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SURFICIAL GEOLOGY ALONG THE LABRADOR–ISLAND TRANSMISSION LINK: ISLAND POND (NTS 12H/07) TO MAIN RIVER (NTS 12H/14), GREAT NORTHERN PENINSULA, NEWFOUNDLAND

J.S. Organ
Terrain Sciences and Geoscience Data Management Section

ABSTRACT

A till-geochemical and surficial-geology program during the summer of 2024 mapped the Labrador–Island Transmission Link (LITL) between Island Pond (NTS map area 12H/07) and Main River (NTS map area 12H/14) on the Great Northern Peninsula, Newfoundland. Field work focused on till sampling, ice-flow indicator and surficial geological mapping to provide a detailed reconstruction of ice-flow dynamics during the Late Wisconsinan glaciation. Fifty-nine new striation measurements identify 4 ice-flow events, three of which fit within the established ice-flow chronology and include: 1) an early northeast flow from the Long Range Mountains and Topsails; 2) an easterly flow, ranging from north-northeast to east-southeast from the Long Range Mountains; and 3) a south-southeast flow attributed to late-stage deglaciation. The fourth, a previously undocumented westerly to west-northwest flow was identified in the northern study area (NTS map area 12H/14) and contrasts with the easterly ice flow identified on the east side of the map area. This divergent pattern of ice flow implies the presence of an ice divide east of Main River as well as, south of Eagle Mountain, where it is located farther west as indicated by striae documenting an easterly flow extending into White Bay.

The study area is characterized by a thin veneer of matrix-dominated silty sandy diamicton (till). Thicker till on the flanks of hills and in valleys in NTS 12H/14, while farther south in NTS 12H/11 till forms thick blankets that mask the underlying topography. Glaciofluvial outwash (sands and gravel deposits) are described from NTS 12H/14 and typically located in low-lying areas, river valleys or side slopes. Sands and gravel form a veneer overlying till, hummocks, short ridges or thicker deposits in valleys. Organic deposits, such as bogs and fens are found throughout the study area, but their thicknesses have not been determined.

INTRODUCTION

The construction of the Labrador–Island Transmission Link (LITL) created a corridor between Shoal Cove and Soldiers Pond, effectively opening access to the previously inaccessible interior of the Great Northern Peninsula (GNP). (Figure 1). This access to the interior has facilitated detailed ice-flow and surficial mapping and till-geochemical sampling.

This area is an under-explored part of the province whose Quaternary history is not fully understood. Implementing a till-geochemical and surficial-mapping program will support mineral exploration efforts in this region. This work complements previous studies to the east (McCuaig, 2003a, b), and south (Vanderveer and Taylor, 1987; Vanderveer, 2011; Organ, 2014; Hashmi, 2018).

The objectives of this program are to: 1) map the surficial geology and document ice-flow indicators; 2) reconstruct the pattern of glacial retreat; 3) collect till samples roads at a density of one sample per linear kilometre; and 4) support mineral exploration by identifying prospective areas through the integration of glacial movement, surficial geology and till geochemical data.

PHYSIOGRAPHY AND LOCATION

The study area encompasses an 80 km transect trending northwest–southeast along the LITL between Island Pond and Main River, covering parts of NTS 12H/06, 07, 10, 11 and 14 (Figure 1). The northern section of the study area lies east of Gros Morne National Park on the GNP and is accessed *via* the Taylors Brook Resource Road from Route 420. The southern part of the study area can be accessed through multiple points along routes 420 and 421.

The physiography of the study area is quite diverse. On the south side of the Hampden River, the terrain rises from an elevation of 60 m above sea level (asl) to 369 m asl south

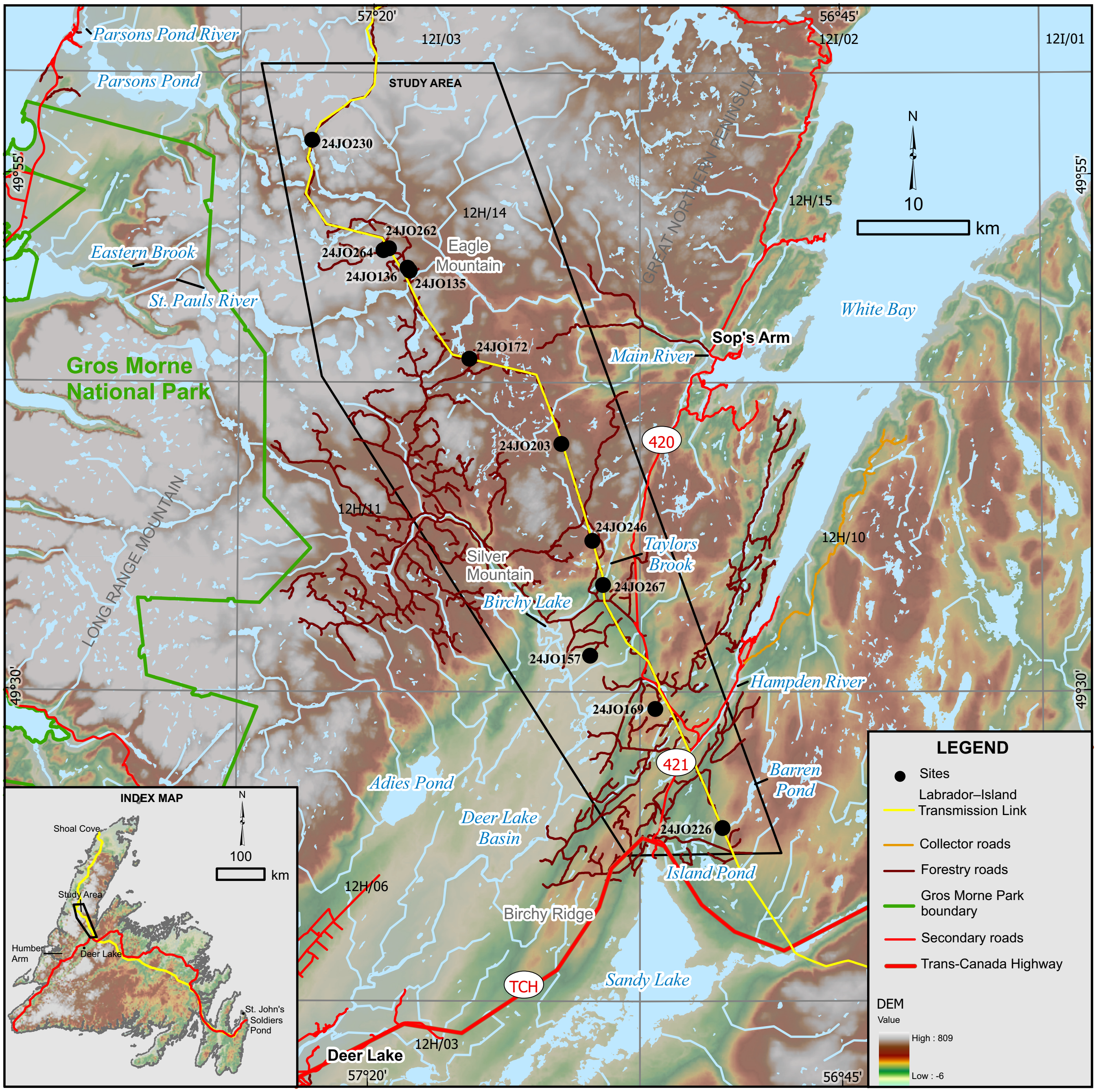

Figure 1. *Location of the study area illustrating the physiography and place names. Inset map shows location of study area and Labrador–Island Transmission Link (LITL) between Shoal Cove and Soldiers Pond. Black dots show location of observation sites and plates mentioned in the text.*

of Barren Pond. Within the study area, Hampden River drains northward into White Bay. On the north side of Hampden River is the northern extent of a northeast–southwest trending Birchy Ridge that acts as a natural division between Sandy Lake and the Upper Humber River. The Upper Humber River is located within the Deer Lake Basin and drains to the southwestward through Deer Lake into Humber Arm. Much of the GNP encompasses the Long Range Mountains. The terrain rises northward reaching elevations of 460 m asl surrounding Silver Mountain (NTS 12H/11) and increases to 520 m asl in the vicinity of Eagle Mountain (NTS 12H/14) and up to 730 m asl in the northwest corner of NTS 12H/14. The Long Range Mountains are responsible for three different drainage patterns identified within the study area. In the south on NTS 12H/07 and 12H10, drainage is northward into White Bay, while farther north along the eastern edge of the Long Range Mountains, water is directed eastward via Main River into White Bay. In contrast to the northwest corner of NTS 12H/14, drainage is guided west *via* fjords into the Gulf of St. Lawrence.

BEDROCK GEOLOGY

The study area lies within the Humber Zone of the Newfoundland Appalachians orogen (Figure 2). The Humber Zone consists of crystalline basement rocks of the Grenville Province (Long Range Inlier) that are unconformably overlain by cover sequences (Erdmer and Williams, 1995; Hinchey, 2010).

The Proterozoic crystalline basement rocks of the Long Range Inlier are composed largely of late Paleoproterozoic to early Mesoproterozoic, amphibolite to granulite faces orthogeniss with minor paragneiss intruded by Grenvillian-aged plutonic rocks (Hinchey, 2010). Detailed descriptions of these units can be found in Hinchey *et al.* (*this volume*), Hinchey (2010, 2020), Owen (1991) and Whalen and Currie (1988).

The cover sequence along the southern margin of the Long Range Inlier comprises Neoproterozoic to Carboniferous cover rocks. These include: 1) a series of Neopreoterozoic arkosic clastic units, Cambrian shales and quartzites, and a thick Cambrian to Middle Ordovician carbonate sequence (Labrador, Port Au Port and St. Georges groups) that are all capped by a Middle Ordovician shale–sandstone unit of the Table Head Group; 2) the Silurian volcano-sedimentary rocks of the Sops Arm Group; and 3) the Carboniferous arkosic clastic units (sandstone and conglomerate) with minor shale and limestone (Anguille, Wigwam, Deer Lake groups of the Deer Lake Basin). The fault running parallel to the Hampden River separates the cover sequences from the westward lying Neoproterozoic to Ordovician metamorphosed clastic rocks of the Fleur de Lys Supergroup. The area is intruded by Silurian magmatism, including the Taylor Brook Gabbro Suite, the Wild Cove Pond Igneous Suite and the Gull Lake intrusive suite.

A total of thirty-one mineral occurrences have been identified within the study area (Figure 2; GSNL, 2024b). These include barium, bitumen, copper, gold, lead, nickel, pyrite, uranium and dimension stone such as granite, gabbro and limestone. Over 65% of these occurrences (barium, copper, gold, granite, nickel and pyrite) are associated with the rocks of the Long Range Gneiss Complex (GSNL, 2024a, b). Bitumen and uranium are hosted by the Deer Lake Basin while lead and gold occurrences are associated with the Sops Arm Group.

QUATERNARY HISTORY

During the Late Wisconsinan glacial maximum, all the Island of Newfoundland was covered by a series of coalescent ice caps that formed the Newfoundland Ice Cap (NIC) that extended onto the continental shelf (Grant, 1989a; Shaw *et al.*, 2006; Figure 3A). Ice divides extended down the Long Range Mountains across central Newfoundland, and shifted in response to the retreating ice margin. By 13 ka BP, ice had retreated inland from the continental shelf. The deglacial configuration was irregular and time-transgressive due to both ice thickness and topography (Shaw *et al.*, 2006). By 11 ka BP, southern White Bay, the Deer Lake Basin, much of the GNP and the interior of the Island was still beneath a significant ice cap whilst a smaller one covered much of the Avalon Peninsula (Dalton *et al.*, 2020; Figure 3B). Ice margin models constructed by Dalton *et al.* (2020) indicate that by 10 ka BP, the ice cap had collapsed creating two smaller caps, one over much of the GNP and the other over the interior regions of Newfoundland. A brief re-advance of ice during the Younger Dryas was preserved as a series of linear moraines located in multiple areas in the interior of the Island and on the northern GNP as the Ten Mile Lake Moraine Complex (Liverman *et al.*, 2000; Shaw *et al.*, 2006; Putt *et al.*, 2010). As ice caps decrease in size the local topography has an enhanced influence on pattern of ice retreat (Shaw *et al.*, 2006). Deglaciation started in White Bay and continued into the Hampden River valley and the adjacent lower elevations while ice remained on the Long Range Mountains. Marine saltwater clam shells (Mya truncata; GSC-4023) collected from Sops Arm imply that nearby White Bay was deglaciated by 10 200 ± 100 yr BP (Blake, 1988). Dalton *et al.* (2020) proposed that ice disappeared from the island prior to 9 ka BP.

GLACIAL HISTORY

Glacial landforms, striae and deposition of surficial sediments identified on the landscape document the glacial history of the NIC. The following section provides a brief description of these features and what is known about the glacial history of the region.

ICE FLOW

Ice flow from the Long Range Mountains was first described by Heyl (1937) in the Sops Arm area described striae and landforms recording a north to northeast flow on the south side of Sops Arm, as well as, an east to southeast flow to the north which he believed was from a small ice centre located centrally on the GNP. Further work in the Sops Arm area by Vanderveer and Taylor (1987) indicated that this east to southeast flow was the oldest, originating

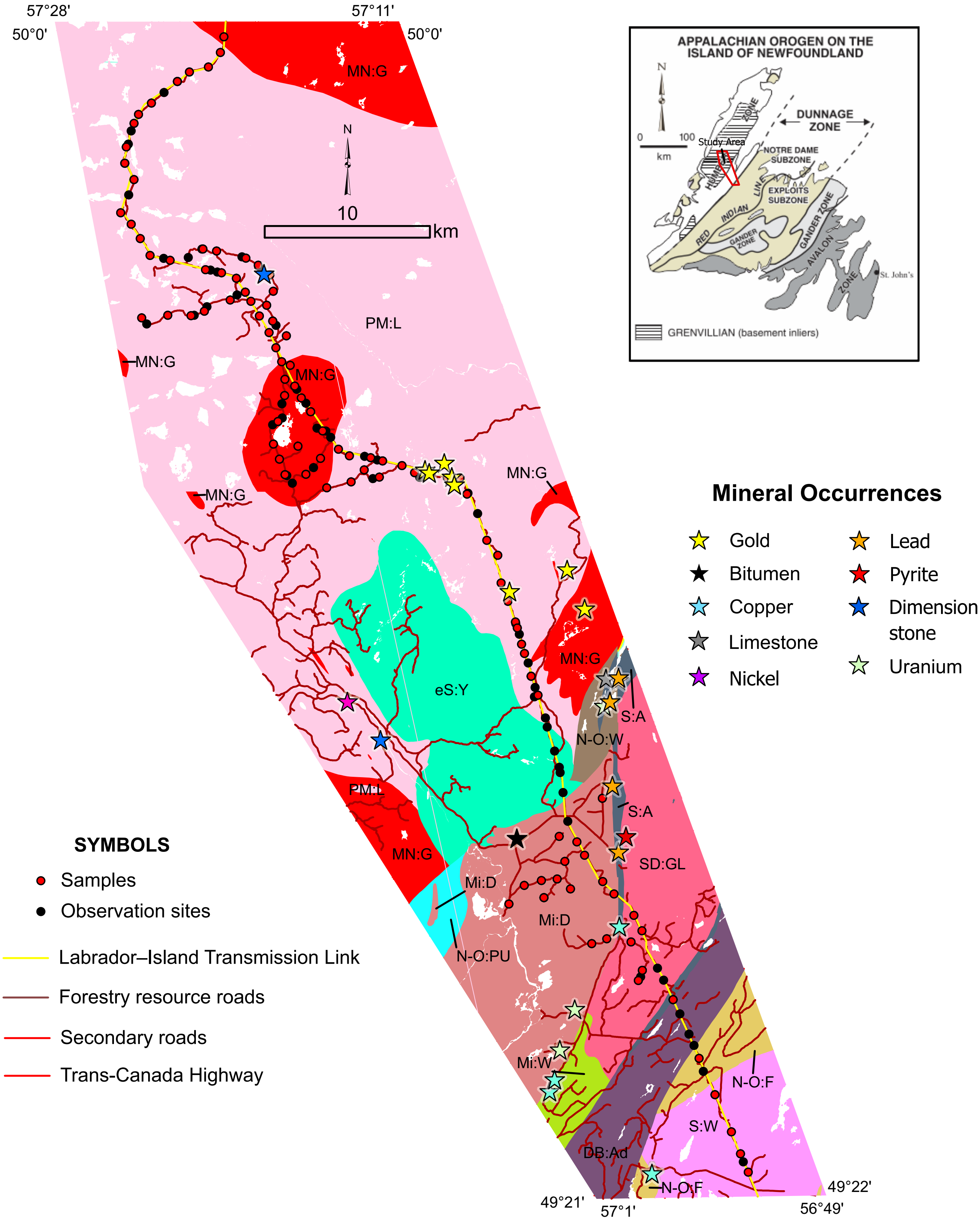

Figure 2. *Geology of the study area (GSNL, 2024a). Mineral occurrences are indicated using coloured stars (GSNL, 2024b).*

LEGEND (for Figure 2)

Mississippian

Deer Lake Group

Mi:D — Red and grey conglomerate, sandstone, siltstone and mudstone

Wigwam Brook Formation

Mi:W — Red, brown and grey sandstone; grey to red pebble to boulder conglomerate; grey limestone

Late Devonian to Mississippian

Anguille Group (Deer Lake Basin)

DB:Ad — Grey and red sandstone, conglomerate, black and grey shale, minor dolostone and limestone

Early Silurian to Late Devonian

Gull Lake intrusive suite

SD:GL — Biotite–muscovite granite and granite porphyry, massive to foliated granodiorite and tonalite, gabbro and diabase

Early to Late Silurian

Wild Cove Pond Igneous Suite

S:W — Diorite, granodiorite, biotite granite and two-mica granite

S:A — Felsic ash-flow tuffs and rhyolite flows, lesser unwelded tuff, volcanic breccia and mafic flows

Early Silurian

Taylor Pond Gabbro

eS:Y — Medium-grained, mesocratic, layered gabbro, layering cut by stock and dykes of massive pegmatitic gabbro

Middle Cambrian to Early Ordovician

Port au Port Group

CO:T — Muddy carbonate rocks, oolitic sequences, silty mudstone and stromatolites

Neoproterozoic to Middle Ordovician

Undivided sedimentary units of the Humber Zone

N-O:PU — Marble, variable recrystallized dolostone, quartzite and schist

Neoproterozoic to Early Ordovician

Fleur De Lys Supergroup

N-O:F — Metaclastic schists with interlayered amphibolite and greenschist

Southern White Bay Allochthon

N-O:W — Tonalite, gabbro, slate, sandstone and greenschist

Neoproterozoic to Middle Cambrian

Labrador Group

NC:L — Red, pink, purple and grey arkosic conglomerate, arkosic, micaceous and hematitic sandstone and siltstone

Late Mesoproterozoic to Neoproterozoic

Grevillian granitoid rocks

MN:G — Equigranular and potassium feldspar–metacrystic biotite ± hornblende granite; lesser biotite–hornblende granodiorite

Late Paleoproterozoic to Early Mesoproterozoic

Long Range gneiss complex

PM:L — Quartzofeldspathic gneiss, including granitic–granodioritic, quartzdioritic and tonalitic compositions

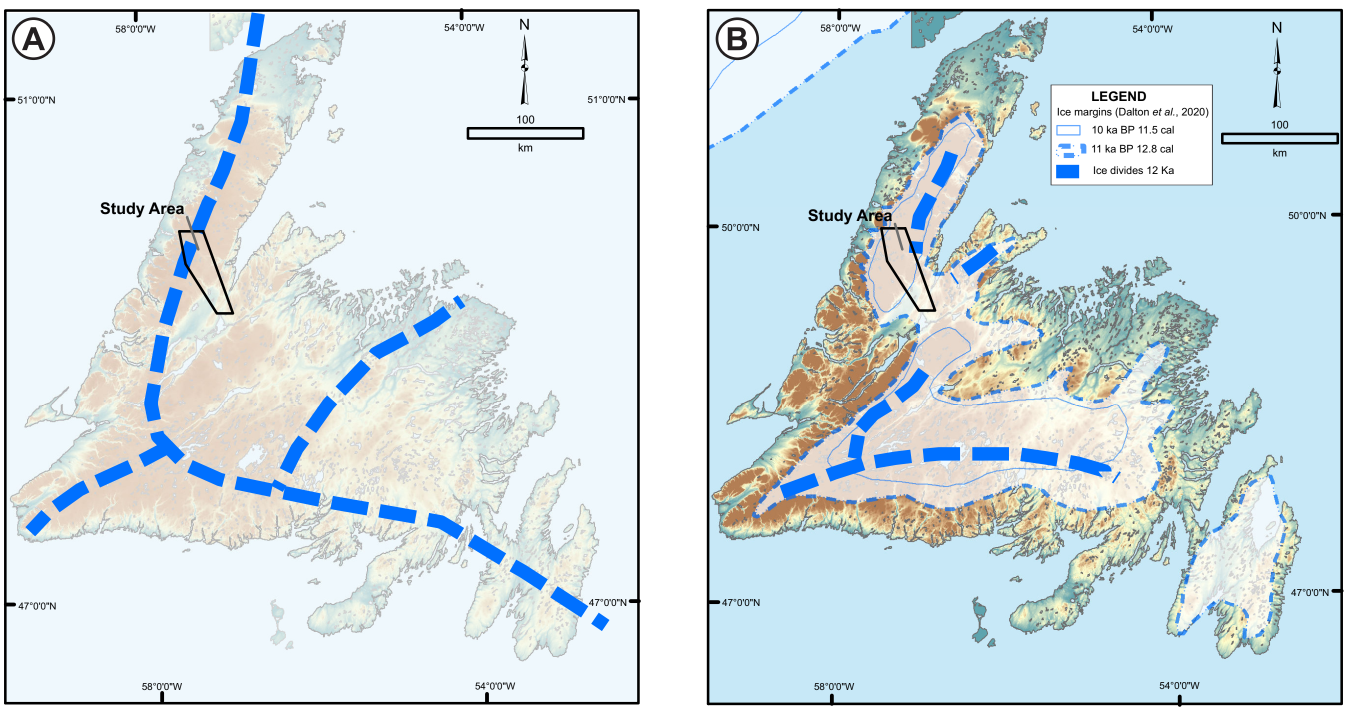

Figure 3. *A) Map showing the glacial maximum extent of the NIC during the Late Wisconsinan. Black outline shows the study area. Ice extends offshore with approximate location of ice divides (dashed blue lines) down the Long Range Mountains through central Newfoundland (Shaw* et al.*, 2006; Dalton* et al.*, 2020); B) Ice extent sequence during deglaciation between 11 and 10 ka BP. Isochrones show the ice margins (*see *Dalton* et al.*, 2020). Isochrons are given in radiocarbon years and calendar years in brackets.*

from the GNP while the northerly flow originated south of Gull Pond. Two major glacial events were described by Vanderveer to the southwest in the Upper Humber River area which included an eastward flow north of Wigwam Brook (NTS 12H/10) originating in the Long Range Mountains, and a late stage topographically controlled southeastward flow towards the Deer Lake Basin. Additional detailed work by Taylor and Vatcher (1993) in west-central Newfoundland proposed the study area was influenced by three ice-flow events: 1) the oldest being an early northeast ice flow (depicted by black arrows on Figure 4) from an ice centre between the Long Range Mountains

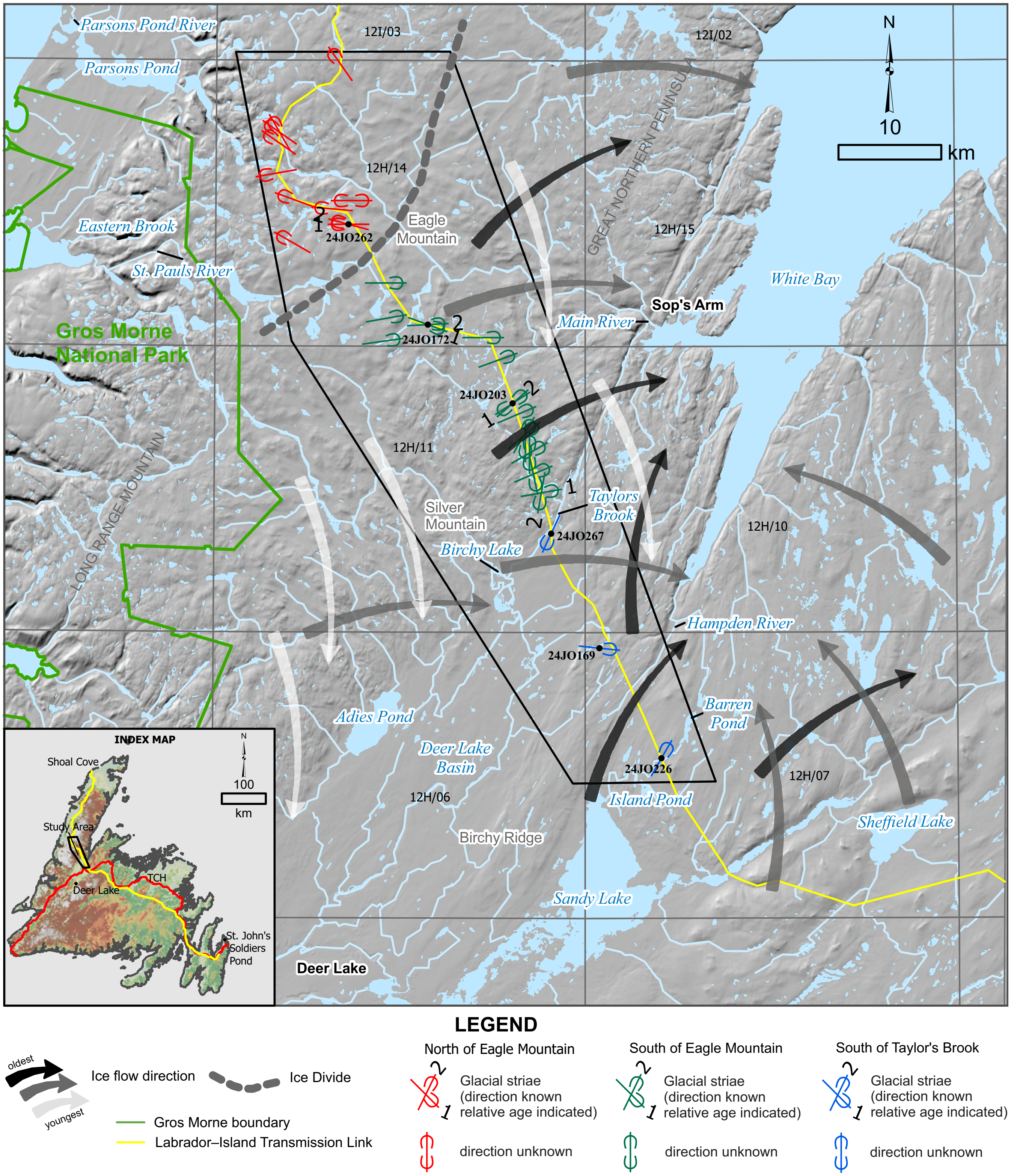

Figure 4. *Regional ice-flow history from Taylor and Vatcher (1993). Black arrows represent an early northeast flow event, grey arrows represent a younger easterly flow from the Long Range Mountains and a northerly flow north of Sandy Lake, and white arrows represent the youngest south to southeast flow. Striation symbols show selective data collected during the 2024 field season, these are coloured red for North of Eagle Mountain, green for south of Eagle Mountain and blue for south of Taylor Brook. Relative ages are noted by numbers with 1 being the oldest. Grey-dotted line shows the ice divide using data collected in 2024.*

and the Topsails; 2) divergent flow of the remaining, thinning ice: eastward across the GNP from an ice centre situated on the Long Range Mountains, while another flow moved northward from the Topsail Hills southeast of Howley (indicated by grey arrows); and 3) the third and youngest ice-flow event was a south to southeast late-stage flow that was topographically controlled from a centre in the Long Range Mountains (shown by white arrows on Figure 4).

SURFICIAL GEOLOGY

The first extensive surficial mapping of the area was carried out by Grant (1989b) followed by Liverman and Taylor (1990) both at a scale of 1:250 000. Both maps (*ibid.*) illustrate that a veneer of till associated with exposed bedrock is dominant particularly in the northern study area (NTS 12H/14, north half of NTS 12H/11). Sands and gravels and ice-contact sediments are located within the valleys. The area around Birchy Lake and Alder Pond includes thicker till deposits, hummocky till and ribbed and drumlinized till along with sand and gravel (Grant, 1989b; Liverman and Taylor 1990). Till veneer, minor out-wash gravels along Hampden River and bedrock make up the southern part of the study area (Liverman and Taylor, 1990).

Detailed surficial mapping has been completed by numerous researchers including Vanderveer (1981), Batterson (2000), McCuaig (2003a, b), Organ (2016) and Hashmi (2020a, b) and can be found on the Geoscience Atlas (https://geoatlas.gov.nl.ca/Default.htm; GSNL, 2024c). Multiple till units have been described by both Vanderveer (1981) in the Upper Humber River area (parts of NTS 12H/03, 07, 10 and 11, all of NTS 12H/06), and Hashmi (2018) in the Silver Mountain (NTS 12H/11) and Cormack areas (NTS 12H/06). Vanderveer (1981) describes three distinct tills based on matrix composition and clast lithologies: 1) a light pinkish grey sandy till that contains red sandstone; 2) a red basal clay-rich till unit derived from the gabbric source; and 3) a local immature clast rich red to grey sandy till. Hashmi (2018) described two tills within the study area. The first is a massive light pearly pink-brown silty sand till near Birchy Lake, characterized by a high clast content, shows no fissility, faceted, silt-capped and bullet-shaped clasts, representative of Grenvillian granitoid rocks. This till may be the equivalent of Vanderveer's (1981) light pink-grey sandy till. The second till unit described by Hashmi (2018) is a dark grey massive silty sand in the Silver Mountain area (NTS 12H/11). This till is fissile and had a medium-high clast content, in which there were faceted, silt-capped and bullet-shaped clasts. Clasts within the till indicate this till is derived from the Long Range Inlier, Taylor Brook Gabbro Suite and/or mafic dykes (Hashmi, 2018).

Glaciofluvial sediments and meltwater channels are described by Vanderveer (1981) in the Adies Pond area. Hashmi (2018) describes fine to medium sand that grades into granule to pebble size gravel in the Silver Mountain area (NTS 12H/11) and suggests it may represent littoral/nearshore deposits associated with localized meltwater ponding.

METHODS

TILL SAMPLING

Field observations of the surficial geology and ice-flow indicators were collected from 159 sites (Figure 2). At each site, GPS location, elevation, sediment type, matrix composition, sedimentary structures, clast information (size, composition, angularity, concentration of clasts) and striae measurements (where present) were recorded.

Till-geochemical sampling focused primarily in NTS 12H/14, along with infill sampling in parts of NTS 12H/07, 10 and 11. Approximately 4 kg of till was collected from each site: 39 road-cuts (average depth 87 cm), 33 roadside ditches (average depth 80 cm), 32 hand-dug pits (average depth 59 cm), 4 quarry sites (average depth 90 cm) and 3 uncategorized sites (average depth 65 cm). Three kilograms of till was collected into plastic bags for geochemical analysis while 1 kg was stored in kraft paper bags for grain size analysis. In addition, ten sites were strategically sampled for heavy mineral concentrates (HMC) along the transect. At these locations, a large 15 kg sample was collected for indicator mineral analysis. Sample spacing was determined by access along existing roadways and the availability of appropriate sampling medium. Along roadways, sample density averaged 1 per linear kilometre. A duplicate sample was collected every 18 samples to check for field reproducibility of elemental concentrations as part of the quality assurance/quality control (QA/QC) process.

ANALYSIS

A total of 111 till-matrix samples were submitted to the Geological Survey of Newfoundland and Labrador geochemical laboratory (St. John's, NL). Samples were air-dried and dry-sieved through 63 μm (230 mesh) stainless-steel sieves to recover the silt and clay fraction for geochemical analysis. Dry till colour was determined using a Munsell Soil Color Chart; wet colour was not recorded. Minor- and trace-element content will be analyzed using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES); Instrumental Neutron Activation Analysis (INAA) analysis for 27 elements will be completed at Bureau Veritas Laboratories (Mississauga, ON). For details of the preparation and analytical methods for till samples, *see* Finch *et al.* (2018). Grain size and HMC samples will be analyzed later.

RESULTS

ICE-FLOW INDICATORS

Fifty-nine ice-flow measurements were recorded from 50 sites (Figure 4). Many of the new sites were located in NTS 12H/14 as the new transmission link provides new access. Nine sites, 3 in NTS 12H/14 and 6 in NTS 12H/11, contained multidirectional ice-flow indicators. Crosscutting and lee-side preservation relationships were used to establish relative age relationships at 3 sites. All striations identified are fresh and unweathered and are interpreted as Late Wisconsinan.

The regional ice-flow history has been established by looking at the spatial distribution of the relative age relationships for all striae and macro-scale landforms. Newly identified striae are described based on their location within three topographic regions: north of Eagle Mountain, south of Eagle Mountain, and south of Taylors Brook.

North of Eagle Mountain (NTS Map Area 12H/14)

Nineteen striae record a westerly to northwest ice flow northwest of Eagle Mountain (red striae on Figure 4). These are the first to be documented in the northern half of NTS 12H/14. The only age relationship identified in this area (site 24JO262) suggests a westerly flow (270°) followed by a subtle shift toward west-northwest (285°). Further to the north, ice flow is towards the northwest (325°).

South of Eagle Mountain (NTS 12H/14 (South) and 12H/11)

Thirty-seven striae were measured along the LITL, south of Eagle Mountain and north of Taylors Brook and are indicated by green striae on Figure 4. All but 6 striae trend from north-northeast to east-southeast. Three relative-age relationships have been identified in this area. The northernmost site, 24JO172, records an older east-southeast flow (110°) followed by a younger easterly flow (87°). A second site, 24JO203, records an older southwest flow (237°) followed by a younger northeast flow (49°). The confidence assigned to the direction and age are moderate for the older southwest flow and high for the younger northeast flow. The third site, 24JO246, records an older easterly (80°) flow followed by a younger southerly (190°) flow. The confidence of this age relationship is high as the easterly flow was preserved in the lee of the southerly flow. The southwest flow identified at Site 24JO203 is rare for this area as the nearest previously recorded site is 13 km to the west (Taylor and Vatcher, 1993). Ice flow and subsequent age relationships identified in 2024 fit within the regional ice-flow chronology identified by Taylor and Vatcher (1993).

South of Taylors Brook

Only three single striation sites were identified south of Taylors Brook (blue striae on Figure 4). The northernmost site, 24JO267, records a south-southwest flow on the southern edge of the Taylor Brook Gabbro Suite. Other south-southwest-oriented striae were identified nearby on the northern edge of the Deer Lake Basin (*see* Batterson, 1989). An easterly (96°) flow is identified on Birchy Ridge at site 24JO169. Batterson (1989, 1993), Grant (1989) and Taylor and Vatcher (1993) have also recorded an easterly flow, however it has been associated with an older southwest flow (215°). On the east side of the Hampden River, site 24JO226 records a north-northeast flow (30°). This agrees with Taylor and Vatcher (1993), who reported a north-northeast flow followed by a northerly flow believed to be originating from an ice centre in the Topsails Hills southeast of Howley and emptying into White Bay.

SURFICIAL GEOLOGY

The surficial geology is dominated by varying amounts of glacial diamicton (till) and sand and gravel. Postglacial organic deposits (bogs, fens and peat) are common, particularly in topographic lows. While not described at any sites, colluvium deposits and landslide scars were seen on steeper slopes particularly in NTS 12H/14. Glacial diamicton, sands and gravel and organic deposits are described below.

Diamicton

Observations from 111 sites are used to describe diamicton (till) within this area, which varies in thickness and morphology including thin veneer, thick blankets, undulating hummocks and streamlined features. Thin diamicton (<1.5 m is most common) is seen throughout the area, particularly in NTS 12H/14. In the north, diamicton is a thin to sometimes discontinuous veneer associated with exposed bedrock highs. At several locations, the diamicton appeared eroded, having a lower silt and clay content, which may indicate coarser bedrock material, short transport distances or meltwater erosion. Thicker diamicton deposits ranging from 2–4 m thick, are observed on the flanks of hills and in the valleys (GSNL, 2024e). Farther south, in NTS 12H/11, thicker deposits, 3–21 m, form a blanket masking the underlying topography in the Deer Lake Basin (GSNL, 2024e). In NTS 12H/07, diamicton forms a thin veneer overlying bedrock with thicker deposits observed in low lying areas and in a few localities, form streamlined features oriented to the northeast.

Sedimentary sections exposed in riverbanks, road-cuts are rare and as a result only one stratigraphic unit is described for the study area. However, two distinct diamictons were observed within a hand-dug pit at site 24JO157, in the southeast corner of NTS 12H/11 (*see* below).

The dominant unit identified at the surface is a poorly sorted, massive, matrix supported, silty sand diamicton. Textural estimations completed in the field indicate that the matrix is composed of silty sand that has variable silt content (1–20%). Sites with higher silt content often featured preserved silt caps on top of the clasts while sites with lower silt content typically have sorted coarse sand under the clasts. The compaction of the matrix varies from compact exhibiting a fissile texture to loosely compact and easy to dig (Plates 1 and 2). The colour of the dry matrix is highly variable across the area but typically ranges from a light olive brown (Munsell color 2.5Y5/3) to light yellowish brown (Munsell color 2.5Y6/4) to light brownish grey (Munsell Color 2.5Y6/2). Most of sites exhibit a low clast concentration (<20%) while only a few sites had moderate clast concentration (21-40%). Clasts average 2.5 cm diameter, but can be as large as 400 cm. They are typically very angular to subrounded in shape. Over 34% of sites recorded striated clasts and 39% of sites recorded faceted clasts. Clast lithologies are predominantly granite, granodiorite, gneiss and gabbro. However, in the south (NTS 12H/11 and 12H/07), there is a notable presence of sedimentary clasts including red and blue sandstone, conglomerate and siltstone. The granite, granodiorite and gneiss are derived from the Long Range Inlier and Taylor Brook Gabbro Suite while sedimentary rocks are sourced from the Deer Lake Group and Anguille Group.

At site 24JO157, located in the Deer Lake Basin in NTS 12H/11, two diamictons were identified (Plate 3). A 20-cm thick light olive-brown diamicton (Munsell color 2.5Y5/3) overlies a compact brown diamicton (Munsell color 7.5YR5/3). The upper diamicton is a massive, matrix-supported, poorly sorted, loose silty sand. The clast content is low (<20%), with average clast size of 3 cm and a maximum of 60 cm. Clasts range from angular to subangular and a few are striated and faceted. Clast lithologies are predominantly granites and gneiss derived from the Grenvillian granitoid rocks.

In the field and under damp conditions the lower diamicton has a more reddish-brown hue, however when dry, the Munsell color is 7.5YR5/3. This lower diamicton is characterized by a massive, matrix-supported, poorly sorted, compact silty sand matrix. The clasts content is low (<20%) and clasts have an average of 2 cm with a maximum of 12 cm. Clasts are angular to subangular in shape. Several bullet shaped clasts were identified, however no faceted or striated

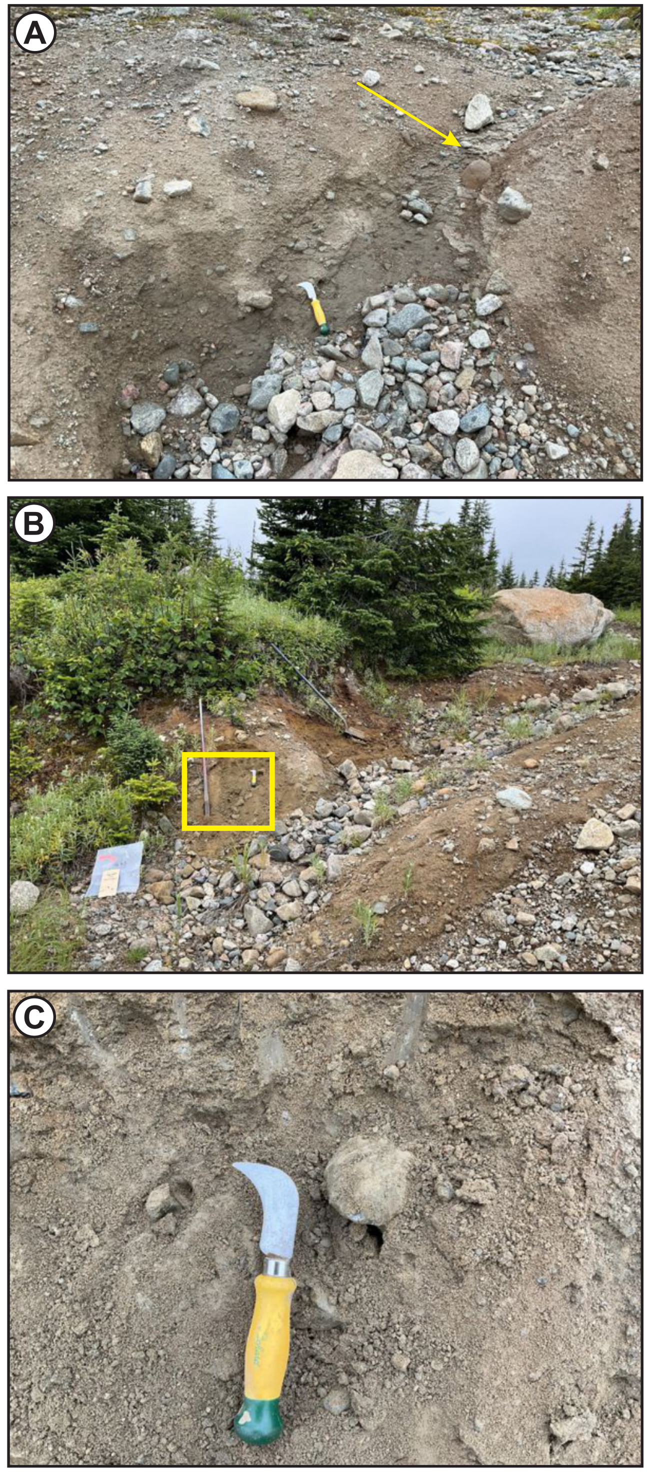

Plate 1. *An example of subglacial basal till at site 24JO183,* see *Figure 1 for location. A) Looking east of a till exposure in an unaltered natural state. Yellow arrow highlights an area of fissility; B) Looking north at cleared section where sample was taken. Note the size distribution of clasts, 2–200 cm. The yellow box shows location of Plate 1C; C) Close up of till A, a light olive brown silty sand. This till is compact, that shows silt caps on clasts and in places is fissile.*

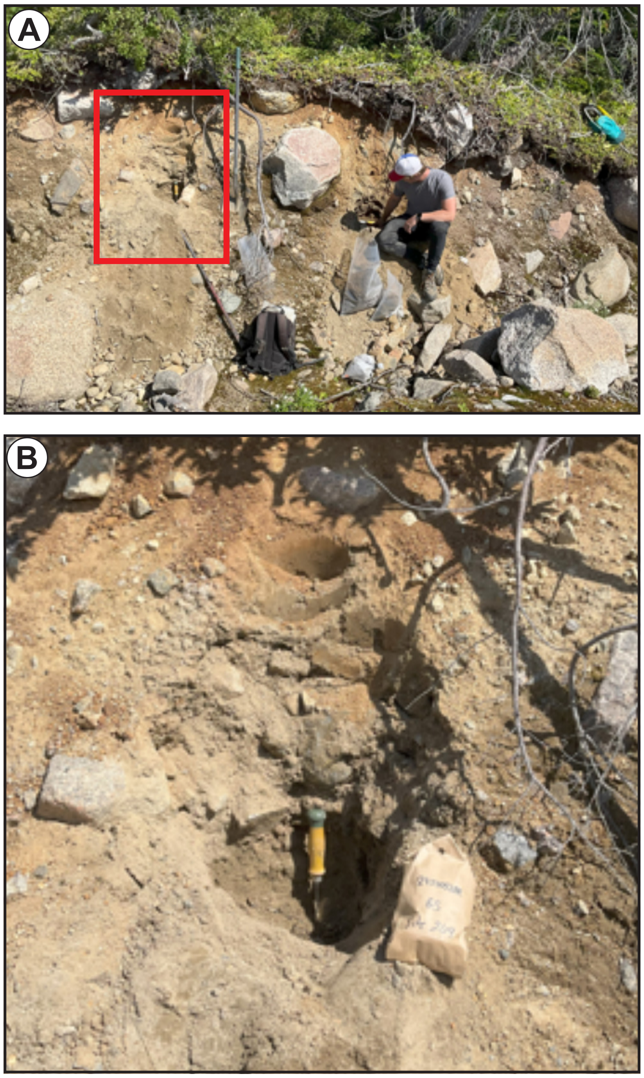

Plate 2. *An example of a melt-out till at site 24JO264,* see *Figure 2 for location. This is a is a light brownish grey silty sand. Clast content at this location is low (<20%). Clasts range from 2–200 cm and are angular to subangular.*

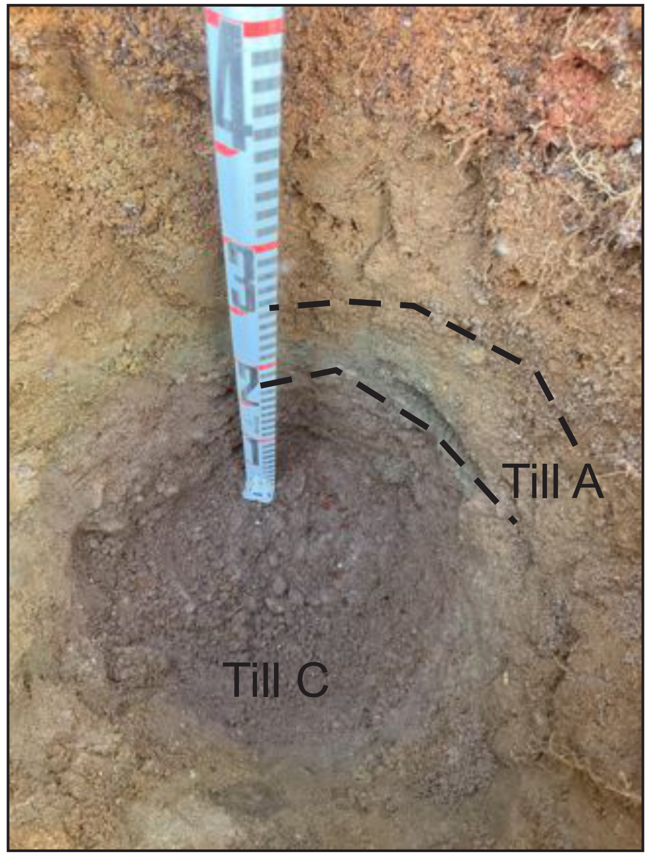

Plate 3. *A test pit at site 24JO157 showing two tills. A thin loose 10–20 cm of non oxidized Till A – Light olive brown overlies Till C – brown compact silty sand. In the field Till C has a reddish hue and contains red sandstone believed to be from the Deer Lake or Anguille Groups.*

clasts were observed. Pebbles are predominantly red sandstones and granites, derived from the Deer Lake Group, Anguille Group and the Grenvillian granitoid rocks.

Loosely compact diamicton typically exhibits less fines, show some sorting, high angularity, large clasts and have fewer striated and faceted clasts are characteristics associated with melt-out till (Benn and Evans, 2010; McClenaghan *et al.*, 2020). Melt-out till forms as material melts out of the glacial ice on to the underlying surface, this can occur either at the ice front or when pieces of debris rich ice break off and melt *in situ* (Benn and Evans, 2010). Approximately 19% of sites share these characteristics and are interpreted as melt-out till. These sites are associated with large angular clasts from 40 to 400 cm indicating that transport distances were relatively short. Identified coarser material (sorting) under clasts indicates the influence of meltwater. The upper diamicton described at site 24JO157 is loosely compact, contains large angular clasts and is interpreted as a melt-out till.

Diamicton that has a high silt content, high compaction, fissility, and the presence of striated, faceted and bullet shaped clasts, along with clast angularity is typically deposited subglacially at the base of the ice (Benn and Evans, 2010; McClenaghan *et al.*, 2020). Diamicton with these characteristics is designated as a subglacial basal till and was observed at 20% of sites. The angularity of the clasts indicate that this basal till is immature and not far travelled. Transport distances to the east in White Bay as described by McCuaig (2003) vary from 1 to 20 km. This subglacial basal till may correspond to the immature grey till described by Vanderveer (1981) and with Hashmi's (2018) dark grey massive silty sand as they have been described to have a silty sand matrix that is poorly sorted, compact, is fissile and whose clasts are more angular and are both faceted and striated. The lower diamicton described at site 24JO157 exhibits characteristics of a basal till and the angularity of the clasts infers this till has not been travelled far.

The remainder of the sites (59%) were not classified. Other analyses such as geochemistry, grain size and clast fabrics will be useful in determining modes of deposition and classifying till units. It should be noted that depending on thermal regimes and sediment load within the ice, different deposition processes can occur simultaneously or after each other and as a result there can be lateral changes in deposition of till along with stratigraphic differences (Benn and Evans, 2010).

Glaciofluvial Deposits

Glaciofluvial deposits were identified within the study area by others (McCuaig, 2003b; Hashmi, 2020a, b), however, observations made in 2024 are only from NTS 12H/14. Six sites record sand and gravel that were deposited during deglaciation. These are typically located in low-lying areas or along side slopes. Sand and gravel deposits form a thin veneer over till, hummocks or thicker deposits within valleys. Site 24JO230 is located on the north side of a north-northwest trending valley. The sand and gravel at this location forms a small ridge that is approximately 40 m wide and 260 m long (Plate 4). Much of this ridge has been removed for road construction with the remaining exposure standing at an approximate height of 5–6 m. The ridge is composed of fine to medium sand and has a moderate clast concentration (<21–40%). The largest granite and gneiss angular to subrounded clasts are 60 cm in diameter. This is interpreted as a short esker ridge, that maybe part of a larger glacial meltwater system.

Thick sand and gravel deposits were identified at two sites, located 350 m apart, on a side slope west-northwest of Eagle Mountain. Site 24JO135 is a 3-m exposure along a road-cut located at 440 m asl situated on an easterly facing slope (Plate 5). The exposure comprises a poorly-sorted matrix and dominant cobble boulder gravel, where the matrix is coarse sand to granule gravel. The clasts are predominately subangular to subrounded granite and granodioritic gneiss lithologies that range from 3 to 60 cm in diameter. The full extent of this deposit is obscured due to thick vegetation cover.

Finer grained sand is observed at site 24JO136 (Plate 6), located 350 m upslope from site 24JO135 at an elevation of 460 m asl. This site is in the back side of a large burrow pit and corresponds to an elongate depression on the digital elevation model. At this location, there is approximately 150 cms of poorly sorted loosely compacted light brownish grey silty sand overlies crudely stratified moderately to well-sorted fine- to coarse-grained sand and granule gravel.

Plate 4. *Photo from site 24JO230,* see *Figure 1 for location. Photo looking north northeast at 5 m cross section through a small esker ridge composed of cobble–boulder gravel with a matrix of fine- to medium-grained sand. Note bedrock in the foreground, believed to be representative of the Long Range Gneiss Complex (GSNL, 2024).*

Organic Deposits

Organic deposits such as bogs and fens are found throughout the study area. In NTS 12H/07 and 12H/11 bogs are found in topographic lows, however in NTS 12H/14 they are also found on top of the plateaus. Thicknesses of these organic deposits have not been determined.

DISCUSSION

The data collected during the 2024 field season along the LITL provides valuable new insight into the region's Quaternary history. Ongoing analyses of till geochemistry as well as grain size analysis will provide additional information to help distinguish between units. This discussion outlines how the existing data fits within the regional context and will identify research questions to guide future work conducted in this area.

Ice-flow patterns and sediment deposition identified within the study area are associated with the Late Wisconsinan glaciation maximum and the subsequent deglaciation of the Newfoundland Ice Cap. The striae collected from areas south of Eagle Mountain (blue striae) and north of Taylors Brook (green striae), along with their respective age relationships correspond with the established regional model described by Taylor and Vatcher, (1993) (*see* Figure 4). This model is indicative of northeast flow from the Topsails (located south of Hampden) and southern portion of the Long Range Mountains, followed by easterly flow from the east side of the Long Range Mountains.

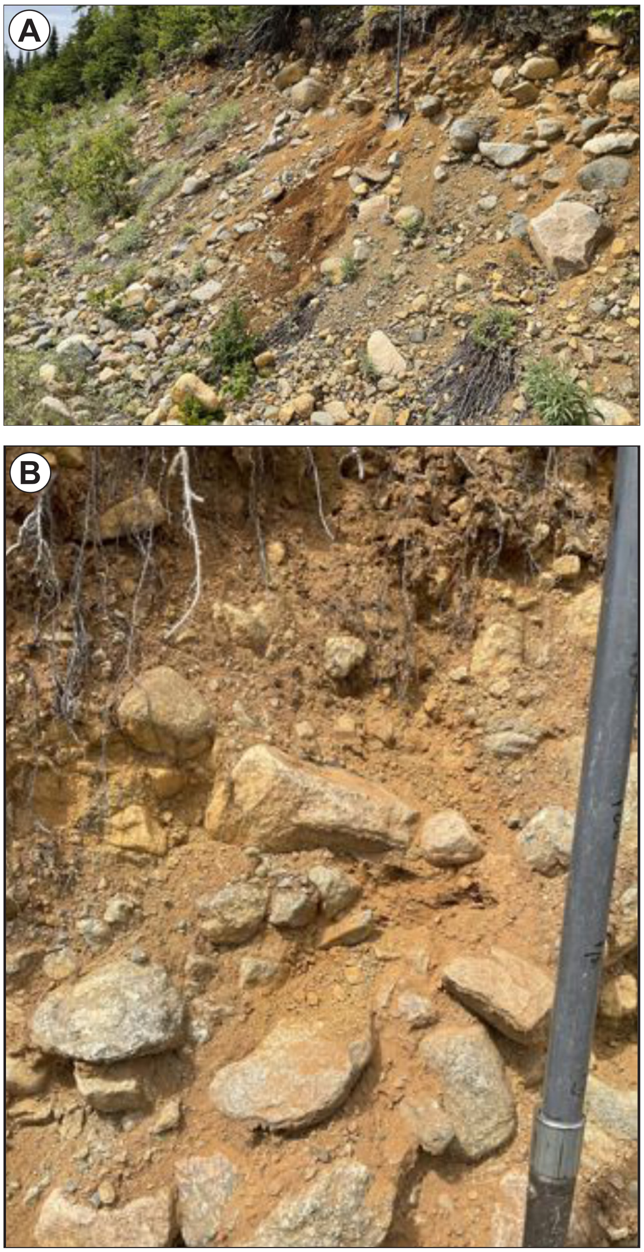

Plate 5. *Photo from site 24JO135,* see *Figure 1 for location. A) Looking south along a 3-m high exposure of boulder gravel; B) Close up of boulder gravel that is clast supported in places but has a matrix of coarse-grained sand to granule gravel. Clasts are of local lithologies of granite, granodioritic gneiss of the Long Range Gneiss Complex.*

The lowest stratigraphic diamicton is identified at Site 24JO157 and is interpreted as a basal subglacial till, likely emplaced by the early northeast flow or easterly flow that moved over the Deer Lake Basin incorporating red sandstones derived from the Deer Lake and Anguille groups, giving the matrix its reddish-brown colour. The angularity of clasts observed within this unit are indicative of short transport distances of up to a few kilometres. The most recent flow was southerly and was topographically controlled, resulting in a range of flows from southwest to southeast (Taylor and Vatcher, 1993). At site 24JO157, the upper unit of light-olive brown diamicton is associated with the youngest (most recent) southerly flow from the Long Range Mountains, as indicated by the Grenvillian granitoid rocks contained within the till, which are derived from north of the site.

The identification of two stratigraphic tills raises a number of research questions including: What is the spatial distribution of the lower till? Is it exposed at the surface? How thick is the lower till? Which phase of ice flow (northeast or easterly flow) is responsible for the deposition of the lower till? Further excavation of the site using trenching techniques would facilitate a broader exposure, allowing clast fabric analysis to be conducted to determine the ice flow responsible for the deposition of the lower till.

Additionally, striae recorded north of Eagle Mountain (green striae) in the northern half of NTS 12H/14 document a transition from westerly flow, followed by a west-northwest flow to a more northerly flow – trends that have not been previously recorded. Conducting a spatial comparison of striae collected in 2024 with the provincial striation database (GSNL, 2024d) supports evidence for an ice divide on the GNP. This concept aligns with previous suggestions by Grant (1989) and Shaw *et al.* (2006), who proposed that an ice divide extended down the entirety of the GNP during the Late Wisconsinan maximum.

Diverging striae indicate that the ice divide was situated east of Main River north of Eagle Mountain on NTS 12H/14 and was located farther west, south of Eagle Mountain (GSNL, 2024d). Considering the absence of striae between Main River and the coast of White Bay, as well as southwest of Eagle Mountain, additional work is required to refine the understanding and the eastern extent of this divide. It is

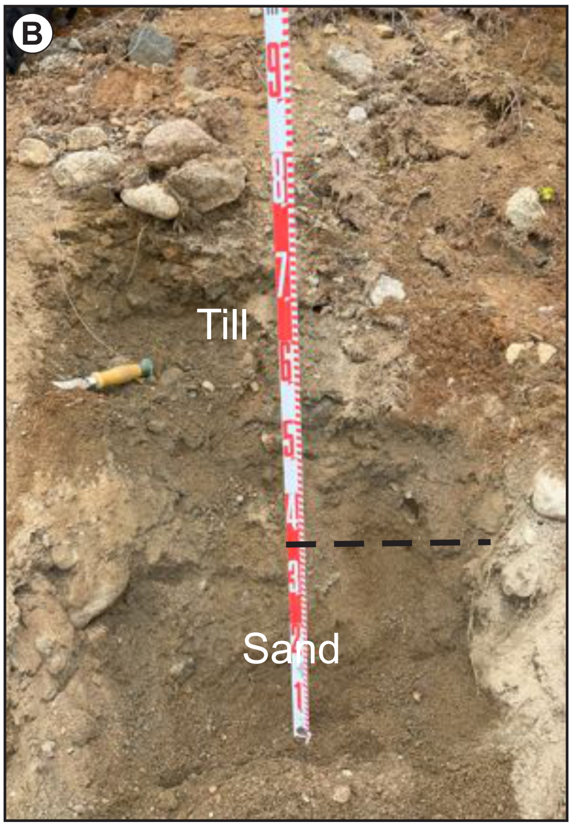

Plate 6. *A 2.5 m section in the back of a burrow pit showing 1.5 m loosely compact light yellowish grey till overlying coarse sand and granual gravel. A) A 2.5 m section in the back of a burrow pit at site 24J0136 showing a 1.5 m loosely compact, light yellowish grey till overlying coarse sand and granual gravel; B) Shows a close-up photo of the undulating contact between the till and underlying coarse sand identified by a yellow box in A; C) A photo of the poorly sorted clast-rich diamicton interpreted as a melt-out till; D) Shows a close up of moderately- to well-sorted, fine- to coarse-grained sand and granual gravel.*

important to note that glacial ice is dynamic and its characteristics such as thickness, pressure and temperature regimes, location of divides along with the extent of the ice margin, change in response to deglaciation (Benn and Evans, 2010).

As the ice cap thinned, ice flow became more topographically controlled, resulting in subtle changes from westerly to west-northwest flow in the north towards Pond River into Parsons Pond and potentially St. Paul's River and Eastern Brook into St. Paul's Inlet. Topographic control is also documented by slight changes in easterly flow to east-southeast on the east side of the GNP, particularly those striae following Little Brook River valley that flows into Sops Arm. There is a 17 km gap, in NTS 12H/14 north of Eagle Mountain, between known striations that record a westerly flow toward the Gulf of St. Lawerence and those that record an easterly flow into White Bay. Thus, refining the position of the ice divide and determining its extent and relative age relationships will be the focus of future field work. These questions can be answered through additional striation mapping east of the LITL in NTS 12H/14, along with the area southwest of Eagle Mountain.

In the area north of Eagle Mountain, only one stratigraphic unit of diamicton has been identified. The poorly-sorted, massive, silty sand displays considerable variation in its characteristics indicating potential subglacial or melt-out deposition, as described previously. In the area north of Eagle Mountain it is common to observe subglacial basal till adjacent to melt-out till, however, stratigraphic relationship between the two has not yet been established. The distinction between these two depositional environments is important for mineral exploration as subglacial deposition is directly related to ice movement and the resulting tills are more representative of the underlying bedrock and serve as optimal sampling medium. No prior studies in this area have investigated the relationship between subglacial basal till and ice flow direction indicated by striae. This could be completed by undertaking clast fabric analysis in areas of known basal till.

The pattern of ice retreat identified by Dalton *et al.*, (2020) suggests White Bay and the low-lying areas of the Deer Lake Basin were the first to be deglaciated, while ice remained in the high elevations of the Long Range Mountains. This pattern is supported by the youngest southerly flow originating from the Long Range Mountains. Further, the spatial pattern of subglacial basal tills adjacent to melt-out till implies that the retreat pattern was irregular and not uniform; as basal tills are deposited by actively flowing ice whereas melt-out till deposited during periods of glacial retreat or stagnation during which the ice melts passively in place (Benn and Evans, 2010). Consequently, low lying areas within the Long Range Mountains would have been have been among the first to be deglaciated. While no age data is currently available to confirm this hypothesis, cosmogenic dating of boulders and bedrock within the region could significantly refine the understanding of the timing and pattern of deglaciation.

During deglaciation, sand and gravel deposits are formed by meltwater draining the receding ice front. These sediments are typically identified as a thin glaciofluvial (sand and gravel) veneer over till, hummocks or esker ridges within valleys. However, site 24JO136 records approximately 150 cm of loosely compact light brownish-grey silty sand overlying crudely stratified, moderately to well-sorted fine-to coarse-grained sand and granule gravel. The location of this site's of 460 m along a valley slope suggests that this could be a stratified ice-contact deposit. Additionally, coarser gravel deposits located 350 m away are interpreted as an ice-contact hummock complex. The presence of till overlying deglacial sand and gravel indicates that either the till was remobilized after deposition or it may suggest a brief readvance of ice during the Younger Dryas, a phenomenon that was documented elsewhere on the GNP (Grant, 1989a; Liverman *et al.*, 2000; Putt *et al.*, 2010). To address this research question, excavation of this site is necessary, so that clast fabric analysis can be completed on the till unit to determine its depositional environment. Moreover, detailed mapping is essential to identify subtle moraine ridges not identified on the existing 10 m digital elevation model, as these features could signify a readvance.

IMPLICATIONS FOR MINERAL EXPLORATION

An improved understanding of the ice-flow history, pattern of ice retreat and the resulting landscape morphology will refine drift-prospecting strategies along the Long Range Mountains. There are several important considerations:

- The area has had a complex ice-flow history, reflecting shifting ice divides during the last glacial advance and retreat. The recently discovered west-northwest striae in the northwest part of NTS 12H/14 show divergent flow compared to the east-southeast flow in the southeast part of the map area, as a result, care must be taken when inferring the source of mineralized dispersal trains within the area.

- Areas characterized by till containing poorly-sorted sediment that includes silt and clay and striated and faceted clasts representing local lithologies are excellent sediments for conducting drift-prospecting surveys. Such sediments, deposited in direct contact with active ice are optimal sampling units. Poorly sorted, compact subglacial tills tend to accurately represent local, underlying bedrock, whereas supraglacial melt-out sediment may contain clasts that have travelled longer distances, in addition the presence of meltwater may have removed the silt and clay material obscuring the geochemical signatures of nearby sources.

- Areas of thin till are favourable for conducting drift prospecting studies as the till is likely deposited by the most recent or last ice-flow event. Understanding the relationship between till and the direction of the last ice-flow event responsible for its deposition allows for geochemical responses within the till to be more accurately sourced.

- In mountainous terrain, till may be obscured by glaciofluvial, fluvial sediments or organic deposits, complicating identification and sampling efforts.

- At least two stratigraphic units and multiple ice-flow phases record multiple deposition and erosional events. In areas characterized by thick till, such as the Deer Lake Basin it is important to determine which ice-flow event was responsible for the deposition. It is critical to note that multiple depositional events can be recorded in a single sediment section and the uppermost sediment may not necessarily reflect the underlying bedrock. Conducting geochemical and textural analysis of samples taken at regular vertical intervals throughout thick till sections can facilitate the identification of multiple units and enhance the understanding of the region's glacial history.

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