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# SPRINGDALE–SHEFFIELD LAKE SURFICIAL ICE-FLOW MAPPING RESULTS WITH POTENTIAL IMPLICATIONS FOR GLACIAL LAKE HOWLEY

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## ABSTRACT

*The 2013 field season was the first of a multi-year till-geochemical and regional geological mapping program. The aim is to link the pattern of glacial retreat, the development of glacial Lake Howley and stratigraphy with the Humber Valley and Springdale areas in north-central Newfoundland. During this past field season the following was conducted: till-geochemical sampling, ice-flow and surficial mapping of the Sheffield Lake NTS map area (12H/07) and in-fill till geochemical sampling of the Dawe's Pond and Springdale NTS map areas (12H/01 and 12H/08). Regional till (diamicton) sampling was conducted at a spacing of 1 sample per 1 km$^2$ along forest-resource roads. In remote areas, helicopter support was required to collect one sample per 4 km$^2$.*

*Forty-one new ice-flow measurements support three different ice-flows that were previously identified. These are described as two phases: Phase 1, the oldest, was a dominantly northeastward flow, from an ice centre that connected remnant ice on the Topsails to that in the Long Range Mountains; Phase 2, the youngest, was a northward to northwestward flow from remnant ice on the Topsails and remnant ice around Twin Lakes. The timing of the remaining southeastern flow has not, as yet, been determined.*

*The study area is covered by varying amounts of diamicton (till), glaciofluvial sand and gravel, fine-grained glaciolacustrine–glaciomarine sediments and organic deposits. Diamicton forms a thin veneer along the coast and becomes thicker inland. Thick extensive glaciofluvial deposits are located in the valleys. Eskers and smaller deposits of glaciofluvial material are located on the Topsails. The glaciolacustrine–glaciomarine sediments underlie gravel in the Sheffield Lake and Birchy Lake–Indian Brook valley areas. The identification of fine-grained sediments and mud interpreted as glaciolacustrine suggests the extent of glacial Lake Howley is larger then previously proposed. Organic deposits comprising peat, bogs and fen make up 40% of the surficial deposits on the Topsails.*

## INTRODUCTION

This is the first year of a multi-year till-geochemical and regional geological mapping program in the area between the community of South Brook and Route 420. The objectives are to: complete a till-geochemical sampling program adding to the provincial till-geochemical database; provide assistance for future mineral exploration; and map the surficial geology, ice-flow history and stratigraphy, in order to determine the pattern of glacial retreat. This information will be used along with detailed Quaternary studies to the east (Liverman *et al.*, 1991; Scott *et al.*, 1991) and west (Batterson, 2003) to determine the link between the pattern of glacial retreat, development of glacial Lake Howley and stratigraphy with the Humber Valley and Springdale areas. This paper describes the bedrock geology, review of the Quaternary geology, sampling methods used, surficial units identified, the ice-flow chronology, the extent of glacial Lake Howley and proposed future work.

## LOCATION AND ACCESS

The study area encompasses over 3300 km$^2$ and includes the following NTS map areas: 12H/01 (western half), 12H/02 (eastern and northern parts), 12H/08 (west of the Trans-Canada Highway, TCH) and 12H/07 (Figure 1). It extends from Millertown Junction in the south to Springdale in the north and from the community of South Brook in the east to Route 420 in the west. The TCH, along with routes 380 (Beothuk Trail–Robert's Arm), 390 (Springdale), 410 (Dorset Trail–Baie Verte), 420 (White Bay South Highway–Sop's Arm) and 421 (Hampton) provide good access across the study area. An extensive network of forestry-resource roads south of the TCH provides ATV access. In

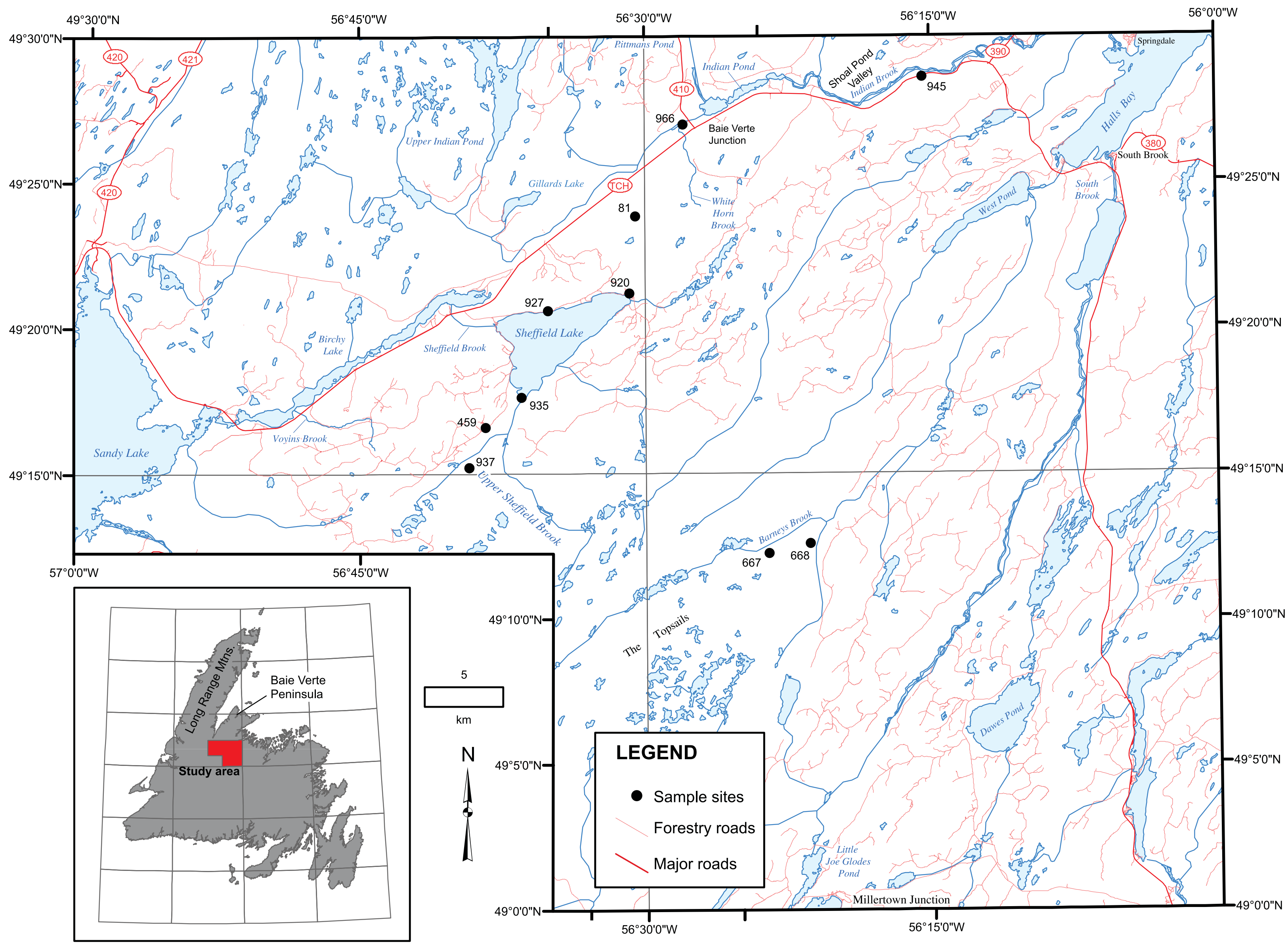



**Figure 1.** *Location of study area and places names used in the text. Roads are shown in red with route numbers circled. Route numbers correspond to the following: TCH – Trans-Canada Highway; 380 – Beothuk Trail–Robert's Arm; 390 – Springdale Access Road; 410 – Dorset Trail–Baie Verte; 420 – White Bay Highway – Sops Arm; 421 – Hampton Access Road. Black dots are sites described in the text and do not necessarily correspond to sample sites shown in Figure 2. Twin Lakes is located outside the study area and is shown on Figure 3B. Inset map shows location of study area.*

remote areas, access was provided by helicopter for mapping and till sampling.

## BEDROCK GEOLOGY

The study area lies within the Dunnage and Humber zones of the Newfoundland Appalachians (Figure 2). Polydeformed schists, gneisses and granitoid intrusions of the Humber Zone record the evolution and destruction of the continental margin of eastern North America (Hibbard, 1983). Ophiolite suites, along with volcanic and intrusive complexes within the Dunnage Zone, are the remnants of the early Paleozoic Iapetus Ocean (Hibbard, 1983). The Baie Verte Line, a complex fault zone, separates the Dunnage and Humber zones. It trends northeastward from Birchy Lake toward Baie Verte and separates the schists of the Fleur De Lys Supergroup from the ophiolites of the Advocate complex (Crisby-Whittle, 2012). Hibbard (1983) and O'Brien (2003, 2009) give detailed descriptions of the bedrock geology within the study area.

Seventy-nine mineral occurrences including asbestos, gold, chromium, copper, nickel, lead, pyrite and zinc are located within the study area (Figure 2; Newfoundland and Labrador Geological Survey, 2013a). More than 60% of the occurrences are associated with marine mafic volcanic rocks of the Roberts Arm Group (Newfoundland and Labrador Geological Survey, 2013a). However, 14 occurrences, comprising nine showings and five indications, are located in the Sheffield Lake NTS map area (12H/07) and are associated with four rock units. Two zinc occurrences are associated with the non-marine felsic volcanics of the Sheffield Lake complex. One asbestos occurrence lies within the felsic plutonic rocks of the Wild Cove Pond igneous suite. One copper occurrence is associated with the schists of the Fleur De Lys Supergroup. The ophiolitic rocks of the Advocate complex contain one chromium occurrence along with four nickel and five asbestos occurrences.

## QUATERNARY GEOLOGY REVIEW

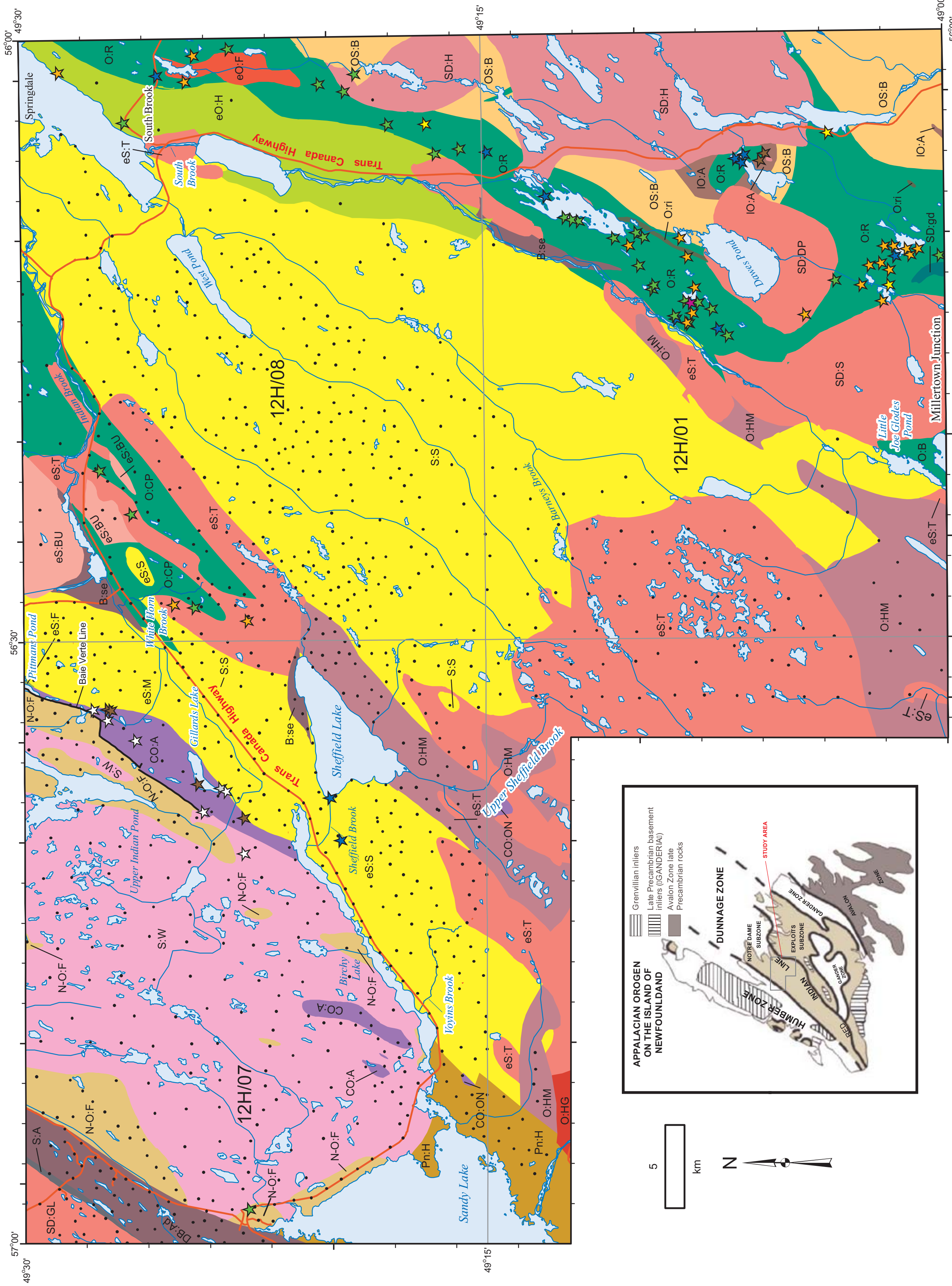
### REGIONAL QUATERNARY HISTORY

During the late Wisconsinan glacial maximum, the Newfoundland Ice Cap extended out to the continental shelf (Grant, 1989; Shaw *et al.*, 2006). Approximately 13 000 years before present (BP), deglaciation became terrestrially based and the deglacial configuration was irregular and time-transgressive due to both ice thickness and topography (Shaw *et al.*, 2006). As can be seen from Figure 3A, the Springdale and South Brook areas were deglaciated by 12 000 BP, with ice still covering much of the Topsails and Sheffield Lake (Shaw *et al.*, 2006). As ice continued to retreat, it disintegrated into a number of small isolated ice caps (Grant, 1974). Three of these are located within the study area, and are situated in the north part of NTS map area 12H/07 on the Baie Verte Peninsula; to the east of NTS 12H/08 near Twin Lakes; and south of NTS 12H/08 on the Topsails (Figure 3B).

Coastal areas were ice-free between 12 470 ± 300 BP and 11 000 ± 190 BP, based on two shell dates collected from marine fauna in muds and delta bottomsets in Halls Bay (TO-2305, Scott *et al.*, 1991 and GSC-2085, Tucker, 1974). These dates represent the time of formation of glaciomarine deltas on the northeast coast of Newfoundland (Grant, 1974; Scott, *et al.*, 1991). A marine limit of approximately 75 m above sea level (asl) is indicated by the contact between the topset and foreset beds of a delta in Halls Bay (Scott *et al.*, 1991).

The southwestern part of the study area was also undergoing deglaciation between 12 600 -12 300 BP based on work completed by Batterson (2003) in the Grand Lake Basin. Radiocarbon dates from the Stephenville area indicate that Grand Lake Basin was deglaciated sometime after 12 600 BP, allowing for drainage from melting glaciers inland to reach St. George's Bay (Batterson, 2003; Bell *et al.*, 2003; Shaw *et al.*, 2006). Glacial Lake Howley developed in front of a rapidly retreating ice margin in the Grand Lake Basin, where Grand Lake is currently situated (Batterson and Catto, 2001). Impounded water formed a long, narrow glacial lake, up to 135 km long and 10 km wide, with a surface area of 650 $km^2$ (Figure 4; Batterson and Catto, 2001; Batterson, 2003). The water level was controlled by the elevation of an outlet at the southwestern end of Grand Lake. Subsequent lowering of the lake was controlled by the opening of topographically lower outlets, as the ice retreated to the northeast. The northeastern extent is inferred from the presence of rhythmically bedded silt in clay, showing the existence of standing water in the Gillards Lake area and in the canal (watershed divide) between Indian Brook and Birchy Lake (Lundqvist, 1965; Batterson, 2003). Batterson (2003) concluded that the ice dam controlling the extent of the lake was east of Birchy Lake. Final drainage of the lake was through a spillway currently occupied by Junction Brook (Figure 4). The lake emptied about 12 300 BP, based on the elevation of the deltas at the head of Deer Lake (Batterson, 2003). Continued ice retreat resulted in shifting ice centres and formed isolated ice caps.

The diamicton (till) deposits of the Sheffield Lake–Indian Pond area were described by Alley and Slatt (1975). They described a stratigraphy comprising two diamictons, a lower red till overlain by an upper grey till. The lower red till is gravelly, oxidized, fissile, and contains clasts from local sources, whereas the upper grey till is sandy, slightly oxidized, massive and contains clasts from more distant sources (Alley and Slatt, 1975).


12H/08
12H/01
12H/07
Springdale
South Brook
Trans Canada Highway
West Pond
Dawes Pond
Millertown Junction
Little Joe Glodes Pond
Barneys Brook
Indian Brook
White Horn Brook
Pittmans Pond
Baie Verte Line
Gillards Lake
Sheffield Lake
Sheffield Brook
Upper Sheffield Brook
Upper Indian Pond
Birchy Lake
Voyins Brook
Sandy Lake
APPALACIAN OROGEN ON THE ISLAND OF NEWFOUNDLAND
Grenvillian inliers
Late Precambrian basement inliers (GANDERIA)
Avalon Zone late Precambrian rocks
DUNNAGE ZONE
HUMBER ZONE
NOTRE DAME SUBZONE
EXPLOITS SUBZONE
GANDER ZONE
AVALON ZONE
RED INDIAN LINE
STUDY AREA
5
km
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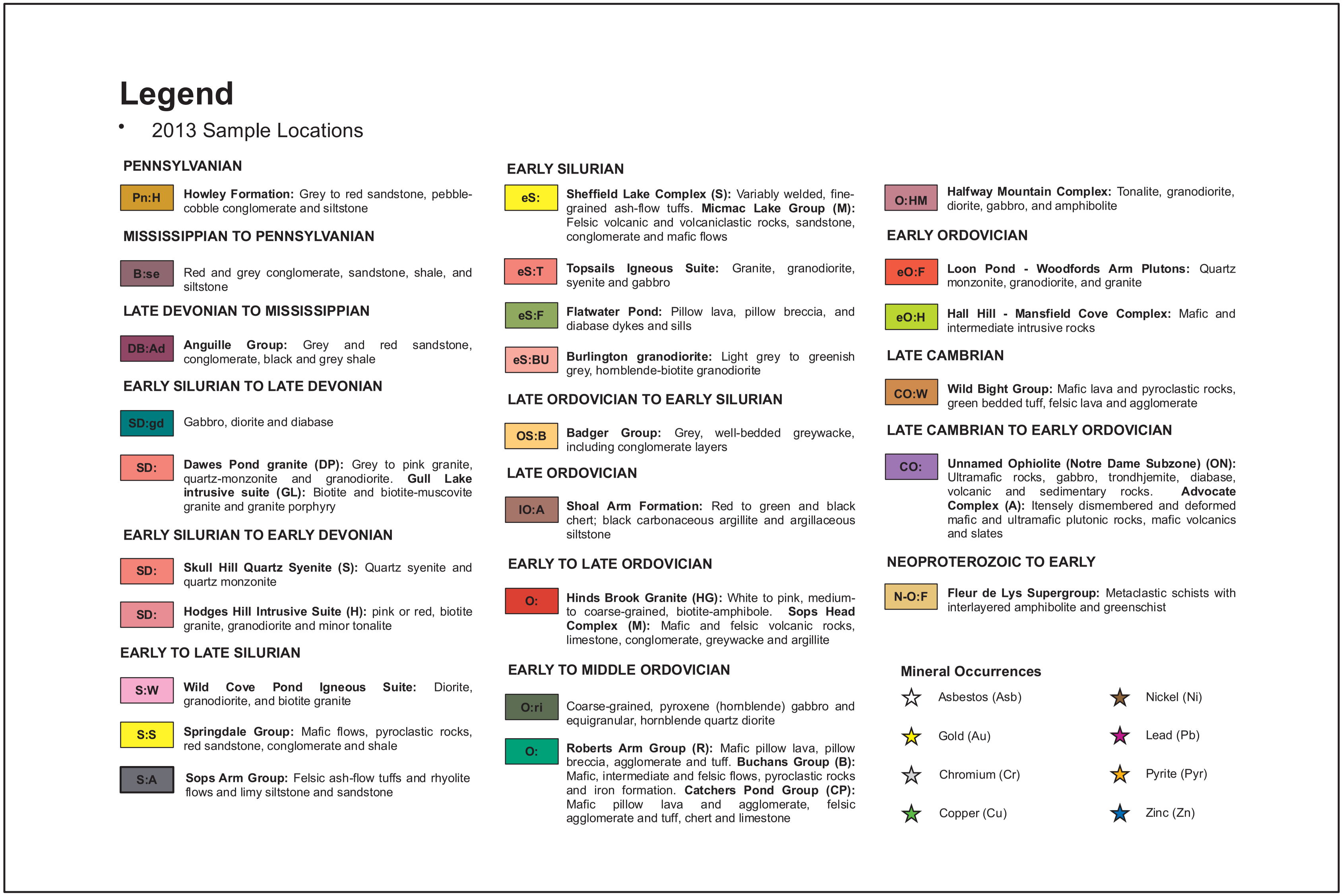


**Figure 2.** *Bedrock geology of the study area (Crisby-Whittle, 2012). Black dots are locations from where samples were collected in 2013.*

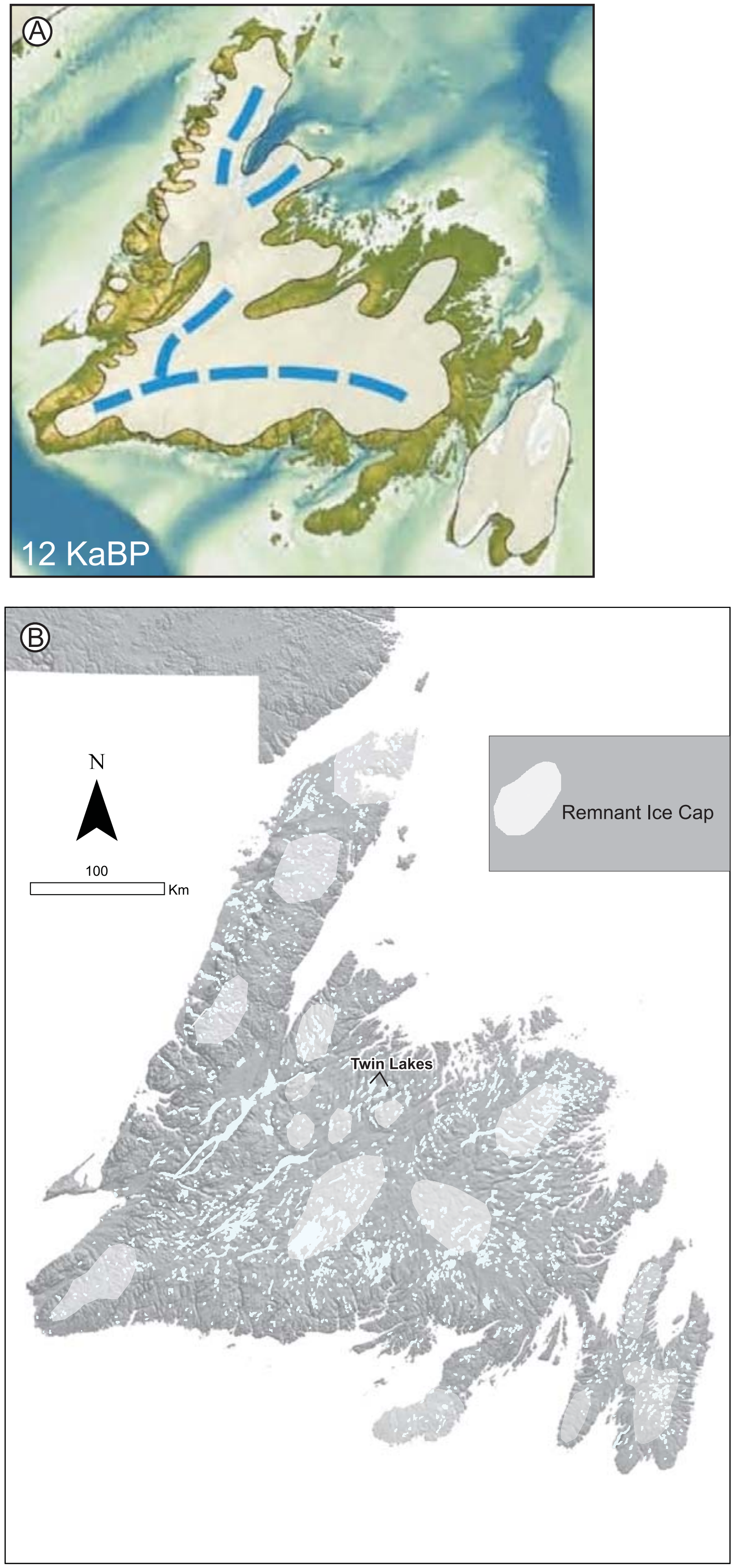


**Figure 3.** *Pattern of glaciation on the Island of Newfoundland. A) Retreat of ice on to land and the location of ice divides at 12 000 BP (~14 000 calendar years) (after Shaw* et al.*, 2006). B) Map of Newfoundland showing the approximate location of remnant ice caps as the Newfoundland Ice Cap disintegrated (modified after Grant, 1974).*

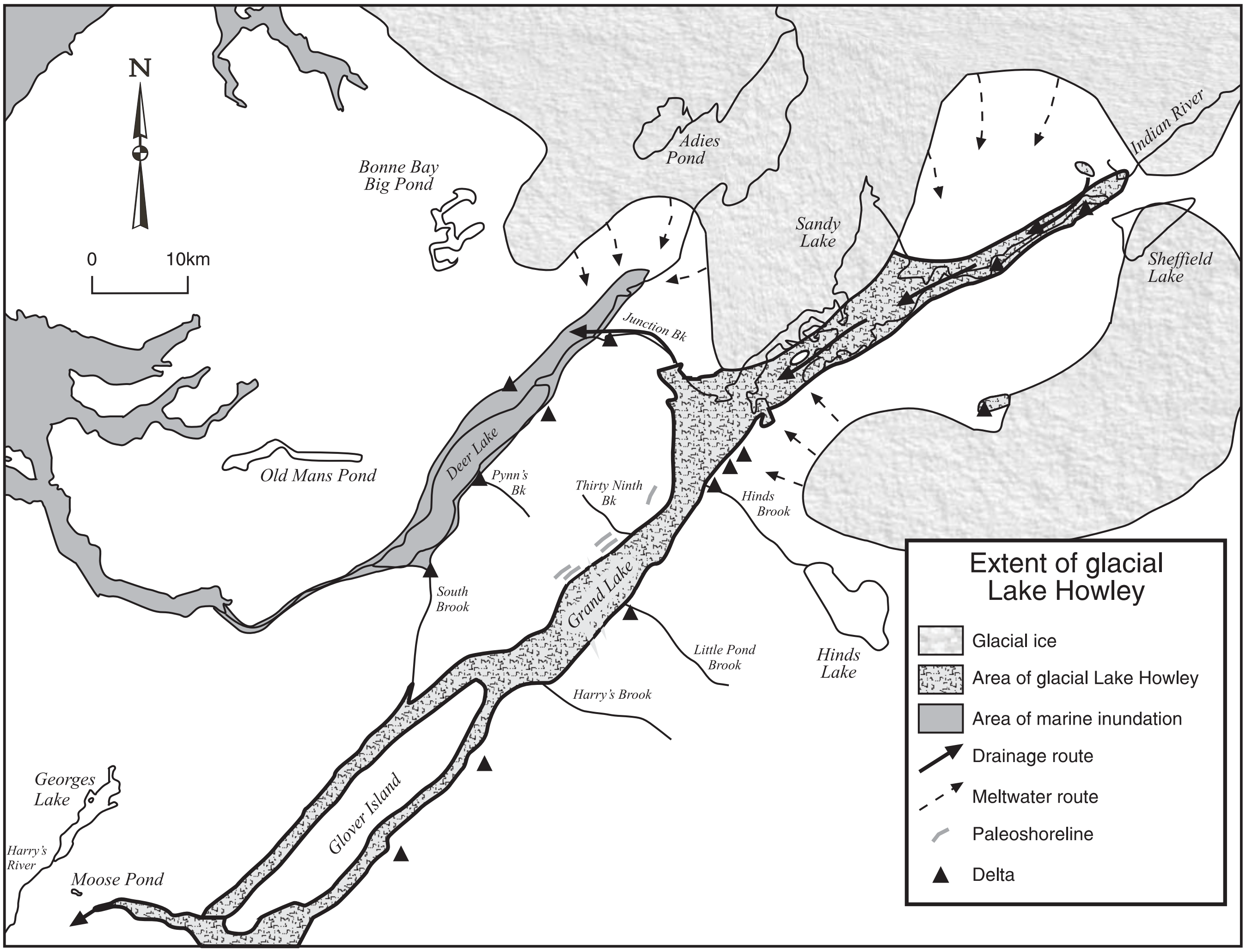


**Figure 4.** *Paleogeography of glacial Lake Howley (modified after Batterson, 2003).*

Liverman *et al.* (1991) mapped the Springdale NTS map sheet (12H/8) and reported that the sediment cover over the area was variable with valleys containing a thick surficial fill of eroded diamicton as well as glaciofluvial and glaciomarine sediments related to marine incursion. Inland areas are mainly composed of diamicton, bogs and outcrops of bedrock (Liverman *et al.,* 1991). In addition to veneers and blanket deposits, the diamicton also formed hummocks and ridges. Liverman *et al.* (1991) described a complex stratigraphy that contained multiple diamictons.

## ICE-FLOW HISTORY

Three ice-flow directions were mapped by Tucker (1974), Alley and Slatt (1975), Liverman *et al*. (1991), Taylor and Vatcher (1993), and Klassen (1994) for NTS map areas 12H/01, /07 and /08. From these, two major ice-flow phases were recognized, although the age of the remaining ice-flow direction was not determined. Phase 1, the oldest and dominant ice-flow, was from the northeast and originated from an ice centre connecting the Long Range Mountains and the Topsails (Taylor and Vatcher, 1993). Phase 2, the younger flow, was a northward to northwestward flow in NTS map area 12H/07 and in the western part of NTS 12H/08. This flow was the result of further ice retreat, and isolation of the ice cap situated over the Topsails (Taylor and Vatcher, 1993). In Phase 2, the northwestward flow identified in the eastern part of NTS 12H/08 was from a minor ice cap in the Twin Lakes area (Taylor and Liverman, 2000). Evidence for an eastward flow was identified on the northwestern side of Halls Bay, and is attributed to late-stage local ice flow toward Halls Bay; however, its relative age has not been determined (Liverman *et al.*, 1991).

## SAMPLING METHODS AND ANALYSIS

The till-geochemical sampling was completed on NTS map areas 12H/01, 02, 07 and 08. With the exception of

NTS map areas 12H/02 and /07, these areas were sampled by the Geological Survey of Canada in the early 1990s (Klassen, 1994; Liverman *et al.,* 1996); in-fill sampling was necessary to provide complete coverage as their sampling was conducted at a wider spacing than currently practiced by the Geological Survey of Newfoundland and Labrador for regional 1:50 000-scale till sampling.

Nine hundred and twenty two one-kilogram samples were collected from BC or C horizons from hand-dug pits, mudboils, ditches and road-cuts (Figure 2). Average sample depths included 50 cm in hand-dug pits, 54 cm from mudboils, 77 cm in ditches and 91 cm from roadcuts. The spacing between samples varied depending on the mode of access. Along forest-resource roads, samples were collected every 1 km, and in more remote areas where helicopter support was required, sample-collection sites were predetermined within grid cells of 4 $km^2$. Duplicate samples were collected every twenty samples to estimate the natural homogeneity of the sample medium.

Samples were submitted to the Geochemical Laboratory of the Geological Survey for analysis by ICP-OES and ICP-MS. Samples will be sent to an external laboratory to analyze for gold and other elements by INAA. Data is anticipated to be released in 2014.

# RESULTS

## ICE-FLOW HISTORY

Forty-one ice-flow measurements were recorded from 35 sites during the 2013 field season (Figure 5). Most striation data were collected along forest-resource roads where bedrock outcrops were visible; only two striation sites were located in remote (helicopter-accessible) areas. At sites where more than one ice-flow direction was determined, the relative ages were established using crosscutting relationships. Five multidirectional sites were identified; however, relative ages were only determined at three of them. All striations identified were fresh and unweathered, and are tentatively interpreted as late Wisconsinan in age.

The following three ice-flow directions were observed: a northeastward flow, a northward to northwestward flow, and an east to southeastward flow (Figure 5). The striae identified at the three multidirectional sites, are consistent with the two-phase ice-flow chronology identified by Liverman *et al.* (1991) and Taylor and Vatcher (1993) and is described earlier (*see* Quaternary Geology Review, Ice-flow History). Further work is required to determine the age relationship and timing of the easterly–southeasterly flow.

## SURFICIAL GEOLOGY

The surficial geology of the study area is complex and reflects sediment deposition under the influence of ice (in the case of diamicton), flowing water (sand and gravel) and standing water (fine-grained sand to mud). The complexity of surficial deposits is the result of an actively retreating, irregular ice margin accompanied by large volumes of meltwater derived from the former. Postglacial organic deposits (bogs, peat and fens) are widespread. The following section describes the surficial geology units: diamicton, sand and gravel, fine-grained and organic deposits.

### Diamicton Deposits

Diamicton deposits vary in morphology and thickness. In coastal areas, the diamicton is less than 1.5 m thick, forming veneers over exposed bedrock. Inland, thicker deposits of diamicton include blankets (>1.5 m), hummocky terrain, and eroded and ridged topography. Blanket diamicton is concentrated on the Topsails and along the Birchy Lake valley. Hummocky terrain is located east and northeast of Sheffield Lake. Northeast-southwest-trending till ridges are located southwest of Sheffield Lake. The general characteristics of the till including sites containing multiple diamictons are described below.

The diamicton is a matrix-supported silty sand. Clast percentage is low (20%); the mean clast size is 2.5 cm and angularity ranges from very angular to subrounded, with the majority of clasts being subangular. Clasts are commonly striated and faceted. The variation in diamicton colour reflects changes in the colour of the underlying bedrock. The diamicton is dominantly brown-dark-brown (Munsell colour 7.5YR 4/4) or dark yellowish-brown (10YR 4/4). At two localities (Sites 81 and 459), two stratigraphic diamicton units were identified (Figure 1).

#### *Site 81*

The lower diamicton at Site 81 is a very compact, matrix-supported, dark-greyish brown (10YR 4/2) silty sand (Plate 1A, B). It contains clasts that have a mean diameter of 5 cm and medium clast content (21-40%). Clast angularity ranges from angular to subrounded with the majority being subangular. The upper diamicton is a fissile, matrix-supported, brown-dark-brown (7.5 YR4/4) silty sand. It contains clasts that have a mean diameter of 3 cm and a lower clast content (1-20%). Clast angularity ranges from subangular to subround with the majority being subangular. The contact between the two diamictons is sharp and undulating.

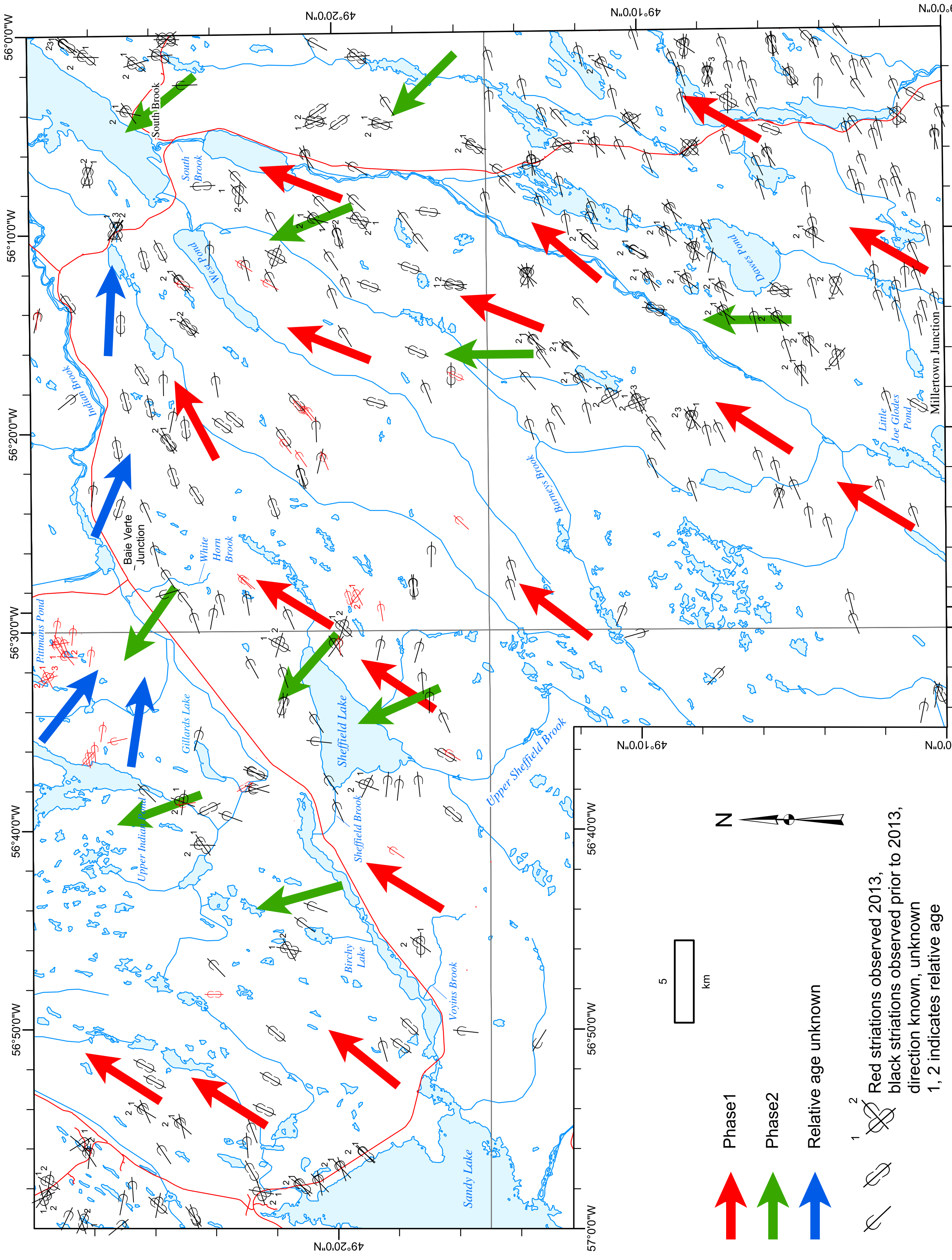


**Figure 5.** *Location of striations (red) measured in 2013. Black striations are those collected prior to 2013 (Newfoundland and Labrador Geological Survey, 2013b). Large arrows indicate the tentative ice-flow history for the area.*

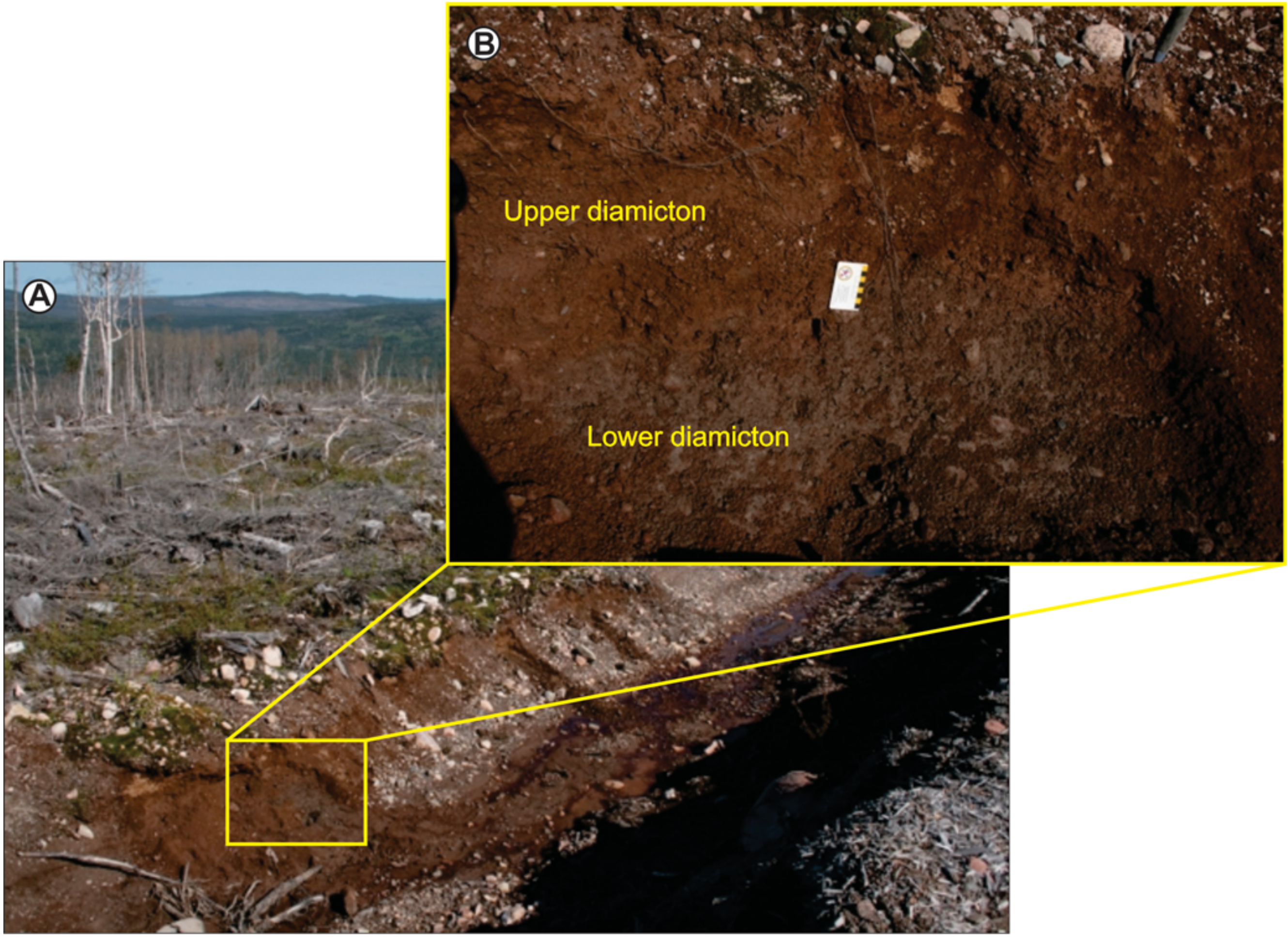



**Plate 1.** *Two sites showing multiple diamictons. Sites 81 and 459 are located approximately 20 km from one another. A) Site 81 looking northwest, yellow box is location of B; B) Shows close up of contact between the lower and upper diamictons identified at Site 81; C) Upper and lower diamictons identified at Site 459.*

***Site 459***

The lower diamicton at Site 459 is a very compact, matrix-supported, light-yellowish-brown (10YR6/4) sandy silt (Plate 1C). The mean clast diameter is 4 cm and it has a medium clast content (21-40%). Clasts range from angular in shape to subrounded with the majority of clasts being subangular. There is a sharp contact with the overlying upper diamicton. The upper diamicton is matrix-supported, brown-dark-brown (7.5 YR4/4) silty sand. Clast content is medium (21-40%) and the mean clast diameter is 4 cm. Clast angularity ranges from angular to subangular with the majority being subangular. The clasts have silt and some are underlain by medium to coarse sand.

Site 459 is located just outside Alley and Slatt's (1975) study area at the southwest end of Sheffield Lake. These authors recorded a stratigraphy consisting of two diamictons: a 'lower red till' overlain by an 'upper grey till'. Liverman *et al.* (1991; Site 242) identified a complex stratigraphy where three diamicton units were overlain by well-sorted pebble gravel. They were unable to reconcile the descriptions of Alley and Slatt (1975) to those they described, and suggested that the latter's work be re-evaluated. Whereas Sites 81 and 495 share similarities to sites described by both Alley and Slatt (1975) and Liverman *et al.* (1991), further pebble and clast-fabric analysis, which will be completed in the next field season, is required to determine if there is a correlation.

*Eroded Diamicton*

Eroded diamicton is common and it is often associated with meltwater channels. For example, along the sides of the Birchy Lake valley, meltwater channels cut thick diamicton deposits. In addition, meltwater channels can show winnowing of fines and lags of cobbles and boulders along valley sides or bottoms, such as along the north side of Birchy Lake. In the Voyins Brook valley, the diamicton is sandy, containing very little silt, and the valley sides have a very high concentration of cobbles and boulders (Plate 2).

*Ridged Diamicton*

Ridged diamicton is located south of Sheffield Lake in the Upper Sheffield Brook valley. Ridges are oriented northwest-southeast and are up to 2 km long and 300 m wide. There are large angular granitic boulders on the surface. No exposed sections were seen in the ridges. Site 937 is located on one of the ridges and a test pit revealed matrix-supported silty sand containing 21-40% clasts. Clasts range in diameter from 3–150 cm and are angular to subround.

**Plate 2.** *Section along Voyins Brook valley with high concentration of clasts at the surface.*

## Sand and Gravel Deposits

The deposits of glaciofluvial sand and gravel have a variable morphology: hummocky, veneer and ridges (eskers) are found on the Topsails, whereas thick plains, blankets, terraced and eroded glaciofluvial sediments are found in the valley bottoms. River valleys such as South Brook and Indian Brook–Birchy Lake contain most of the sand and gravel in the study area and often exceed 10 m thick. Glaciofluvial sediment is commonly encountered overlying marine and glaciolacustrine sediments. Glaciofluvial hummocks are associated with till hummocks and are found adjacent to other diamicton deposits. Two esker deposits, as well as, a 12 m section with the Indian Brook–Birchy Lake valley are described in the following sections.

***Barneys Brook***

The ridges adjacent to Barneys Brook form a complex of bifurcating ridges and boulder-covered ridges. The bifurcating ridges trend southeast and turn sharply northeast, whereas the boulder-covered ridges are oriented southeast-northwest (Plate 3A). The bifurcating ridges contain exposed sand and very few clasts on their surface, as a result are easy to recognize. The ridges range from 1 to 3 km in length, and are 10 to 15 m high and 5 to 10 m wide. Steep-sided ridges are composed of coarse-grained sand to matrix-dominated granule gravel with low clast content. Clasts range from 2 to 25 cm and are angular to subround. The boulder-covered ridges are oriented southeast-northwest. Most of them are located northwest of the eskers; however, one ridge is located to the east of the esker (Plate 3A, B). Oriented perpendicular to the esker ridge and cut by a stream, the ridge is covered by angular clasts that range

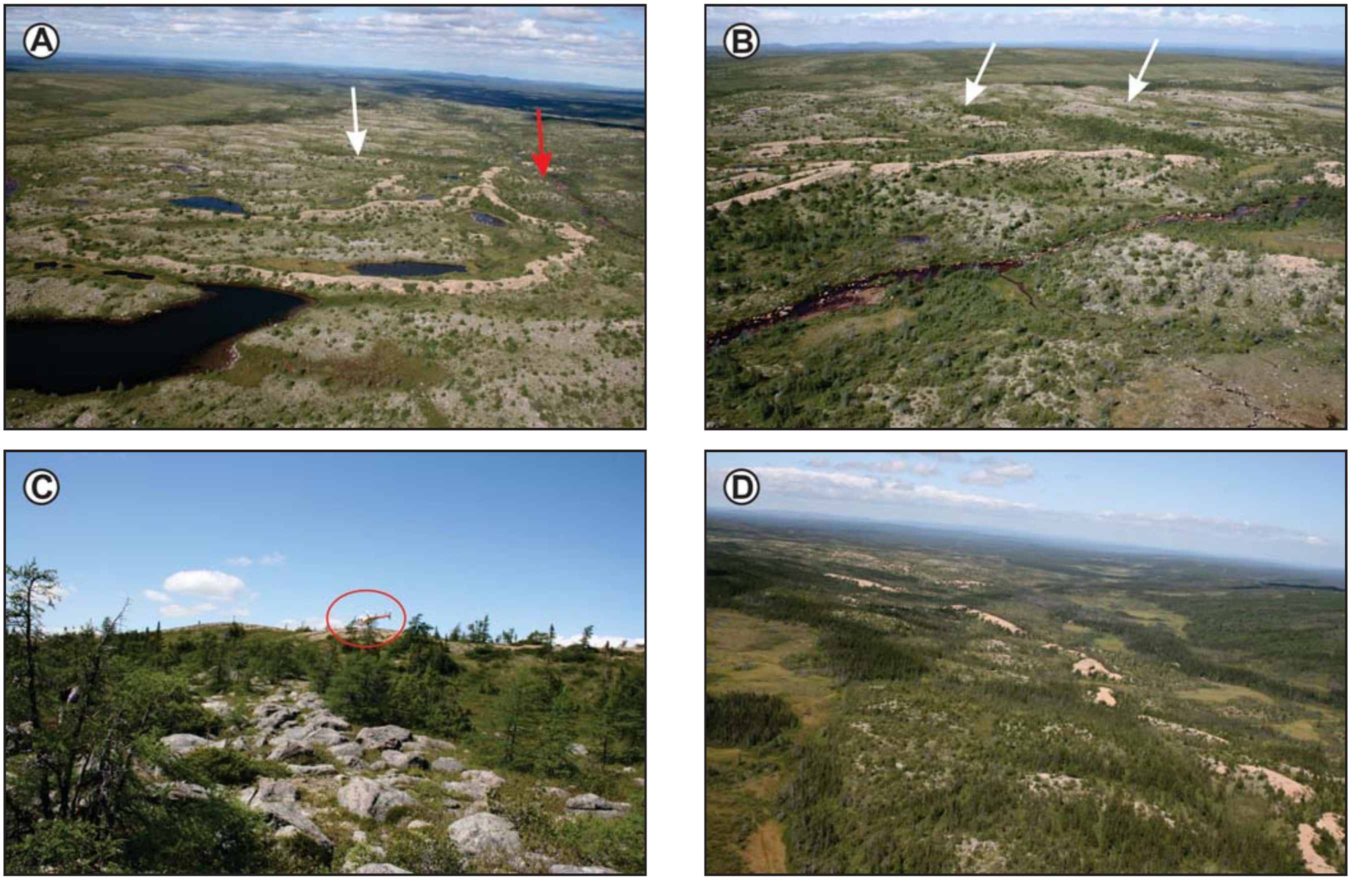


**Plate 3.** *A) Esker complex near Barneys Brook, looking north-northeast. Red arrow points to perpendicular boulder-covered ridge adjacent to esker, which is shown in B. Additional boulder-covered ridges are located on the left side of the esker and are shown by the white arrow; B) Northwest view of esker and adjacent boulder-covered ridge. Note that the latter ridge is cut by Barneys Brook. Additional boulder ridges are shown by the white arrows; C) Looking northwest across boulder-covered ridge that is arrowed in A. Note helicopter, circled in red, on esker ridge in background for scale; D) Discontinuous esker ridge north of Little Sandy Pond in Sandy Pond valley, looking north.*

from 50-100 cm (Plate 3C). Sediment is clast-supported with clasts ranging from angular to subround, and a matrix composed of fine-grained sand to granule gravel. The lack of silt within the matrix indicates that this ridge is covered by a veneer of glaciofluvial material or is entirely formed from it. The presence of more than 12 parallel boulder-covered ridges to the northwest suggests that they were formed in contact with ice; however, further work is needed to determine their origin.

***Little Sandy Pond***

Located 5 km north of Little Sandy Pond is a beaded esker (Plate 3 D). Segments of the esker are up to 250 m long and have steep sides and rounded tops. The esker is composed of material with a coarse-grained sand matrix and few clasts. Clasts are subangular to rounded and range in size from 5 to 10 cm, with very few cobble and boulder-size clasts.

***Indian Brook–Birchy Lake Valley***

A 12-m-high glaciofluvial section (Site 945) was identified in an active quarry pit 4.5 km west of the Springdale access road (Route 390) along the TCH. The section is oriented approximately east-west and is 20 m long (Plate 4A). In places, only the upper 2 to 4 m is exposed with the lower section being covered with slumped material. The pit also has a north-south exposure adjacent to the east-west section that is approximately 15 m long and approximately 4 m high, although the top of the section has been removed (Plate 4B).

Three units were identified within the sections at Site 945. Unit 1, the lowermost unit, is composed of a cobble gravel with a medium- to coarse-grained sand matrix. Clasts range from 0.5 to 8 cm and are subangular to round in shape. No sedimentary structures were observed. The unit dips toward the west and has a sharp contact with Unit 2, and an

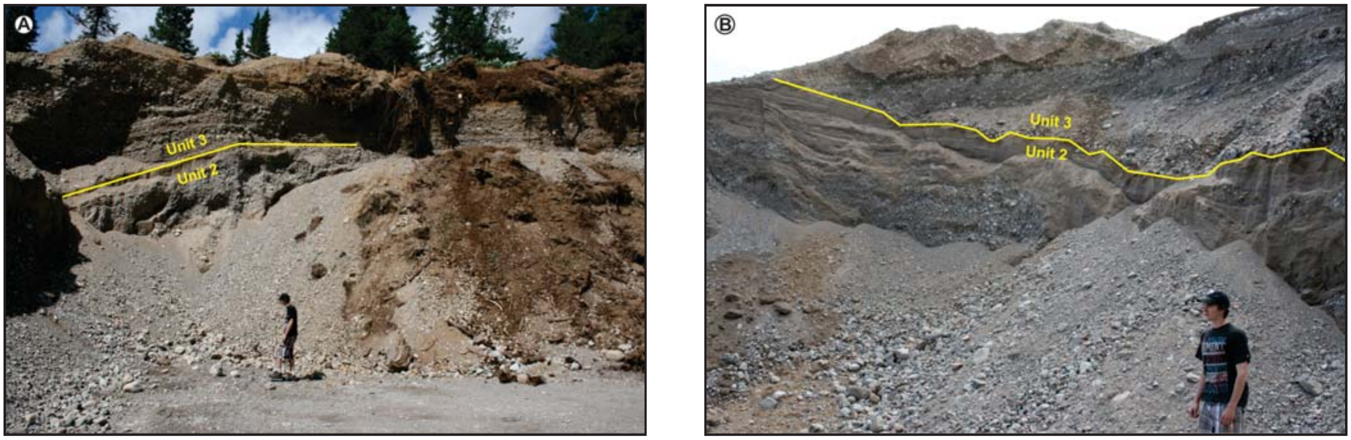


**Plate 4.** *Sand–gravel sections at Site 945 adjacent to the TCH, approximately 4.5 km west of the Springdale turn off (Route 390). A) 12-m-high east-west-oriented section, only the upper 2 to 4 m is exposed, the rest is covered by slumped material. The upper 2 to 3.5 m is cobble-boulder gravel described as Unit 3. Fine-grained matrix of Unit 2 can bee seen by dipping beds (yellow line seperates the two units); B) The north-south section exposed at Site 945 contains dipping fine-grained sediments of Unit 2, which are overlain by boulder-cobble gravel of Unit 3. Unit 1 is not seen in this photograph.*

erosive contact with the uppermost Unit 3. Unit 2 dips west and is composed of well-sorted, very fine- to fine-grained bedded sand that thickens toward the south. It is 1 to 2 m thick and undulates along its extent. Toward the southern end of the section, northerly dipping beds were observed. Convolute laminations were observed in the lower part of the unit. The upper contact is sharp, and at its northern extent appears to be erosional with the overlying Unit 3. Unit 3 is cobble–boulder gravel that is clast-supported in places. It is 2 to 3 m thick and is traceable along both the east-west and north-south sections. The matrix is a medium- to coarse-grained sand. Clasts range in size from 0.5 to 30 cm in diameter and are subangular to rounded. The unit appears to be horizontally bedded and contains some lenses of medium sand.

The sediment within this section is indicative of varying flow regimes in a glaciofluvial environment (Benn and Evans, 1998). High-flow regimes are responsible for the deposition of cobble gravel (Units 1 and 3). Erosive contacts and the dipping beds of Unit 2 indicate that erosion of a channel took place and as flow in the channel waned it was filled with fine sediment of Unit 2.

## Fine-grained Deposits

Fine-grained sediments were observed at three sites within the Sheffield Lake area and one site at Baie Verte Junction. The following is a description and interpretation of these sites.

### ***Sheffield Lake***

#### *Sites 920 and 927*

The exposures at Sites 920 and 927 have limited extent and are located at the east end and on the north side of Sheffield Lake. These exposures record moderately to well-sorted fine-grained sediments with laminations of silt. The elevations of these sites are 140 m and 170 m asl, respectively.

The exposure at Site 920 shows four 5 to 15 cm sequences, grading upward from silt to fine-grained sand that were observed in the upper metre (Plate 5). Contacts appear to be undulating. From 1 to 1.3 m, the section consists of fine-grained sand with rare granules and clasts ranging between 5-15 cm in diameter which are subangular to subround.

At Site 927, 60 cm of very fine-grained sand containing silt laminations overlie medium- to coarse-grained sand; contacts between the sand and silt are sharp. A 40-cm granite boulder was also observed within these sediments. The underlying medium- to coarse-grained sand contains pebbles and cobbles.

#### *Site 935*

Site 935 is an 8-m-high, 200-m-long section, located at 140 m asl on the north side of Upper Sheffield Brook where

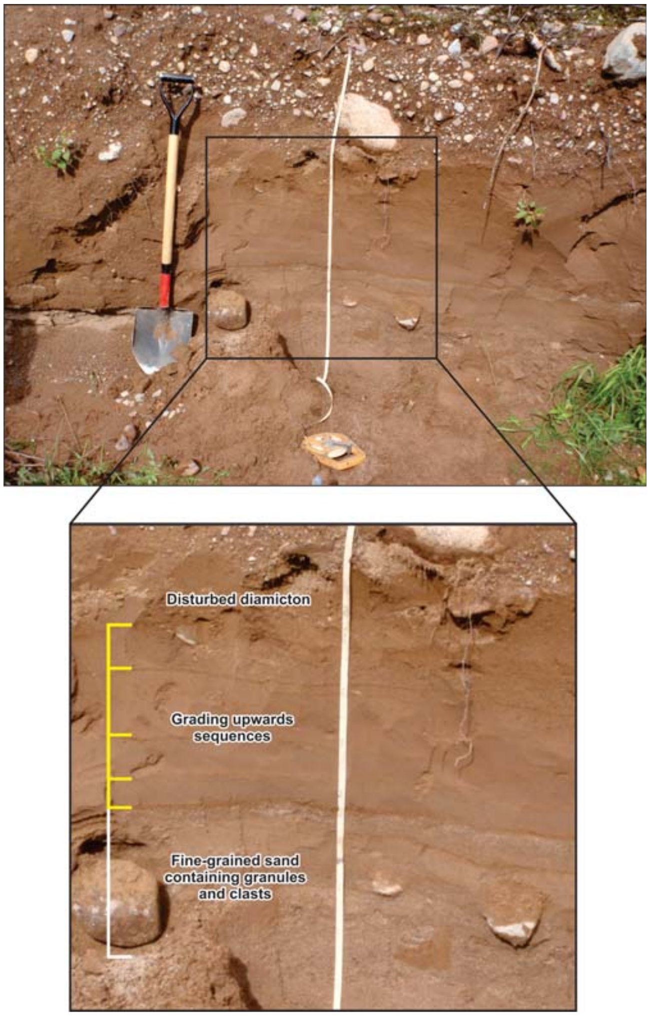


**Plate 5.** *Fine-grained sediments at Site 920 adjacent to Sheffield Lake. Sediment above black shovel handle has been disturbed.* In-situ *sediment within the section is approximately 1.3 m in height. In the interval between the shovel handle and the large clast next to the shovel blade, four 5 to 15 cm sequences are present, grading upward from silt to fine sand. The lower 30 cm consists of fine-grained sand containing a few granules and clasts.*

it empties into the southwest end of Sheffield Lake (Plate 6A). Three units were observed in this section. The lower 2 m (Unit 1) of the section consist of muds including interbedded silt and very fine-grained sand that is more clay-rich at the base (Plate 6B). These sediments contain scarce pebbles and cobbles, ranging from 0.5 to 10 cm. The contact between Unit 1 and Unit 2 is sharp and slightly undulating.

Unit 2 is composed of 5 m of bedded well-sorted, very fine- to fine-grained sand. A number of sedimentary structures were observed, including convolute laminations at the base of the unit, ripples and crosslamination, irregular dipping beds and horizontal bedding toward the top (Plate 6C, D). The contact between Unit 2 and Unit 3, where observed, is sharp and erosional.

The thickness of Unit 3 varies laterally between 1 and 4 m. It is composed of sandy-pebble-cobble gravel. The gravel is clast-supported in places and the matrix is made up of medium- to coarse-grained sand. Clasts range in size from 0.5 to 50 cm and are angular to subround.

The fine-grained nature of Unit 1 indicates these sediments were deposited in a calm-water environment (Benn and Evans, 1998; Eyles and Eyles, 2010). The convolute laminations indicate the sediment was partially liquefied and deformed during underflow currents (Benn and Evans, 1998). The ripples and crosslaminations also point to deposition in water and subsequent modification by waves. The sandy gravel of Unit 3 is the result of a prograding glaciofluvial system.

The fine-grained sediments surrounding Sheffield Lake are suggestive of deposition in standing water. The elevation of Sheffield Lake at 131 m asl, approximately 56 m above marine limit, indicates that these sediments were deposited in a glaciolacustrine environment. The lack of coarser material indicates that the sediments were deposited by overflow currents carrying sediment in suspension that settled out in calm parts of the lake, which was distal to the ice margin (Benn and Evans, 1998). Rare clasts within the sediment are interpreted as ice-rafted dropstones (Eyles and Eyles, 2010). The lake drained into Birchy Lake *via* Sheffield Brook through an incised channel at the northwest end of Sheffield Lake. The extent of this glaciolacustrine system is unknown and will be the focus of further work.

***Baie Verte Junction***

Fine-grained sediments were observed in an old gravel pit behind the motel at Baie Verte Junction. A 3 m excavation situated in the middle of the pit exposes stratified sand and gravel overlying interbedded silty clay and fine-grained sand (Site 966, Plate 7A). The elevation of Site 966 is between 50 and 60 m asl, as determined from a topographic map. Interbedded silty clay and fine-grained sand, with laminations of silt, make up the lower 1 m of the section (Plate 7B). The silty clay beds range in thickness from 1 to 3 cm, whereas fine-grained sand beds are typically 0.5 cm thick; there are rare beds of up to 5 cm thick. Toward the base of the section overlying the silty clay bed, there is a single 3.5 cm bed of silty granule gravel that contains a few pebbles and is overlain by 2 cm of fine sand. Contacts between beds are sharp and locally wavy. No *in situ* shells or shell fragments were identified.

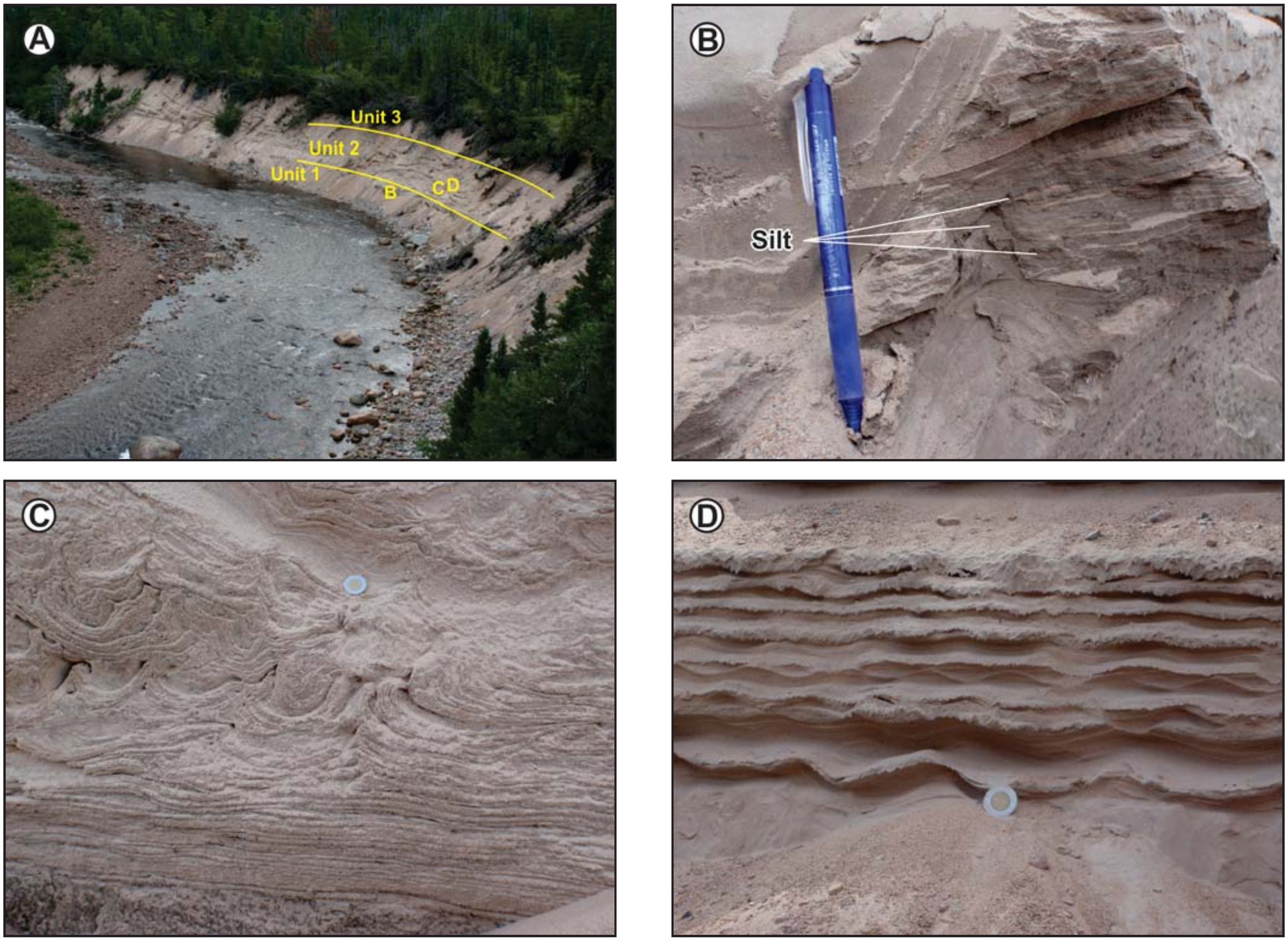


**Plate 6.** *A) 8-m-high section along Upper Sheffield Brook, looking southwest. Units 1 through 3 are labelled and are described in text. Letters B, C and D in the photograph refer to the location within the section of pictures shown in this plate; B) Unit 1 - interbedded silt and very fine-grained sand; C) Convolute and horizontal laminations overlying interbedded silt and very fine-grained sand (Unit 2); D) Beds of small-scale ripples in fine-grained sand (Unit 2).*

The upper 2 m consist of dipping fine- to medium-grained, moderately to well-sorted sand beds containing scarce pebbles and cobbles interbedded with both granule gravel and pebble gravel beds. The coarser beds are typically clast-supported and have a medium- to coarse-grained sand matrix. Fine- to medium-grained sand beds range in thickness from 10 to 50 cm, whereas granule and pebble gravel beds are 5 to 15 cm thick. Contacts between the sand and gravel beds are sharp. Beds dip between 20º and 24º toward the north.

The 1 m of interbedded silty clay and fine-grained sand is indicative of an ice-distal glaciomarine or glaciolacustrine environment in which sediment is supplied by plumes of suspended sediment and mass-flow events (Eyles and Eyles, 2010). The elevation of this site, 50 to 60 m asl, is below the established marine limit of 75 m asl, suggesting that these fine sediments are of a marine origin. The overlying gravel beds dip north and were deposited from meltwater draining the White Horn Brook into the Indian Brook valley. Within this same area, Liverman and St. Croix (1989) identified westerly dipping gravels that they interpreted as delta foresets, and suggested that the gravels formed in an ice-marginal lake west of Baie Verte Junction. These muds are not as clay-rich or as extensive as those marine muds described by Scott *et al.* (1991; Site SS1) at the bridge over Indian Brook on Route 390. No textural analysis/comparison or examination for microfauna have been completed to date; this will be the focus of further research to confirm if these muds are of a glaciolacustrine origin.

### Organic Deposits

Organics consisting of peat, bog and fen are found throughout the study area and typically form less then 5% of the surficial unit. Large expanses of bog (40%) are found on

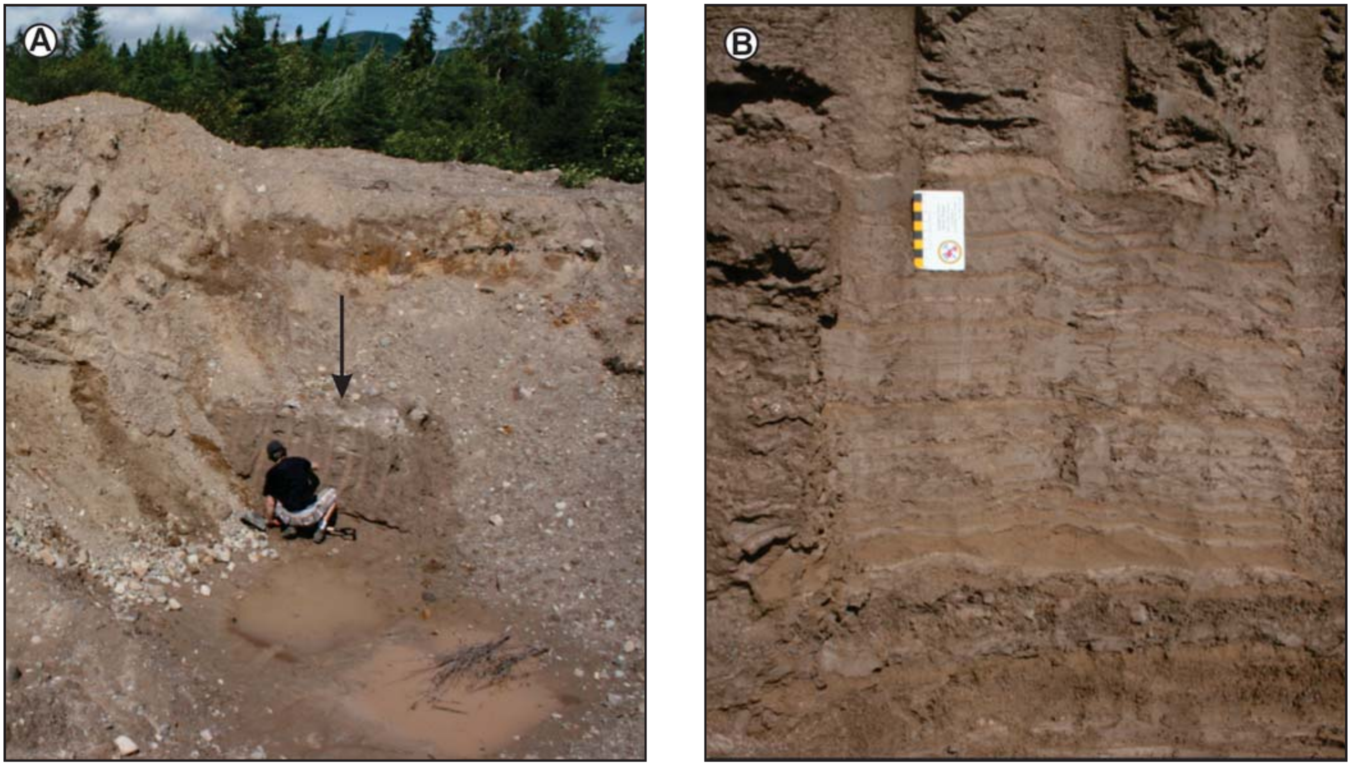


**Plate 7.** *A) 3 m section in an excavated pit at Baie Verte Juction (Site 966). Pit exposes 2 m of stratified sand and gravel overlying 1 m of interbedded silty clay and fine-grained sand. Black arrow shows location of interbedded silty clay overlain by sand and gravel; B) Interbedded silty clay and fine-grained sand with laminations of silt.*

the Topsails (west side of NTS map areas 12H/01 and 12H/02) and the area north of Birchy Lake (15%) (NTS 12H/07). Organics on the Topsails form extensive plains interspersed with thick bouldery diamicton, and are locally associated with glaciofluvial sand and gravel. Organics north of Birchy Lake are associated with undulating topography and in some places till hummocks. Typically, the deposits are less than 1 m thick; however, thicker deposits are present locally.

## DISCUSSION – EXTENT OF GLACIAL LAKE HOWLEY

The identification of fine-grained sediments in the Sheffield Lake area and muds found at Baie Verte Junction suggest that the extent of glacial Lake Howley may have been larger than proposed by Batterson (2003). The eastern extent of Batterson's (2003) glacial Lake Howley model was based on evidence of standing water in the Gillards Lake area (140 to 170 m asl) and the canal (watershed; 104 m asl) between Indian Brook and Birchy Lake. He proposed that the ice dam containing glacial Lake Howley was east of Birchy Lake (Batterson, 2003).

The elevation of fine-grained sediments at Sheffield Lake range in elevation from 140-170 m asl and are similar in elevation to those of Gillard Lake. This suggests that the extent of glacial Lake Howley could have included the area currently occupied by Sheffield Lake. Further investigation of glaciolacustrine features in this area will help determine if Sheffield Lake sediments are a part of the glacial Lake Howley system or a smaller ice marginal lake.

The interpretation of muds at Baie Verte Junction as glaciolacustrine allows for the location of the ice dam proposed by Batterson (2003) to be refined. In order for the muds to be included in glacial Lake Howley the ice dam would have to be located east of Baie Verte Junction, but no farther west than the western end of Indian Pond. This location of the ice dam would allow muds to be deposited while preventing drainage eastward down the Indian Brook valley and northeastward down the Shoal Pond valley.

Preliminary calculations indicate that the position of the ice dam at the western end of Indian Pond would increase the length of the glacial Lake Howley by approximately 20 km, to 155 km. The incorporation of the Sheffield Lake area would not likely increase the width of the lake, but would increase the surface area.

There are a number of research aspects relating to glacial Lake Howley that will be addressed during future work in this area. These are listed in the following section.

## FUTURE WORK

Future work in the Springdale–Sheffield Lake area includes:

- Documentation of the extent of the two stratigraphic glacial diamictons identified in the study area.
- Completing detailed diamicton study including clast provenance, grain-size analysis and clast fabrics.
- Conducting a backhoe program within the Birchy Lake–Indian Brook valley and Sheffield Lake areas to gain a better understanding of the stratigraphy.
- Documentation of the location, elevation and composition of any glaciolacustrine features such as deltas, shorelines, terraces and fine-grained sediments in the Birchy Lake–Indian Brook valley and Sheffield Lake areas. This will help to refine the extent of glacial Lake Howley and determine if smaller ice-marginal lakes existed in the Sheffield Lake area.
- Completing microfaunal work on fine-grained sediments from Baie Verte Junction.
- Completing geochemical and textural analysis of the fine-grained sediment units identified in the Sheffield Lake area, Gillards Lake Road, the canal (water shed between Birchy Lake and Indian Brook) and Baie Verte Junction to determine the relationship between the units and marine muds identified on Route 390. Further examination of fine-grained sediments at Baie Verte Junction (Site 966) will determine if these sediments were deposited in a glaciolacustrine or glaciomarine environment.

Further work in the area between Birchy Lake and Springdale will provide a better understanding of the stratigraphy and deglacial history of the area, which in turn will provide guidance in selecting the optimal sampling techniques in mineral-exploration programs.

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