest of which is 940±50 years BP (GSC-5706) on a tree stump at sea level at Lansey Bank Cove on the southern Avalon Peninsula that also provides evidence for rising sea levels in the last millennium.

The data indicates that the Burin Peninsula is characterized by a Type B sea-level curve; a rapid sea-level fall to below present in the early Holocene and a continuous rise subsequently.

Modern 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, along Fortune Bay, and Western Cove, St. Kryan's and Long Beach on Placentia Bay (Figure 1). Tombolos were identified at Proweston, Bar Haven, Spanish Room and Allan's Island, along Placentia Bay and Bay L'Argent, Little Bay East, and Frenchman's Cove, along Fortune Bay, and spits were noted in Fortune Bay at Grand Le Pierre and Terrenceville. Most are gravel-dominated, have a variety of structures, including small- and large-scale cuspate features, and beach berms, with back-beach 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 in length.

### 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 in the field through a 5-mm-mesh sieve, and approximately 1 kg of sediment was placed in a paper bag.

A total of 748 samples were collected (Figure 8) and submitted to the Geological Survey's geochemical laboratory in St. John's for analysis, either internally by gravimetric analysis, and inductively-coupled plasma-emission-spectrometry (ICP-ES) 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 2007.

## SUMMARY OF GLACIAL HISTORY

The lack of radiocarbon dates from the Burin Peninsula means considerable uncertainty exists concerning the chronology of glacial events. Grant (1989), and Tucker and McCann (1980) have argued that much of the Burin Peninsula was beyond the limit of late Wisconsinan ice, apart from small remnant ice caps along the spine of the peninsula. This argument was largely based on weathered striated surfaces, and on the long-distance correlation of exposures along Fortune Bay, where exposures contained similar stratigraphy and foraminiferal content to that found in Salmon River, Nova Scotia, which have been interpreted as interstadial. Diamictons below the interpreted interstadial sediments were linked to southward striations from ice that crossed Fortune Bay.

Striation and landform evidence confirm a regional southward (south to southeastward) flow event covered the Burin Peninsula. The striations are generally fresh and unweathered, although some weathered facets were noted, the significance of which is uncertain. The consistency of flow patterns across the area suggests that they are of the same age as those on the main part of Newfoundland, which has been interpreted as late Wisconsinan. This ice flow produced most of the glacial streamlined landforms in the area. The southward ice flow was followed by a regionally extensive westward (southwest to northwest) ice flow that crossed the Burin Peninsula from Placentia Bay to Fortune Bay. Evidence for this event is crossing striations, rather than a depositional record. The source of this event remains uncertain. Striations produced by a westward to northwestward ice flow are found at the southern tip of the peninsula.

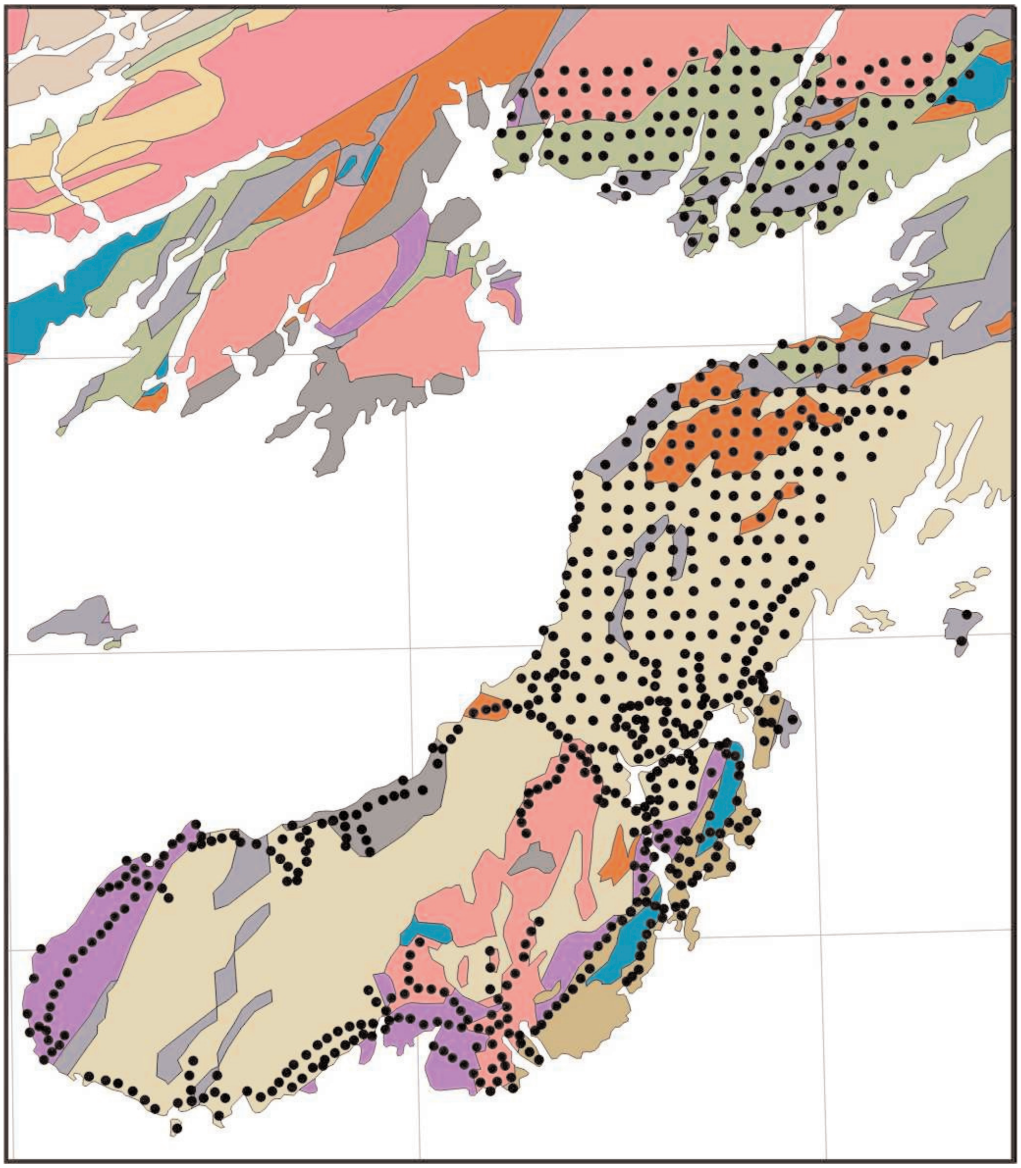


**Figure 8.** *Map showing the distribution of till samples from 2006 survey.*

Deglaciation led to the production of extensive glaciofluvial deposits in many of the major valleys that are commonly graded to the postglacial sea level. Raised marine features (mostly deltas and terraces) suggest marine limit was about 20 m asl on both the Fortune Bay and Placentia Bay coasts. There is no evidence for raised postglacial seas in the southern part of the peninsula, suggesting the area has experienced continual submergence during the Holocene (*i.e.,* south of the 0 m isobase) or that the area was ice covered at a time when the areas to the north were ice free. Preliminary work indicates that raised marine features are not graded toward a 0 m isobase and that remnant ice on the southern part of the peninsula may better explain the sea-level history. During deglaciation, proglacial lakes formed at Gisborne Lake and south of Fortune. The lack of shoreline features and glaciolacustrine sediments suggest these were short-lived features.

This ice flow may be the same as the westward flow found farther north, but the lack of striated bedrock means that link cannot be established.

Sea level has been rising through much of the Holocene following the postglacial lowstand. Rising sea levels, as a combined result of isostatic rebound and global sea-level changes, will continue to be a major influence on coastal change on the Burin Peninsula.

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

| Method | Elements Analyzed |
|---|---|
| Gravimetric analysis | LOI |
| Inductively-coupled-plasma-emission spectrometry (ICP-ES) | 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 |

## FURTHER RESEARCH

Detailed examination of Quaternary stratigraphy exposed in cliffs south of Fortune and in other isolated areas on the peninsula, a clearer definition and description of raised marine features and sediments, and a sedimentological and geomorphic link to the submarine environment in Placentia and Fortune bays are required. Completion of sampling for till geochemistry in interior regions on the southern part of the Burin Peninsula is also planned.

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