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# QUATERNARY GEOLOGY OF THE GANDER LAKE AND GAMBO MAP AREAS (NTS 2D/16 AND 2C/13)

D. Brushett
Geochemistry, Geophysics and Terrain Sciences Section

## ABSTRACT

*The results presented here are from the first year of a multi-year till-geochemistry and surficial-mapping program in northeast Newfoundland. The 2009 field component focused on sampling the soil for till-geochemistry, and surficial-geology mapping in areas north and east of Gander Lake (NTS map areas 2D/16 and 2C/13).*

*The study area is dominated by till, of varying thicknesses, and organic deposits. Inland, the till cover is generally extensive and it conceals much of the bedrock creating a gently undulating topography. Toward the coast, the topography is more rugged and till cover is generally thinner (or absent) and bedrock more prominent. Sediments in the Butts Pond–Gambo area include glaciofluvial and hummocky deposits, esker-like ridges, and a Gilbert-type delta that likely formed during deglaciation, as the ice was retreating toward Gander Lake.*

*The data from ice-flow mapping showed two regionally extensive events. The earliest ice flow was eastward throughout the field area, likely from a source north of Red Indian Lake. The most recent regional flow was north-northeastward and was only observed in the western edge of the study area, the remainder being covered by stagnant ice.*

*Regional till sampling was conducted at a spacing of 1 sample per 1 km$^2$ in areas of good access and 1 sample per 4 km$^2$ where helicopter support was required. A total of 502 till samples were collected. Geochemical data is expected to be released in mid- to late-2010.*

## INTRODUCTION

This report is the first from a multi-year till-geochemistry and surficial-geology mapping program in northeast Newfoundland that commenced in 2009. The area is of considerable mineral-exploration interest, particularly for gold and base metals; however, exploration is hampered by limited details on the Quaternary history and a lack of regional till-geochemistry coverage. This project is a systematic study of the surficial geology and till geochemistry of the area and includes investigations of the region's geomorphology, sedimentology, ice-flow history, and its glacial dispersal patterns. The objective of this project is to further our understanding of the region's Quaternary history as it relates to mineral exploration and provide a basis for the evaluation of geochemical data; it will identify suitable sampling media for further geochemical exploration, especially in the more inaccessible and drift-covered areas.

The 2009 field component focused on till sampling and mapping in areas north and east of Gander Lake (NTS map areas 2D/16 and 2C/13). Only limited Quaternary investigations have been completed in the field area – in the Gambo area (part of NTS map area 2D/16) by McCuaig (2006) and Vanderveer and Taylor (1987) and in the Weir's Pond area (parts of NTS map areas 2D/16 and 2E/1) by Butler *et al.* (1984). Thus, this project will fill a gap in geochemical data coverage and provide an important addition to the provincial geochemical database expanding to cover areas that have not been included in previous surveys. The results of this project will supplement results from similar projects in surrounding areas, including the Bonavista Peninsula (Batterson and Taylor, 2001), Grand Falls–Mount Peyton area (Batterson and Taylor, 1998), Hodges Hill area (Taylor and Liverman, 2000), and Gander area (Batterson and Vatcher, 1991).

## LOCATION AND ACCESS

Fieldwork was conducted over two 1:50 000-scale map areas in northeastern Newfoundland: Gambo (NTS map area 2D/16) and St. Brendan's (NTS map area 2C/13), covering an area of approximately 1260 km$^2$. The field area extends from the community of Benton in the southwest to

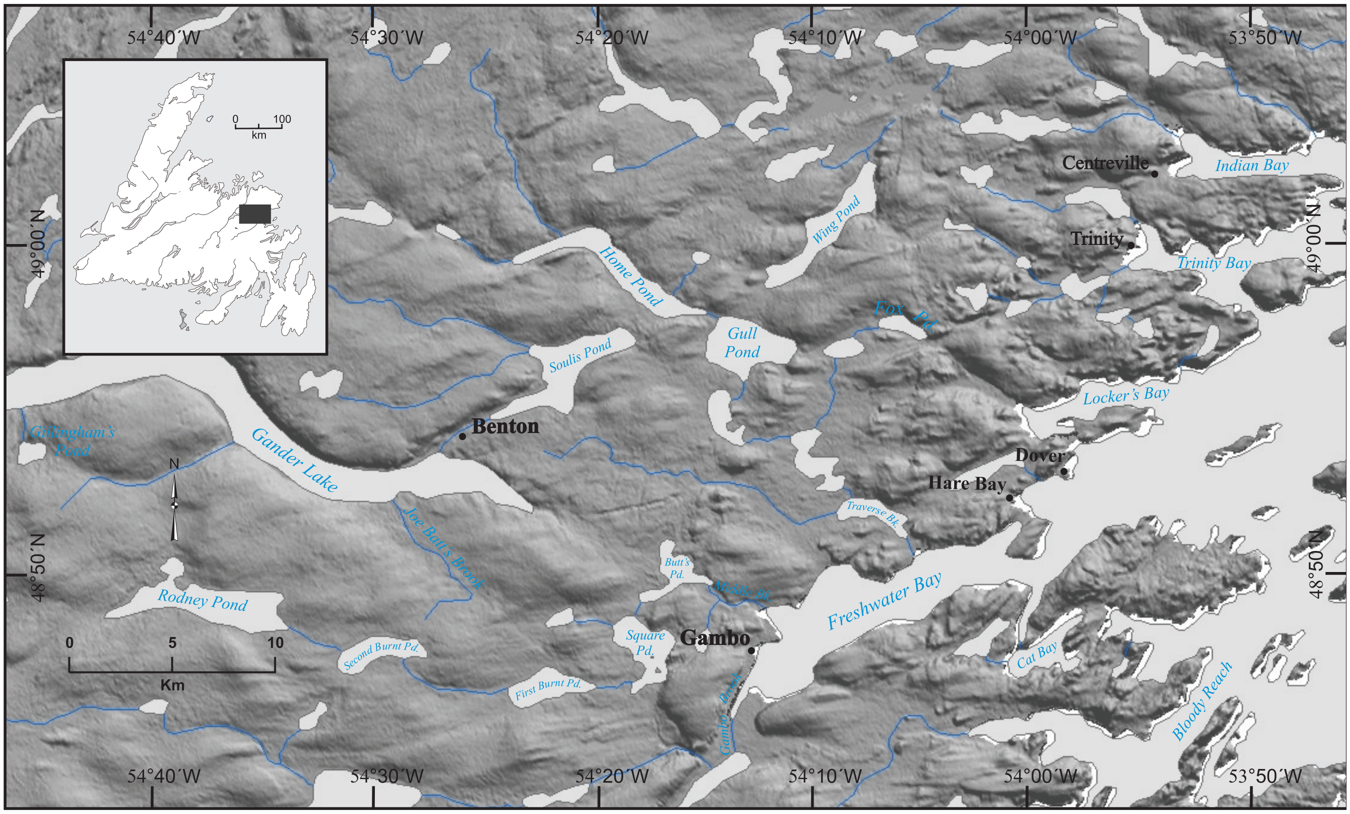



**Figure 1.** *SRTM image of study area showing physiography and places mentioned in text.*

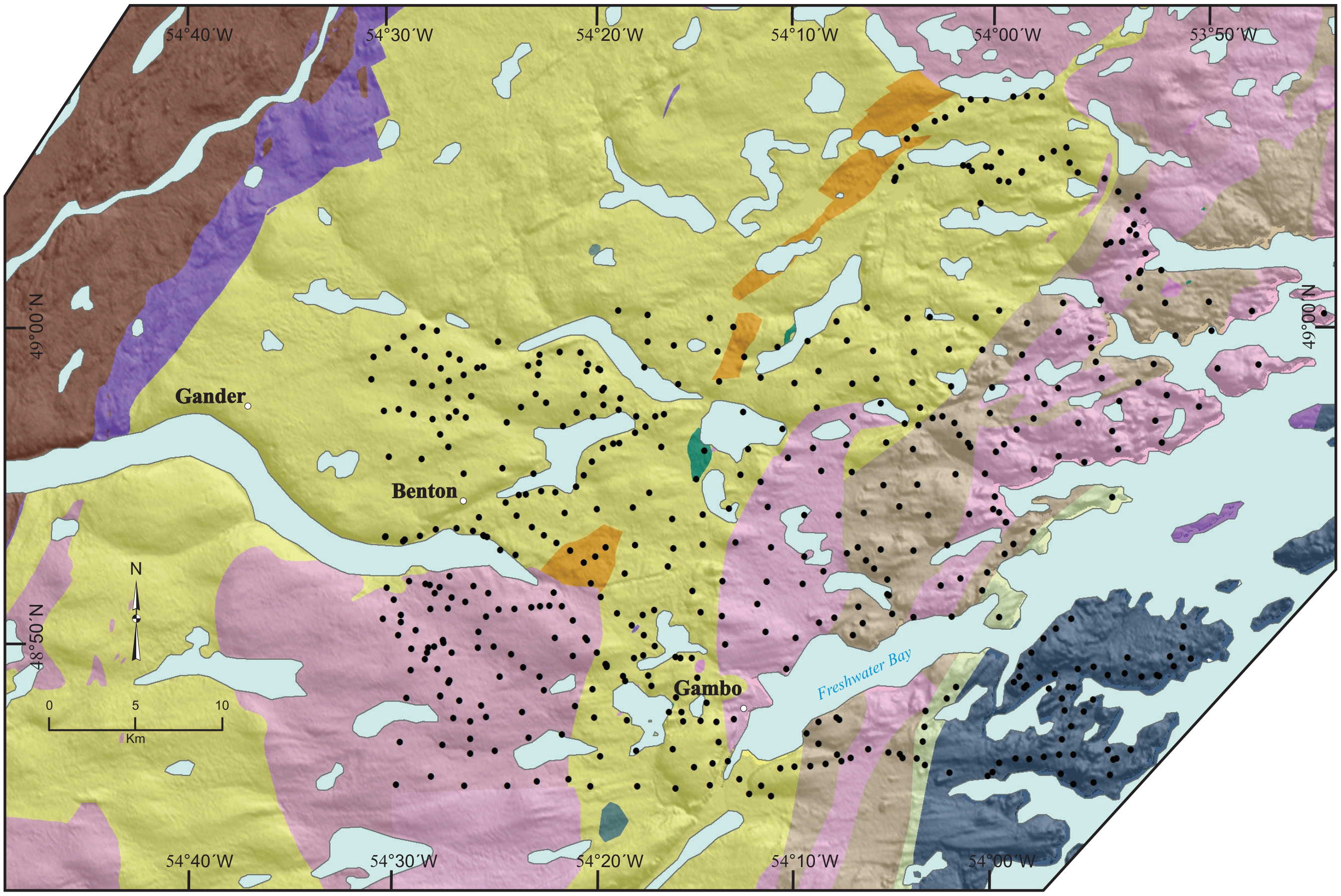
Centreville in the northeast (Figure 1). The Trans-Canada Highway (TCH) and Route 320 (Gambo to Wesleyville) provide good access and cross the map area from southwest to northeast. Logging roads throughout the area provide access inland and ATVs were used along smaller trails and the old railway bed. Remote areas were accessed by helicopter.

## BEDROCK GEOLOGY

The study area is predominantly within the Gander (tectonostratigraphic) Zone of the Newfoundland Appalachians (O'Brien and Knight, 1988; Williams *et al.*, 1988), although rocks of the northwestern Avalon Zone outcrop in the easternmost part of the study area. Much of the area lies within the Gander Group of the Gander Zone, which comprises a north-northeast-trending belt of Ordovician metasedimentary rocks of the Indian Bay Big Pond and Jonathans Pond formations (Figure 2; Blackwood, 1982; O'Neill, 1990). The Indian Bay Big Pond formation consists of grey to purple, pebble and cobble conglomerate interbedded with grey quartz-rich sandstone, maroon siltstone, and greyish-green pelite. The Jonathans Pond Formation consists of interbedded psammite, semipelite and greyish-green pelite predominantly metamorphosed to greenschist or amphibolite facies (O'Neill, 1991). The Gander Group grades eastward into amphibolite-facies rocks of the Square Pond Gneiss and Hare Bay Pond Gneiss (O'Neill, 1987). Exposures of gabbro and biotite or hornblende granite in the Wing Pond, Gull Pond, and Square Pond areas and of ultramafic rock near Square Pond and Butts Pond are associated with the Wing Pond shear zone (O'Neill, 1991).

The Gander Group is intruded by several Devonian granitic plutons, the most extensive being the Gander Lake Granite, a predominantly massive, K-feldspar megacrystic biotite granite, which underlies much of the study area south of Gander Lake. Other plutons include a fine-grained, equigranular, pink- to red-weathering granite and gabbroic intrusions of the Mount Peyton intrusive suite to the west (Blackwood, 1982) and a medium- to coarse-grained, white- to pink-weathering, muscovite granite in the Gillingham's Pond area, which may be correlative with the Middle Ridge granite to the southwest (O'Neill, 1990).

The Gander Zone is separated from the Avalon Zone in the southeast by a 300- to 500-m-wide mylonite zone that defines the Dover Fault (Blackwood and Gibbons, 1977). Bedrock in the area includes Neoproterozoic rocks of the Love Cove and Musgravetown groups. The Love Cove Group, the oldest rocks in the area, consists of sericite and chloritic schist, associated acidic and intermediate volcanic lava, strongly foliated pyroclastic rocks, and minor sedimentary rocks. Most of the area west of Bloody Reach is




## LEGEND

**DUNNAGE ZONE**

**Late Cambrian to Middle Ordovician**

*Gander River Complex:* pyroxenite - locally serpentinized, talc-carbonate rocks, gabbro and mafic volcanic rocks

**Early to Late Ordovician**

*Davidsville Group:* marine siliciclastic sedimentary rocks, including slate, shale, argillite, siltstone, sandstone, conglomerate; minor limestone and felsic and mafic volcanic rocks

**GANDER ZONE**

**Early Cambrian to Middle Ordovician**

*Indian Bay Big Pond Formation:* medium- to thick-bedded, buff, grey and maroon sandstone; thinly bedded, maroon and green siltstone and black pelite; brown-weathering, possibly tuffaceous semipelite

*Jonathans Pond Formation:* quartzite, psammite, semipelite and pelite, including minor black slate, conglomerate, limestone, mafic and felsic volcanic rocks, and unseparated migmatitic rocks

*Hare Bay Gneiss:* migmatite, gneiss and shist

**GANDER ZONE (continued)**

**Early Silurian**

*Wing Pond Shear Zone*: locally foliated, medium- to coarse-grained hornblende gabbro

**Silurian to Devonian**

Gabbro and diorite intrusions, including minor ultramafic phases

**Devonian to Carboniferous**

Granitoid intrusions

**AVALON ZONE**

**Neoproterozoic**

*Musgravetown Group:* bimodal, mainly subaerial volcanic rocks, including unseparated siliciclastic sedimentary rocks

*Love Cove Group:* bimodal, submarine to subaerial volcanic rocks, including minor siliciclastic sedimentary rocks

**Figure 2.** *Bedrock geology of the study area, superimposed on SRTM data (mostly taken from Colman-Sadd and Crisby-Whittle, 2005). Black dots show the location of till samples collected during the 2009 field season.*

underlain by the Musgravetown Group, which comprise red and green conglomerate, sandstone, siltstone, red, buff and grey flow-banded rhyolite with minor rhyolite breccia and tuff (O'Brien and Knight, 1988).

Rocks of the Gander River complex and Dunnage Zone, occurring to the west of the study area, could potentially be used as indicators of glacial transport directions and distances. The Dunnage Zone is composed of Middle Ordovician quartz-poor sandstone, siltstone and conglomerates of the Davidsville and Botwood groups that are nonconformable over the Gander Group. The Gander River complex marks the boundary between the Gander and Dunnage groups and is restricted to a thin north-northeast to south-southwest belt mainly composed of locally serpentinized pyroxenite, but also includes local exposures of carbonate, talc, and gabbro (O'Neill, 1990). Historically, rocks of the Gander River complex have been the main focus of mineral exploration in the area.

Current mineral-exploration activity is centred in areas underlain by quartz-rich sandstones and quartz breccias of the Indian Bay Big Pond and Jonathans Pond formations. Gold is the main target of exploration. The first gold discovered in the area, reported by O'Neill and Knight (1988), is located south of Southern Pond and known as the Little Wing Pond showing. Regional gravity–magnetic data (Miller, 1988) and lake-sediment survey data (Davenport *et al.*, 1988) indicate a correlation of arsenic, antimony and gold along a gravity–magnetic boundary and suggest a potential new gold belt that has had little previous exploration. The Little Wing Pond showing and the discovery of other numerous showings, including the occurrence of visible gold in the Stallion/Star Track project area east of Benton, support this hypothesis.

## PHYSIOGRAPHY

The topography for much of the study area is gently undulating with glacial cover that varies in both thickness and aerial distribution. North of Gander Lake, in areas underlain by bedrock of the Gander Group, the topography is typically flat and featureless. Surficial cover is thin, particularly along the TCH where bedrock is frequently exposed. The area south of Gander Lake is dominated by a hilly topography and thicker sediment cover, hummocky terrain and rare bedrock outcrops. Boulder fields are common in areas underlain by the Gander Lake granite. The topography becomes more rugged toward the coast where sediment cover generally becomes thinner and bedrock prominent (Figure 2).

Gander Lake, a dominant feature in the area, is a long, narrow lake reaching a maximum depth of at least 288 m (O'Connell and Dempson, 2002). Hills to the south of the lake rise to 215 m asl, giving a maximum relief of 503 m for the trough. The steep sides, shape of the basin and alignment with known ice-flow directions are consistent with the description of fjords of glacial origin as suggested by Jenness (1960).

The study area has numerous ponds and is dissected by streams that generally drain eastward into Freshwater Bay. Home Pond drains eastward through a series of ponds to Traverse Pond and into the bay. Rodney Pond drains eastward through Second Burnt, First Burnt and Square ponds. Square Pond drains northeastward to Butts Pond, which drains into Freshwater Bay through Middle Brook.

## QUATERNARY GEOLOGY REVIEW

### REGIONAL QUATERNARY HISTORY

Regional interpretations that include the Quaternary history of northeast Newfoundland have been previously described by Jenness (1960), Lundquist (1965), Grant (1974, 1989), Vanderveer (1985), Vanderveer and Taylor (1987), Shaw (2003), and Shaw *et al.* (2006).

During the last glacial maximum (~21 ka BP), Newfoundland was covered with multiple local ice-dispersal centres producing almost complete glacial cover extending out to the continental shelf edge (Grant, 1989; Shaw *et al.*, 2006; Figure 3). Ice divides extended south and southeast across Newfoundland along the axis of the Long Range Mountains, and east through central Newfoundland and the Avalon Peninsula. Early ice retreat was facilitated by calving along deep channels, particularly off northeast Newfoundland through the Notre Dame channel and Trinity trough, where depths greater than 600 m have been reported (Shaw, 2003). Ice retreat continued *via* calving embayments until ~13 ka BP when ice margins reached coastal areas and the configuration of ice divides shifted as deglaciation became land-based; retreat of isolated ice centres continued by ablation, predominantly through melting (Shaw *et al.*, 2006; Figure 3).

Grant (1974) suggested that at least fifteen remnant ice centres were present during deglaciation, five of which had the potential to influence ice flow in northeastern Newfoundland. These ice centres were located near Red Indian Lake, Meelpaeg Lake, Middle Ridge, north of Grand Falls (in the Twin Ponds area) and in the Gander area (Figure 4). Smaller local ice-dispersal centres also persisted, especially on headlands and peninsulas located between deep channel margins. The Gander area was likely ice-free by ~11.5 ka BP (marine macro-fauna radiocarbon dates from the lower Gander River valley and Exploits River valley; Batterson and Taylor, 1998; McCuaig, 2006).

### ICE-FLOW HISTORY

Regional ice-flow directions determined from glacial erosional evidence, mostly striations, indicate the existence of at least two separate ice-flow events in northeastern Newfoundland during the last, late Wisconsinan glaciation. Relative age relationships are determined from crosscutting relationships and leeside preservation (St. Croix and Taylor, 1990, 1991).

The earliest ice-flow event was eastward (90° ± 20°). This flow was identified around Gander Lake (Vanderveer,


**Figure 3.** *Glacial extent at ~13 ka BP. Last glacial maximum (dotted black line), major ice divides (thick blue dashed lines) and generalized ice-flow lines (thin blue lines; modified from Shaw* et al.*, 2006).*

1985; Vanderveer and Taylor, 1987; Batterson and Vatcher, 1991; St. Croix and Taylor, 1991) and eastward into Freshwater and Bonavista bays (Jenness, 1960; Butler *et al.*, 1984; St. Croix and Taylor, 1991). This flow parallels Gander Lake in its central part and along the southeast-oriented portion of the lake. The probable source of this ice-flow event was from north of Red Indian Lake, based on the presence of eastward striations in the northwest Gander River area (Proudfoot *et al.*, 1988), the Grand Falls–Glenwood area (Batterson and Taylor, 1998) and the Red Indian Lake area (Vanderveer and Sparkes, 1982).

The eastward ice-flow event was followed by north-northeast ice flow. Evidence for this northward ice flow is widespread throughout most of northeastern Newfoundland (Butler *et al.*, 1984; Vanderveer and Taylor, 1987; St. Croix and Taylor, 1990, 1991; Batterson and Vatcher, 1991; Scott, 1994; Batterson and Taylor, 1998). This flow roughly parallels the southwest Gander River valley and the Outflow, but obliquely crosses Gander Lake. Evidence for this ice flow is sparse east of Gander Lake; whether this is because striations recording this ice flow have not been identified or because the north-northeast ice flow did not affect this area is not clear. The source of this ice flow is likely from an ice divide situated between Middle Ridge and Meelpaeg Lake (Proudfoot *et al.*, 1988; St. Croix and Taylor, 1990, 1991).

## SURFICIAL GEOLOGY

The study area predominantly lies within the 'outer drift' zone described by Jenness (1960), and is characterized by thin till cover and valleys containing glaciofluvial sediments from melting ice inland. It is separated from an 'inner drift zone' by a discontinuous boulder-till moraine; the moraine generally contains thicker till cover and has a hummocky or ribbed topography, which suggests that inland ice stagnated. The boundary of this zone crosses a small part of the field area to the south of Gander Lake. Jenness (1960) suggested that this zonation evolved as a result of rapid ice retreat from its terminal position on the northeast coast to a major stillstand position marked by the moraine. Only one till unit has been recognized and its composition varies from a silty-sandy grey to pink grey till where it overlies the Gander Group (Butler *et al.*, 1984), to a sandy till where it overlies rocks of the Musgravetown Group or granite (Jenness, 1960).

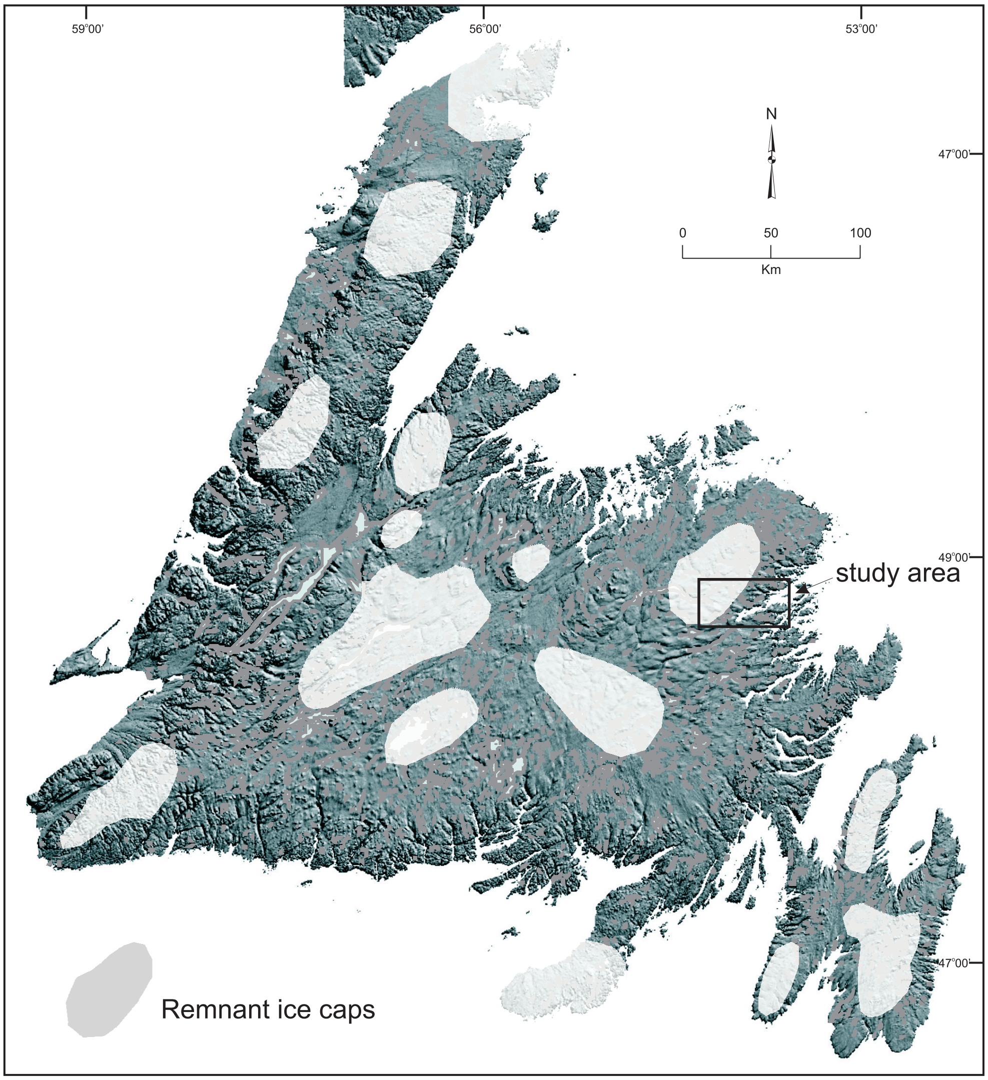



**Figure 4.** *Approximate locations of remnant ice caps during the deglaciation of Newfoundland (modified from Grant, 1974).*

Previous research detailing the surficial geology of the study area is limited to the thick sand and gravel deposits extending from the eastern end of Gander Lake to Gambo through Butts Pond, first interpreted by Butler *et al.* (1984) as ice-contact deposits that indicate drainage to the east during deglaciation. McCuaig (2006) further examined these deposits and divided them into four geomorphic units including hummocks, braided river, esker and deltaic deposits (Figure 5). The four geomorphic units are:

1. A zone of hummocky glaciofluvial sediments containing an abandoned meltwater channel located at the eastern end of Gander Lake. This zone increases in elevation away from Gander Lake, reaching a maximum elevation of 35 m asl. As the surface of Gander Lake is at ~26 m asl, drainage from the lake could no longer occur to the southeast. No meltwater channels are present that incise the deposits to a level below 26 m asl.
2. Braided river sediments to the southeast of the hummocky zone consist of poorly to moderately sorted gravel–boulder beds with some crossbedding. Clasts are mainly subrounded and boulders are generally large (up to 125 cm diameter). Boulder size, rounding, and crossbedding suggest high-energy fluvial flow to the east.
3. An esker complex, surrounding Butts Pond, comprising a series of sinuous features made up of mainly poorly sorted, large subrounded boulders in a fine sand to cobble gravel matrix.
4. Deltaic sediments extending from Butts Pond to Gambo and consisting of planar to undulating deposits containing predominantly sandy beds. Gravel beds containing large-scale crossbeds dipping southeast overlie the sandy beds and were interpreted as foreset beds. Horizontal gravel beds, interpreted as topset beds, cap the gravel unit and support a deltaic interpretation. Flat-lying beds, 10 to 100 cm thick, contain large-scale crossbeds that dip to the southeast. These sediments were interpreted as bottomset beds of a delta with a southeastward direction of progradation (McCuaig, 2006).

McCuaig (2006) suggested that these four depositional environments were part of a glacial spillway where meltwater flowed eastward into Freshwater Bay from westward-retreating ice. The elevation of the topset beds was at 43 m, providing a marine limit for the area. Ground-penetrating radar (GPR) profiles taken seaward of the delta show reflections that are consistent with Gilbert-type deltas. The elevation of topset beds in GPR profiles is 30 m, suggesting that the delta began to develop at 43 m asl and the 30 m topset beds formed as the delta adjusted to sea-level fall.

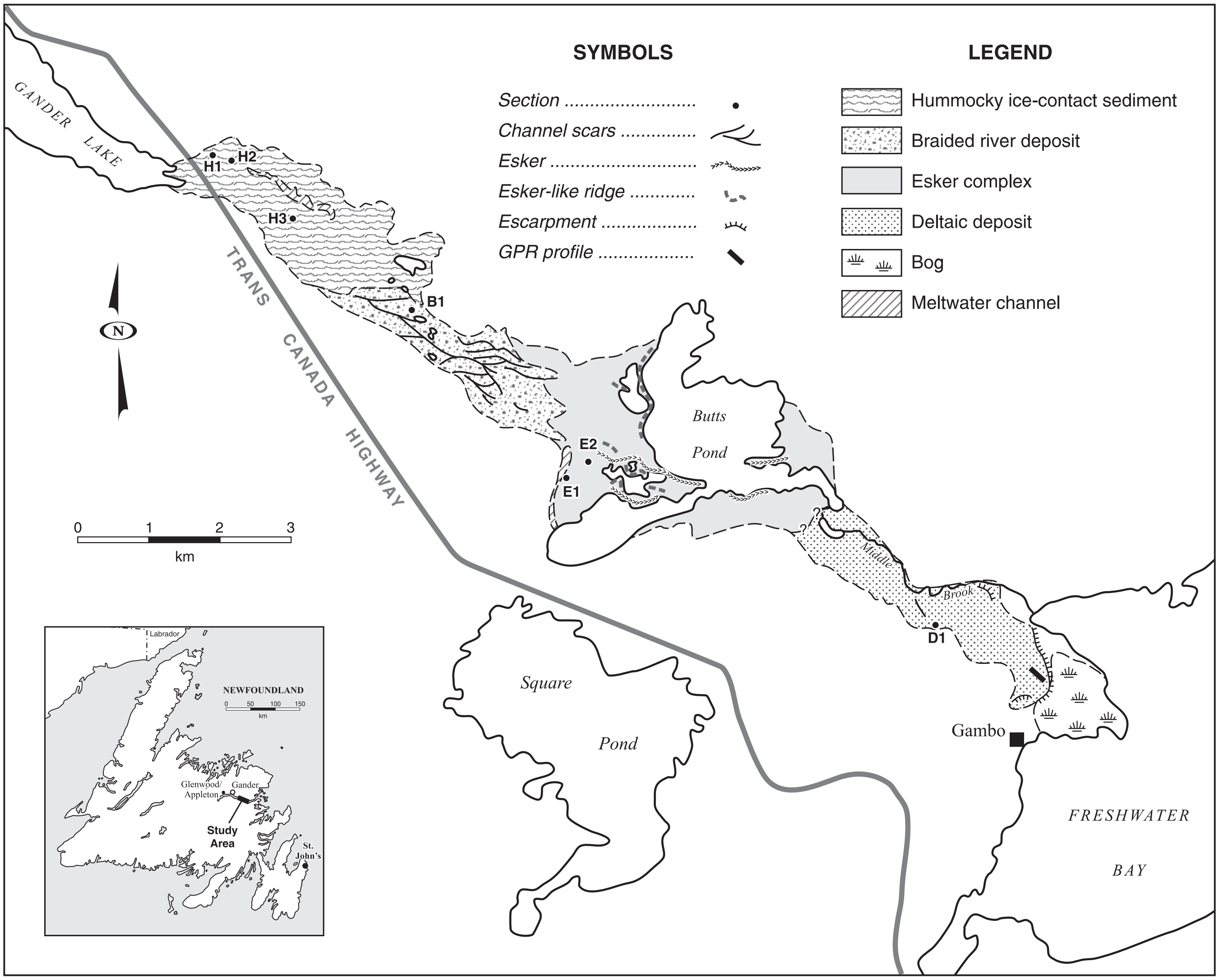



**Figure 5.** G*lacial spillway deposits in Butts Pond–Gambo area (taken from McCuaig, 2006).*

The coastal region of the study area likely had a type-B sea-level curve, characterized by rapid sea-level fall followed by lesser sea-level rise caused by forebulge migration. Sea level fell below present between 10 and 9.5 ka (Liverman, 1994). However, data to determine the amount of sea-level fall below modern sea level are lacking within the study area. Age constraints on the deglaciation of the study area come from radiocarbon dates on marine macrofauna (*Hiatella arctica*) found in silty clay near the shore of Gander River, approximately 15 km northeast of the northern outlet. These dates indicate that ice had retreated from this area and was open to the sea by 12 220 ± 90 radiocarbon years BP (11 595 to 11 240 calendar years BC; McCuaig, 2006).

## METHODS AND RESULTS – 2009

### REGIONAL TILL GEOCHEMISTRY

A total of 502 samples were collected from the C- and BC-horizons, mostly from hand-dug pits (40 to 60 cm depth) and roadcuts (50 to 100 cm depth). Mudboils were sampled at shallower depths (average 25 cm). In rare cases, where there was a lack of surface sediment, samples were collected from bedrock detritus. Marine and fluvial or glaciofluvial sediments were avoided during sampling, because of the possibility of reworking and the difficulty in defining distances and directions of transport. Samples were collected every 1 km$^2$ in road-accessible areas, and every 4

$km^2$ in more remote areas where helicopter support was required. Duplicate samples were taken every 20 samples to test for field reproducibility. Samples are analyzed in the Geological Survey's geochemical laboratory for a suite of elements determined from ICP-ES, and at an external laboratory for other elements, including gold, using INAA techniques. Data release is anticipated by mid- to late-2010.

## ICE-FLOW PATTERNS

Striations were identified on fresh, unweathered surfaces, suggesting that they are related to the most recent glaciation. Ice-flow directions were determined from cross-cutting relationships and by preservation of older striations in the lee of younger ones. A total of 64 striations were recorded from 51 sites. Multi-directional patterns were observed at 10 sites; however, relative age relationships were only determined at 7 sites.

Striations recorded in 2009 are generally consistent with regional ice-flow patterns (St. Croix and Taylor, 1990) and indicate that the study area was affected by 2 separate ice-flow events (Figure 6). The earliest flow was eastward (~095° ± 25°) and is found across the entire study area. In the eastern Gander Lake area, this ice-flow direction roughly parallels the lake. Eastward ice flow continues toward the coast into Freshwater Bay and is also observed in the Cat Bay area. These eastward striations range between 70° to 120°; this variability likely reflects topographic influence as thinning ice was drawn down toward the coast. Evidence for northward ice flow is limited to only a few sites in the westernmost part of the study area. In the only site where striations related to both the northward and eastward ice-flows are observed, the northward flow is interpreted to be the younger of the two. This relationship is consistent with regional ice-flow relationships events recorded to the west of the study area.

## SURFICIAL GEOLOGY

### Till

Diamictons are the dominant surficial deposit within the study area. Their aerial distribution is variable, with a strong contrast between deposits in the coastal areas and deposits inland. North of Gander Lake, diamicton cover is generally thin with numerous bedrock exposures, particularly adjacent to the TCH. In the Soulis, Home and Gull pond areas, and south of Gander Lake, blankets of diamicton (>2 m) are common and bedrock exposures are rare (Plate 1). Hummocky terrain is also present in the area south of Gander Lake. Hummocks commonly have a surface cover of boulders, likely derived from a supraglacial source. Drumlinoid features and crag-and-tail hills were identified from aerial-photograph interpretation and Shuttle Radar Topography Mission (SRTM) data. Orientations of these features, along with those of isolated crag-and-tail hills, are consistent with the regional eastward striations observed in the area (Figure 6). In coastal areas, exposed bedrock is dominant, the topography is more rugged and diamicton occurs as either a discontinuous veneer or is absent (Plate 2).

Few natural sections were observed and only a single stratigraphic unit of diamicton was noted. Sedimentary structures were not generally noted, but this may be due to poor exposure. Diamicton texture and colour vary throughout the field area and reflect the underlying bedrock geology. Diamicton underlain by the Gander Group is generally light brownish grey to grey, whereas diamicton underlain by Gander Lake granite are typically pinkish grey. The matrix is predominantly silty sand, poorly sorted and slightly to moderately compacted. Diamicton in areas underlain by Gander Lake granite generally have a coarser, sandier matrix. Clasts are granule- to boulder-sized clasts (up to 3 m diameter) and are generally subrounded to angular. Clasts are commonly striated and have thin silt coatings on their upper surfaces. Clast lithology and shape are generally controlled by the underlying bedrock. Angular, fragile shale clasts are common in areas underlain by bedrock of the Gander Group, whereas granite clasts are generally subrounded. Clast content varies between 30 to 70 percent and averages about 55 percent. South of Gander Lake, boulders 1 to 3 m wide are common on and in the upper surface of the diamicton.

The characteristics described above (subrounded clasts, striated and fragile clasts, and silt coatings) are interpreted to represent deposition as subglacial melt-out till (Dreimanis, 1988). These sediments are commonly associated with stagnating glaciers. Detailed clast-fabric analysis and examination of the stratigraphy, to be conducted in future work, will provide further details on the depositional environment.

### Glaciofluvial – Glaciomarine – Marine Sediments

Glaciofluvial, glaciomarine and marine sediments were not the focus of the 2009 field season and thus no detailed descriptions are provided. Thick deposits of ice-contact and ice-proximal sediments were produced by meltwater from receding ice at the eastern end of Gander Lake and eastward through Butts Pond and Gambo into Freshwater Bay. These deposits (described above) include hummocky and braidplain deposits, esker-like ridges, and a marine delta at Gambo. With the exception of the delta in Gambo, no other raised glaciomarine features were observed.

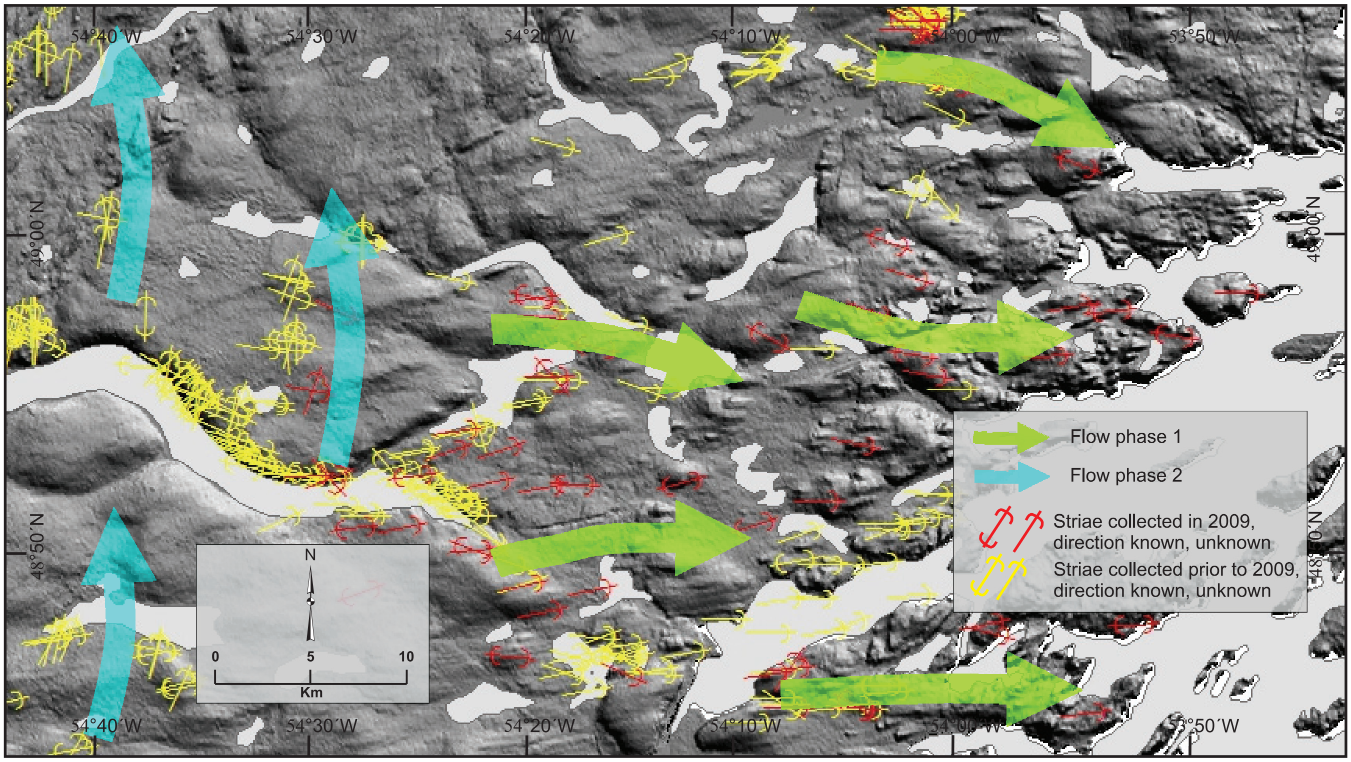



**Figure 6.** *Ice-flow patterns overlain on SRTM image. At least two regional ice flow events affected the study area. The first (Flow phase 1) was a regionally extensive eastward flow from a source likely north of Red Indian Lake. Stagnant ice was likely present in the eastern area for some time and deflected the later northward regional ice-flow event. Flow phase 2, originating from the Middle Ridge area.*

**Plate 1.** *Thick till blanket to the south of Gander Lake. Hummocky and boulder strewn terrain are common in this area.*

**Plate 2.** *Thin till veneer with exposed bedrock in the Hare Bay area. Toward the coast, the topography is typically more rugged with till either absent or occurring as a discontinuous veneer.*

## Organic Deposits

Organic deposits, common within the study area, are generally associated with poorly drained areas. Numerous bogs are found in valleys along the coast, low-lying areas in the interior of the region and in depressions associated with hummocky moraine.

**Glacial History and Implications for Mineral Exploration**

The study area was covered by ice from two distinct sources during the last, late Wisconsinan glacial period. The first ice-flow event was a regional eastward flow that extended into Bonavista Bay. This ice flow is recorded across much of northeast Newfoundland and likely had a source area north of the Red Indian Lake area (Vanderveer and Sparkes, 1982; Proudfoot *et al.*, 1988; Batterson and Vatcher, 1991; St. Croix and Taylor, 1990, 1991; Scott, 1994).

The eastward ice-flow event was followed by a north to northeastward ice flow. The lack of northward striations in most of the study area suggests that either evidence supporting this flow has not been found or this flow did not cross the eastern part of the study area. The source of this northward ice flow is likely from the Middle Ridge area. It is possible that stagnant ice at the eastern end of Gander Lake deflected northward-flowing ice around this ice centre. Support for stagnant ice comes from the presence of hummocky moraine at the eastern end of Gander Lake, hummocky topography south of Gander Lake, and esker-like ridges in Joe Batt's Brook and Fox Pond. This is in agreement with a remnant ice centre postulated by Grant (1974).

The area became ice free sometime before 12.2 ka BP (11.3 cal years BP) based on shells from Gander River (McCuaig, 2006). To date, no radiocarbon dateable material has been found in the Freshwater Bay area that could further constrain the region's deglacial history.

This preliminary glacial history is based on observations of ice-flow patterns and glacial deposits in the Gander Lake–Gambo survey area. The Quaternary history of the area is important for interpretations of till geochemistry and the development of mineral-exploration strategies. The following should be considered:

1. The regional eastward ice-flow event was the dominant ice-flow event to have affected the area. This flow produced the areas' glacial landforms, and thus is the main ice flow to be considered in glacial dispersal studies.
2. Only one till unit was observed. Given the previous comment, future work will likely confirm that the till was derived from eastward-flowing ice.
3. Sampling in glaciofluvial, fluvial and marine settings should be avoided due to the possibility of sediment reworking, and the difficulty in defining distances and directions of transport. These areas include the Butts Pond–Gambo area, valley bottoms and areas below the 45-m marine limit.
4. Hummocky deposits south of Gander Lake likely formed in a stagnating environment and may contain a greater proportion of supraglacial (and more far travelled) sediment then basally deposited till.

## FUTURE WORK

Issues arising from preliminary field work that will be addressed in future work include:

1. Completion of 1: 50 000-scale surficial maps of NTS 2D/16 and 2C/13, including aerial-photo interpretation.
2. Clast-fabric and clast-provenance studies to determine dispersal distances and patterns in the area.
3. Investigation of the stratigraphy of the area, which will include trying to understand the subsequent sequence of deglacial events following the northward ice flow, including the role of Gander Lake in the deglaciation of the area. Glaciomarine–marine deposits will also be examined for radiocarbon dateable material that may be able to constrain the region's Quaternary history.

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