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QUATERNARY GEOLOGY OF THE BOTWOOD (NTS 2E/3) MAP AREA

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ABSTRACT

Detailed surficial mapping, combined with investigations of the ice-flow history, the glacial dispersal of material, and the sea-level history, has yielded the following initial results for the Botwood map area.

Till is the most dominant surficial deposit within the study area, accounting for 30 percent of all surficial deposits. It was deposited by either an easterly or northerly ice flow. There are considerable glaciofluvial deposits within the study area, including areas of potential aggregate sources. The highest stand of sea level is 58 m asl, with subsequently lower stands at 42, 35 and 11 m asl. As well as the potential for aggregate sources and drift prospecting, there are significant areas of organic material (e.g., peat) that could be commercially exploited.

INTRODUCTION AND OBJECTIVES

Till is normally sampled when using drift-prospecting methods in mineral exploration. A detailed knowledge of the distribution and the type of till deposits will make drift prospecting in the area more efficient. Establishing the regions ice-flow history and subsequent dispersal of material within the study area will aid in the tracing of geochemical anomalies and mineralized boulders to their bedrock sources. Glaciofluvial deposits are important sources of aggregate. This study should result in greater knowledge of the extent of known sources, as well as locating new sources. Glaciomarine deposits are present as a result of higher stands of sea level and may contain placer deposits as they are known to do offshore (Emory-Moore, 1991).

The main objectives of the project are; to produce an accurate 1:50 000 scale-map of the surficial geology; to determine the ice-flow history, and to investigate the regions sea-level history. The map, based on both airphoto interpretation and field reconnaissance, will provide information on the distributions of till, glaciofluvial, glaciomarine and postglacial deposits. This map could also be used for identifying areas suitable for commercial exploitation of peat, agriculture, and liquid-waste disposal sites.

LOCATION AND ACCESS

The Botwood map area (NTS 2E/3) is located at the head of the Bay of Exploits (Figure 1), and extends from Bishops Falls in the southwest to Lewisporte in the northeast. The map area covers approximately 1000 km^2, of which 900 km^2 is land. Access to the area is generally good via paved highway and logging roads. The areas south of the Trans-Canada Highway and north of Norris Arm are less accessible.

PHYSIOGRAPHY

The topography of the study area is controlled by the relative resistance of the sedimentary and volcanic bedrock to glacial erosion. In areas of less resistant bedrock, the ice has carved out troughs (e.g., through Northern Arm out into the Bay of Exploits, and along the Exploits River through Norris Arm). Elsewhere, the bedrock has been moulded and smoothed by the ice. The northwestern part of the study area is hilly, with maximum elevations of 245 m; it slopes steeply into Northern Arm Brook valley to the south. A rolling plateau extends from the Exploits River to Northern Arm Brook and eastward to Botwood. This plateau is also present on the east side of the Bay of Exploits through Norris Arm and as far north as Laurenceton. The area south of the Trans-Canada Highway has undulating hills, with elevations of over 300 m. The hilly area between Laurenceton and Lewisporte has maximum elevations of 155 m and then slopes toward the north. The coastline of the study area consists of rock cliffs in the north, and as far south as Laurenceton on the east coast and Philips Head on the west coast. Bars have formed on northerly facing headlands at Laurenceton, Northern Arm and Wigwam Point. The rest of the coastline is essentially estuarine, in which mud flats are exposed at low tide.

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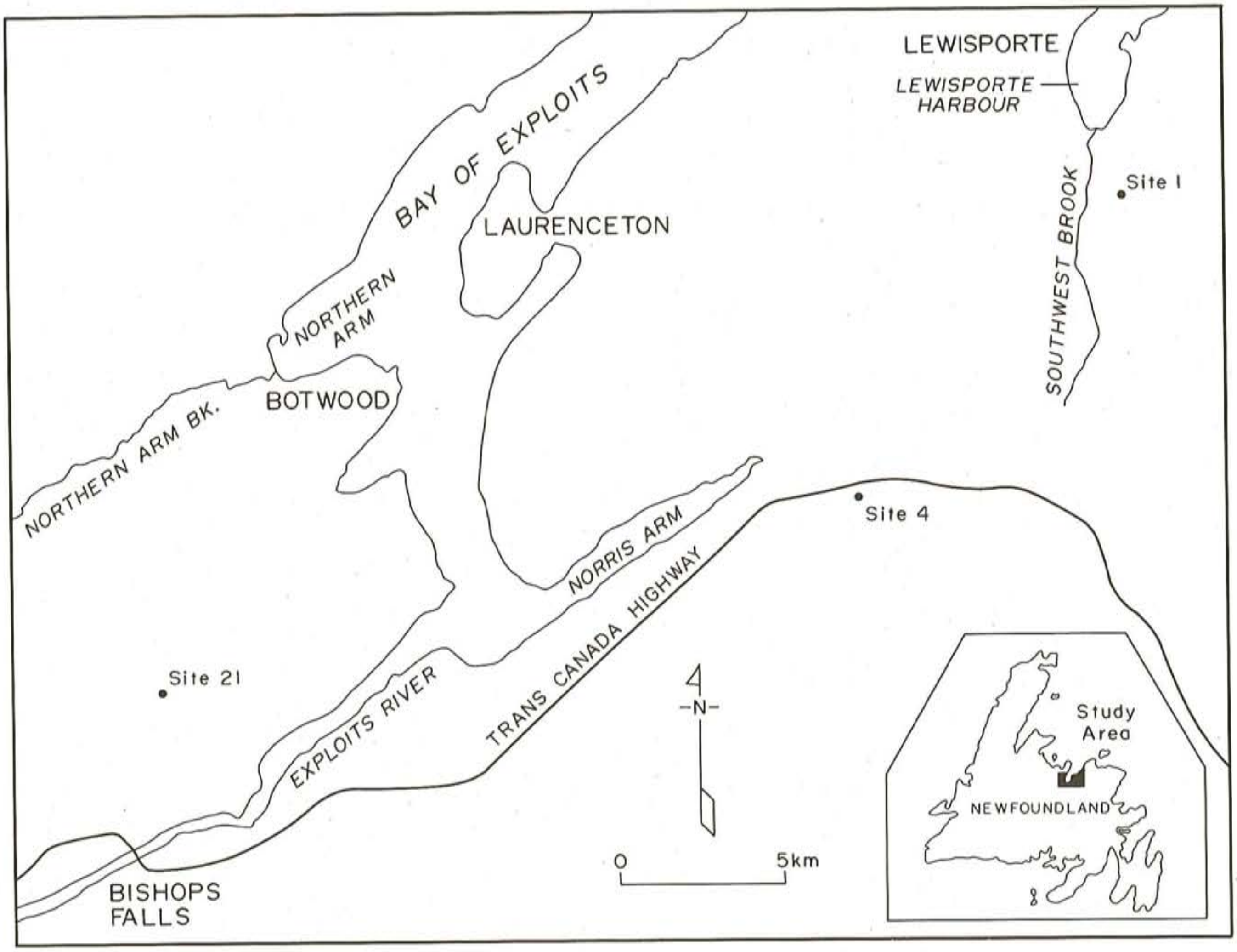


Figure 1. *Generalized location map for the Botwood (NTS 2E/3) map area.*

PREVIOUS WORK

The surficial geology of the study area has been mapped by Kirby *et al.* (1988) at a 1:50 000 scale. This was based on airphoto analysis along with some ground checking. Within the study area, extensive striation mapping has been undertaken (St. Croix and Taylor, 1991). Using this data, St. Croix and Taylor (1991) established a tentative glacial history for the area during the Late Wisconsinan. The first event was an easterly ice flow; this was followed successively by a northeasterly ice flow, a northerly flow, and finally by an easterly flow. This final event was possibly the result of a re-advance of the ice cap during the Younger Dryas (St. Croix and Taylor, 1991).

Quinlan and Beaumont (1981) developed a theoretical sea-level fluctuation model for Atlantic Canada based on crustal warping due to ice loading and placed the study area in Zone C of this model. This zone is on the leading edge of the peripheral crustal bulge, with sea levels below present at the last glacial maximum. As the bulge migrated due to deglaciation, sea levels fell and then rose to present levels. Grant (1980) cited a limit of 49 m above sea level (asl) as the marine limit in the study area. Shaw and Forbes (1991) have produced a sea-level curve for the Cape Freels area to the east of the study area, which suggests that it is in Zone B of the Quinlan and Beaumont (1981) model. Evidence from the Halls Bay area to the west of the study area (Scott *et al.*, 1991) indicates that sea levels were above present during the last glacial maximum and therefore in Zones A or B of the Quinlan and Beaumont (1981) model. Zone B is also on the leading edge of the peripheral depression but experienced sea levels higher than present at the glacial maximum. The sea level progressively fell as the peripheral bulge migration proceeded until it reached a minimum level below present, it then rose to present levels.

METHODOLOGY

Prior to the field season, airphoto interpretation was undertaken, with particular emphasis on geomorphological features that indicate ice-flow direction. These interpretations were later confirmed by field surveys. In the field, all exposed sediment exposures were examined, and clast fabric, lithological, roundness and sphericity were measured; sampling was restricted to areas close to the access roads. Sampling for grain size was also undertaken.

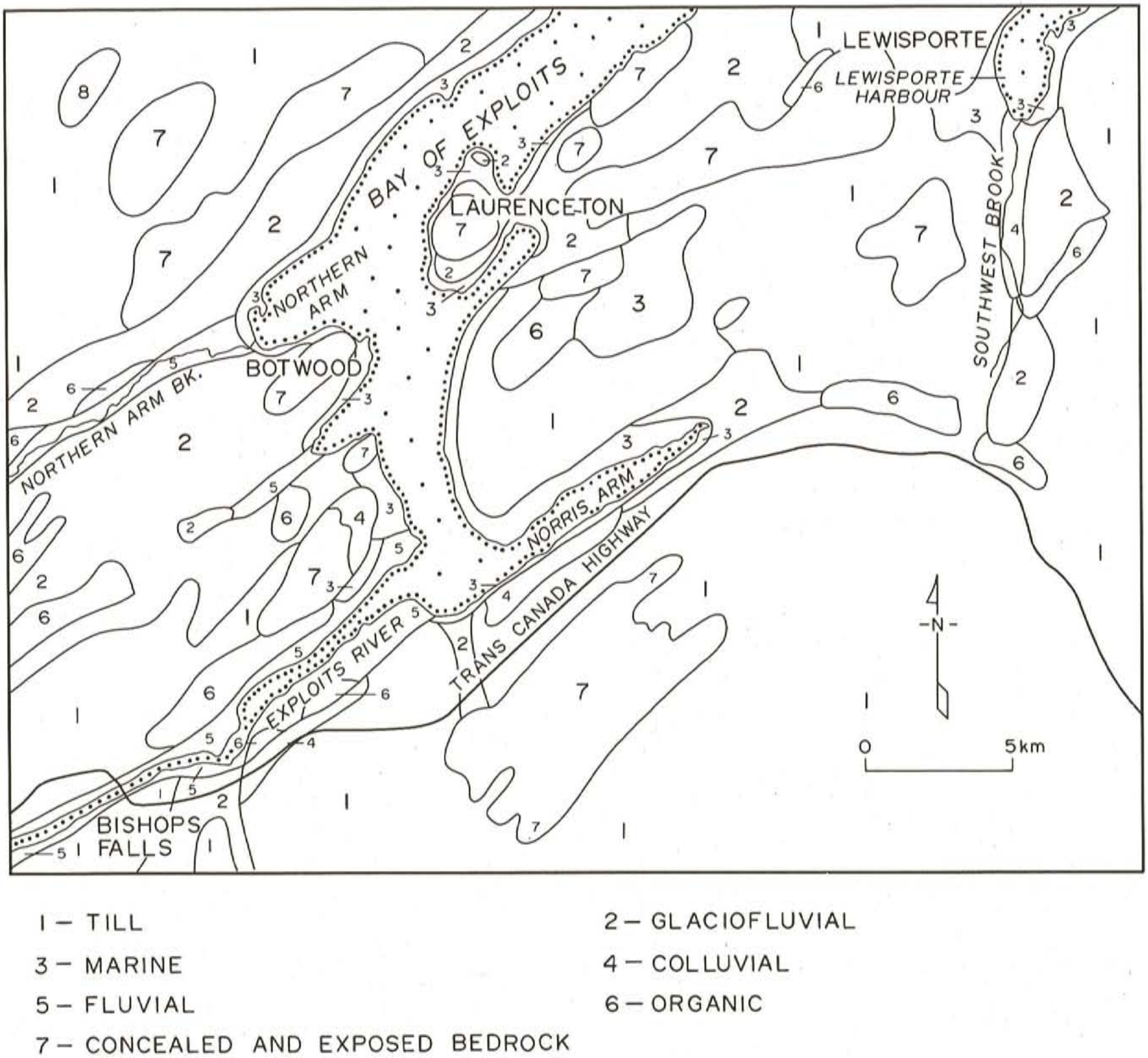


Figure 2. *Simplified surficial geology of the Botwood (NTS 2E/3) map area.*

QUATERNARY GEOLOGY

SURFICIAL GEOLOGY

The surficial sediments are classified into three main groups:

(i) Till, bedrock concealed by till veneers, and exposed bedrock sculpted by glaciation (see Figure 2, Units 1 and 7) are the result of the advance and subsequent retreat of ice sheets. These deposits and landforms are dominant in the areas south of the Trans-Canada Highway, north of Northern Arm Brook valley, and the high ground between Lewisporte and Laurenceton. Glaciofluvial deposits forming deltas, kames and outwash veneers occur in the areas between Exploits River and Northern Arm Brook, east of Norris Arm to the Lewisporte Highway, east of Lewisporte and north of the high ground between Lewisporte and Laurenceton.

(ii) Marine deposits were formed following deglaciation, when the sea advanced across the isostatically depressed terrain. Isostatic rebound and continued ice retreat led to successive lower stands in sea level. Marine deposits consisting of fine sands, silts and clays occur around most of the coastline. They also occur between Exploits River and Northern Arm Brook and between Norris Arm and the high ground between Laurenceton and Lewisporte.

(iii) Postglacial deposits include fluvial, colluvial, and organic sediments. Colluvial deposits are found at several localities, in particular along the south side of Norris Arm. Fluvial deposits are found along Exploits River and along

Northern Arm Brook. Extensive areas of organic deposits occur along the Exploits River as well as in the area between Norris Arm and the high ground between Laurenceton and Lewisporte.

Till: Unit 1

Tills are sediment deposited directly by glacial ice which undergo no significant reworking. It is also the most widespread and has the most variable composition of all glacial and glacigenic sediments (Dremanis, 1988). Throughout the study area (Figure 2, Unit 1) the till is matrix supported (60 percent matrix). The matrix consists of silt and sand and the clasts range in size from pebbles to boulders. Generally, the tills are unsorted, although some units display a moderate degree of sorting resulting from post-depositional reworking by melt water. Within the study area, till occurs in a variety of geomorphological forms; the most extensive being till veneers and eroded till, and cover 30 percent of the study area. Till also occurs as drumlins, flutings, crag-and-tail, and Rogen moraines.

Drumlins are subglacially formed mounds of glacigenic sediment (Lunqvist, 1988). They range from 700 to 1000 m long, 200 to 300 m wide and 50 to 60 m high, and cover less than 5 percent of the study area. Drumlins are found at the head of Lewisporte Harbour, west of Southwest Brook. Lineated till (flutings) are long narrow ridges of glacigenic sediment that form parallel to the ice-flow direction (Boulton, 1976; Lundqvist, 1988). These forms are best preserved on the north side of the Exploits River and are also present south of the Trans-Canada Highway. They are between 3.5 and 4 km long, 130 to 150 m wide and 15 to 20 m high. Within the study area, the flutings indicate a generally northeasterly flow direction and cover less than 5 percent of the study area. Crag-and-tail features consisting of glacigenic sediment deposited on the lee side of a bedrock obstruction (Lundqvist, 1988) are well developed at the head of Lewisporte Harbour. They cover less than 5 percent of the study area and are between 600 and 700 m long, 150 and 200 m wide and 45 and 50 m high. Rogen moraines are common in the area south of the Trans-Canada Highway, and cover less than 5 percent of the study area. These moraines, which form perpendicular to an ice flow (Lundqvist, 1988), are between 200 and 500 m long, 75 to 100 m wide and 15 to 20 m high.

One of the best till exposures is represented by Site 4, south of the Trans-Canada Highway (Figure 1). This is typical of the till in the study area. The exposure, through a dissected hummock, is 2.70 m high. Two units were identified within the exposure. Unit 1 is 1.75 m thick and consists of matrix-supported diamicton containing 30 percent clasts, ranging from pebbles to fine cobbles. The upper surface of the clasts are coated with thin layers of clay and silt. Concentrations of coarser material occur underneath the clasts. The matrix consists of silt to coarse sand and lenses of granules. The contact with unit 2 is gradational. Unit 2 is 0.95 m thick and also consists of matrix-supported diamicton. It contains 35 percent clasts, which are predominately cobbles. Silt and clay coatings occur on the upper surface of the clasts, and coarse material is concentrated underneath. The matrix is poorly sorted and massive, consisting of silt to granules. This upper unit contains larger clasts and a lesser amount of sorting than the underlying unit. Fabric analysis on clasts within the two units showed a strong northwesterly trend for both units (Figures 3 and 4). Thus, ice flow was likely to be to the northwest when the sediment was deposited. The units in this section represent basal tills. This is suggested by the strong fabrics, the moderate degree of sorting within the matrix of Unit 1, and the presence of striated clasts within both units (Dowdeswell and Sharp, 1986; Lawson, 1979). Deposition of multiple basal till units from different levels within the same overriding ice mass has been reported elsewhere (Broster and Dremanis, 1981).

Glaciofluvial Deposits and Landforms: Unit 2

Glaciofluvial deposits consist of well-sorted material ranging in size from fine-grained sand to coarse cobbley gravel. These deposits form various features within the study area including kames, deltas, eskers and veneers that cover 20 percent of the study area (Figure 2, Unit 2). Kames form at the ice margin usually against a bedrock obstruction, as a terrace of stratified glaciofluvial sediment. Deltas form where glaciofluvial meltwater flows into standing water, high stand of sea level in this area. They form isolated mounds or are part of a kame. Eskers form subglacially, they are deposited by meltwater flow and form long sinuous ridges. Glaciofluvial veneers or outwash deposits are thin layers of glaciofluvial sediment and occur extensivley in the area between Exploits River and Northern Arm Brook. They are generally 1 to 2 km thick and form areas up to 4 km^2.

A typical kame deposit is exposed in a 5.25 m section on the east side of Southwest Brook, and is currently being exploited for aggregate. The section consists of fining-upward channel sequences of cobbles to silts. The sand beds are generally well sorted and stratified, and contain ripples, which indicate a northerly paleocurrent direction. Some of the finer beds are deformed by loading induced from overlying coarser beds. Channel-fill and bank-collapse sequences marked by poorly sorted gravel and diamicton beds with weak stratification are common in the southern part of the exposure.

Deltaic deposits within the study area are divided into two groups: proximal deltaic sediments and distal deltaic sediments. Proximal deltaic sediments such as those at Laurenceton, tend to be slightly coarser and less well sorted than distal deltaic sediments, such as those that occur along Northern Arm Brook valley. Both sediment types consist of stratified sand to cobbles, with the beds dipping steeply northeastward into Bay of Exploits.

Glaciofluvial activity also forms meltwater channels, which are useful in reconstructing paleocurrent flow directions (Figure 5), as well as being indicators of the location of glaciofluvial deposits. The complex of meltwater channels above Northern Arm Brook supplied the sediment that formed the kames and deltas on the northern side of

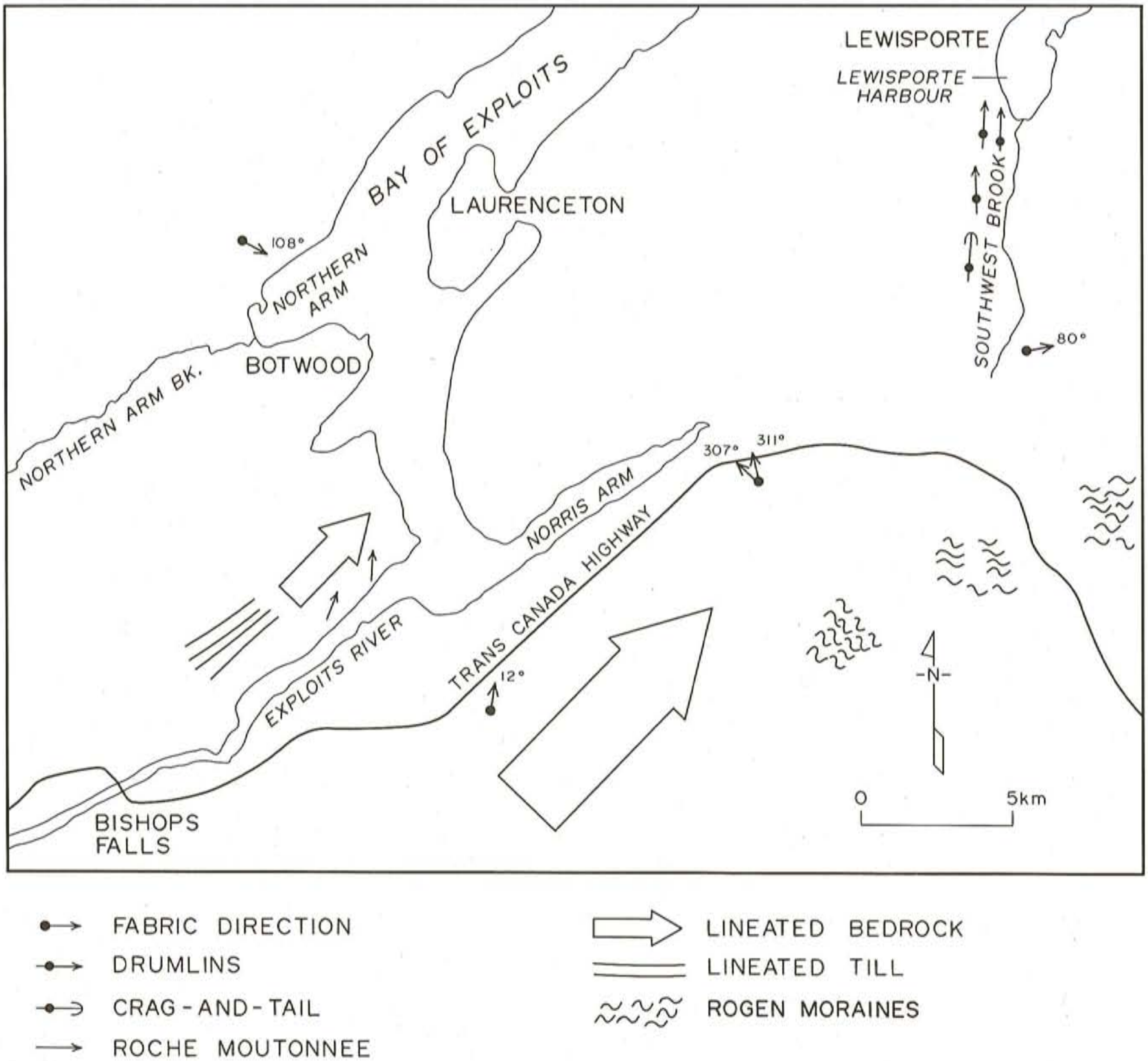


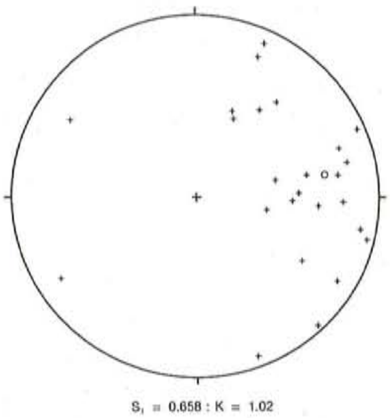
Figure 3. *Ice-flow indicators and ice-flow directions in the Botwood area.*

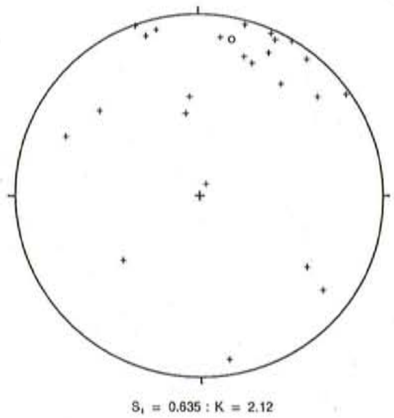
Northern Arm Brook valley. These channels are a maximum of 1.5 km long and 50 m wide and occur at elevations between 45 m and 120 m asl.

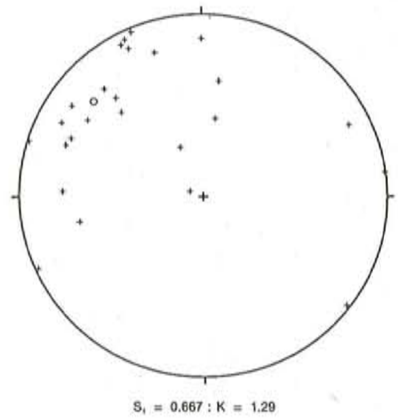
Glaciomarine Landforms and Deposits: Unit 3

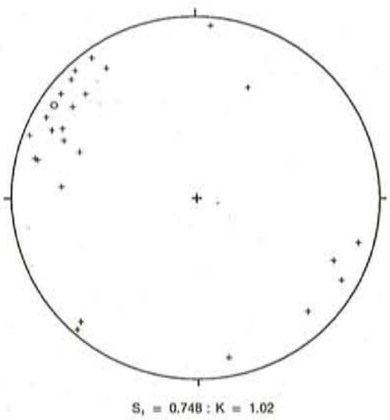
Glaciomarine deposits (Figure 2, Unit 3) in the study area consist of sorted and stratified fine sands, silts and clays, and typically form veneers and blankets. Elevated wave-cut terraces also occur throughout the study area. Elevated beach deposits do not occur within the study area and these glaciomarine features account for 10 percent of the surficial deposits which can be extremely thick.

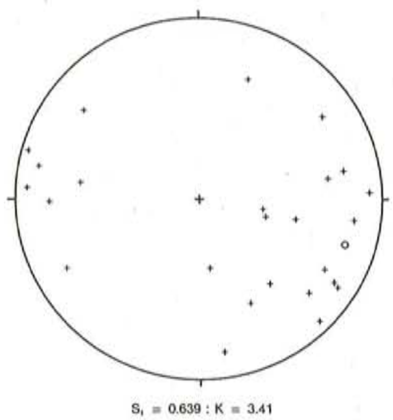
Site 21 is a typical section (Figure 1), located west of the Botwood highway. The section is 16 m high. The basal unit, consisting of glaciofluvial gravel deposits, is overlain by 3 to 6 m of glaciomarine–marine stratified fine sand and coarse silt. The beds display a range of deformation structures including reverse faulting, rotational slumping, and recumbent drag folds. Above this are similar glaciomarine deposits, which show a much lower degree of disturbance than the underlying sediments. These sediments are deltaic bottomsets formed when sea level stood at 42 m. These deposits consist mainly of rhythmically bedded silts and display a wide range of deformation structures (Brodzikowski and van Loon, 1991).

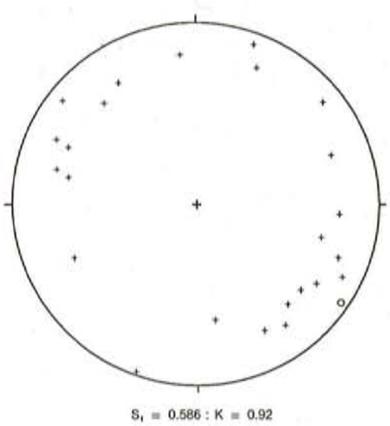


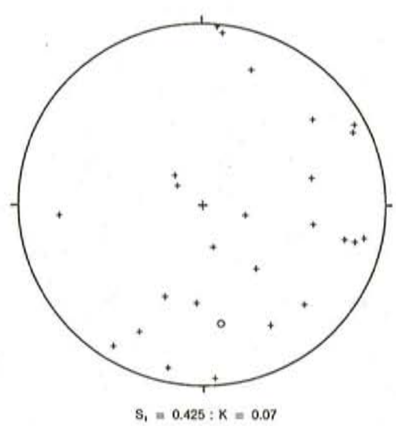


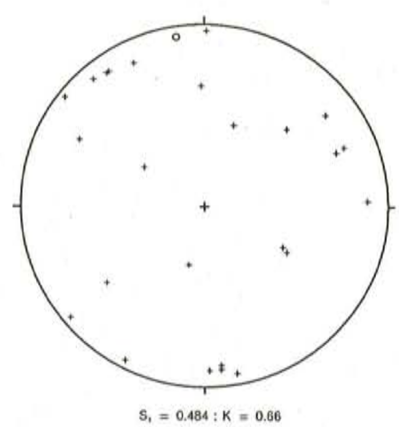












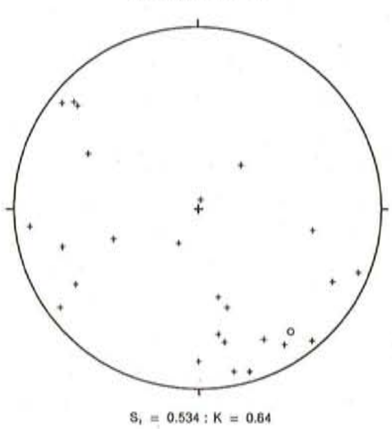


Figure 4. *Clast fabric plots, S_1 and K-values of the tills in the Botwood region.*

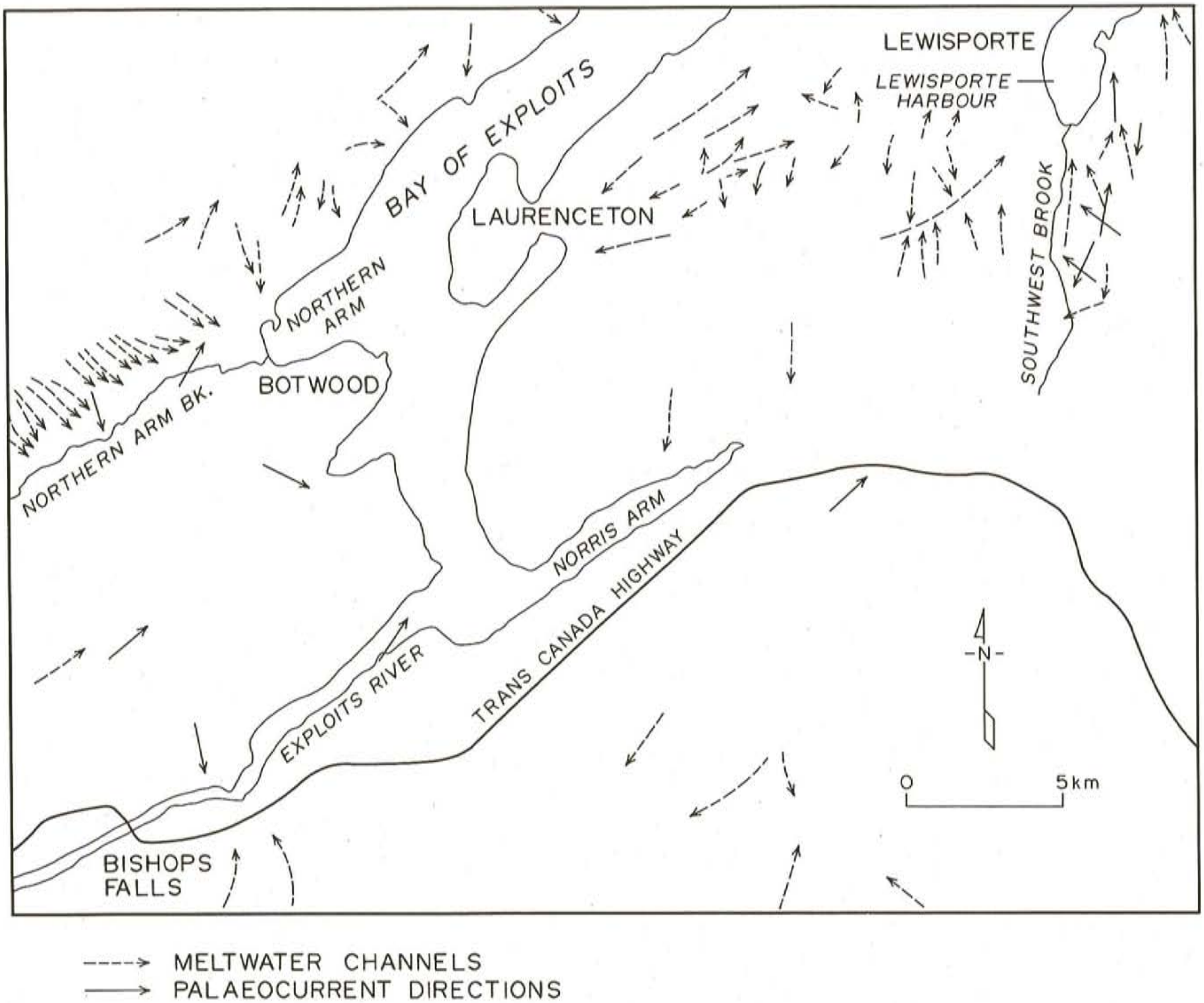


Figure 5. *Palaeocurrent directions and orientation of meltwater channels.*

POSTGLACIAL LANDFORMS AND DEPOSITS

Colluvial Deposits: Unit 4

Colluvial material (Figure 2, Unit 4) consists of mainly coarse-grained bedrock-derived materials. It is the result of postglacial weathering and is usually present on steep slopes, forming veneers and aprons. Colluvial diamictons account for less than 5 percent of the surficial sediment and occur to the north of Northern Arm Brook valley, on the south side of Norris Arm, and to the south of the Trans-Canada Highway.

Fluvial Deposits: Unit 5

Fluvial deposits (Figure 2, Unit 5) are associated with modern stream channels and vary in grain size from silt and clay to bouldery gravel. They usually form terraces and plains as a result of higher river base levels. These occur at elevations of between 10 and 15 m and cover 5 percent of the study area.

Organic Deposits: Unit 6

Organic terrain (Figure 2, Unit 6) consists of poorly drained accumulations of peat moss and other organic material that cover 10 percent of the study area. The deposits at Botwood, which are currently being exploited, are between 1.5 m and 8 m thick. These deposits occur in areas of poor drainage, commonly overlying till and marine deposits, which have a high silt content and are thus impermeable and are poorly drained.

ICE-FLOW HISTORY

During the 1992 field season, striae, which are used as indicators of ice-flow direction (St. Croix and Taylor, 1991) were not found. Ice-flow directions are established from geomorphological features and fabric analysis (Figure 4). Drumlins, flutings and crag-and-tail all form parallel to ice flow and within the study area they indicate either a north–

south trend or a northeast-southwest trend. Rogen moraines form perpendicular to ice flow and indicate either north–south trends of northeast–southwest trends. Preferential bedrock erosion has also exerted an influence; this is evident in the northeasterly trend exhibited by whalebacks, lineated bedrock and rôche moutonées. The whalebacks and rôche moutonées occur on the sedimentary rock of the Botwood Group (Dean, 1977); their northerly and northeasterly orientation reflects the strike of the rock. The lineated bedrock occurs in the mafic rocks of the Mount Peyton Pluton.

Nine till exposures were examined in detail and the orientation and dip of the a-axis of 25 clasts within each unit were measured. The data were plotted on stereograms (Figure 5): normalized eigenvalues and K-values were calculated using Stereo™ for the Apple Macintosh computer (MacEachran, 1989). Normalized eigenvalues, S1, S2, S3, are a measure of the degree of clustering of data around the respective eigenvectors: where the eigenvector V_2 is perpendicular to the eigenvectors V_1 and V_3. The K-value is a numerical value that describes the type of distribution of a sample (Woodcock, 1977). If K is greater than one then the fabric has a cluster distribution; if K is less than one then it forms a girdle distribution. The fabrics, that most accurately indicate flow direction are those that have an S_1 value greater than 0.6 and a K-value greater than 1. Out of the nine till fabrics analyzed, only five met the criteria stated above (Figure 5). Three of these fabrics indicate a northerly ice-flow direction and two indicate an easterly ice-flow direction (Figure 4).

Two main ice-flow directions are evident in the study area; an easterly flow and a northerly flow. This is in general agreement with the model proposed by St. Croix and Taylor (1991). Unlike the striae evidence (St. Croix and Taylor, 1991), it is not possible to assign a relative age to the ice-flow directions from clast fabrics, although they do indicate, which ice-flow directions deposited till in the study area. Detailed lithological analysis is currently in progress, the result of which should yield further information concerning ice-flow direction as well as possible estimates of transport distances.

SEA-LEVEL HISTORY

Based on the evidence of depositional features, such as deltas and marine terraces, a history of sea-level change for the area has been established. A high stand of sea level occurred at 58 m, based on the height of the delta at Laurenceton (Plate 1), which is considerably higher than the estimate of Grant (1981). As isostatic rebound continued, and relative sea level fell, further stands were recorded at 42, 35, and 11 m; these heights were measured using an altimeter. When available ^{14}C dates of shells, peat and wood recovered from the Botwood and Exploits rivers area will enable the age of these stands to be determined. Shells of *Hiatella arctica*, were found in marine ooze overlying stratified clays at an elevation of 15 m. Peat and wood were found overlying marine silts and clays at an elevation of 11 m. These are directly related to the stand of sea level at 11 m. The shells are related to a higher stand of sea level.

Plate 1. *The delta at Laurenceton, indicating that the high stand of sea level in the area was 58 m.*

The study area is either Zone A or B of the model proposed by Quinlan and Beaumont (1981). No offshore evidence exists to indicate whether sea level fell below its current level.

ECONOMIC IMPLICATIONS

MINERAL EXPLORATION

Previous mineral showings in the Botwood region are confined to a single occurrence of copper (chalcopyrite) mineralization north of Northern Arm Brook valley (Andrews, 1979), and several newly discovered gold showings associated with vein mineralization and arsenopyrite (Tuach, 1992). These recent discoveries of gold, coupled with interest in offshore-placer deposits (Emory-Moore, 1991), currently represent the main focus of mineral exploration in the region. Till, as well as the soil and stream sediment, is sampled during mineral exploration. Detailed mapping of all surficial sediment thus enables selection of till outcrops, hence maximizing sampling efficiency. The majority of the till exposures in the region are either veneers or areas of eroded till. As a result, till deposits are not thick, generally between 1 and 2 m. Surface reworking is confined to the zone of pedogenesis (soil formation), and the till beneath this zone is generally homogenous texturally and lithologically and representative of the deposit as a whole. Trenching is therefore not required to obtain a representative lithological or geochemical sample. There are two main ice-flow directions represented by the till: an easterly flow and a northerly flow. Easterly flowing ice will have traversed areas to the west where showings of chalcopyrite, pyrite, sphalerite, pyrrhotite, and gold have previously been documented (Hibbard, 1983; Tuach, 1992). The provenance of the northerly flowing ice includes areas where showings of magnesite, chalcopyrite, bornite, gold and arsenopyrite have been recorded (Meyer *et al.*, 1984). Thus, mineralization evident in sampling of the tills within the study area may indicate transport from showings to the south and west. The tills are dominated by silt and sand matrixes (60 percent). So, relatively small samples of matrix material will give representative results, as mineralogy within a single till unit is dependent on matrix texture (Dremanis and Vagner, 1972). The tills are not laterally homogenous (both lithologically and mineralogically); this implies very local derivation, which is ideal for mineral exploration.

The sea-level history of the area is important in terms of locating onshore placer deposits and assessing the degree of surface reworking and modification of the original geochemical signature. Most of the diamicton below the marine limit of 58 m asl is covered with fine-grained marine sediment. Rare surface exposures show limited reworking. The rapid recession of the marine waters (Shaw and Forbes, 1990) indicates that little opportunity for reworking or surficial modification of the tills existed. Placer exploration in the offshore area has been conducted recently (Emory-Moore,1991), although no showings have been reported. The onshore glacial sediments in the Botwood area, however, consist of silts and clays, which are too fine grained to contain placer deposits (Emory-Moore, 1991).

AGGREGATE SOURCES

Aggregate resources in the region were documented by Kirby and Ricketts (1983). Several aggregate sources are already being exploited in the study area including kames, eskers and deltas west of the Botwood highway, kames and deltas at Northern Arm and kames east of Southwest Brook. The material is generally coarse, ranging from sand to boulders, with variable degrees of sorting. The deltaic deposits to the west of the Botwood highway are well sorted, ranging from granules to small pebbles. The kame deposits, less than a kilometre farther north, are very poorly sorted, with the material ranging from sand to boulders.

There is a potential source of aggregate deposits in the deltaic deposits along the Northern Arm Brook valley (Kirby and Ricketts, 1983). These deposits are a minimum of 20 m thick and cover an area of approximately 4 km^2. A second source of aggregate is located to the north of Laurenceton. This kame deposit is 60 m asl, a minimum of 20 m thick and encompasses approximately 5 km^2.

ENVIRONMENTAL GEOLOGY AND LAND USE

The only area that may have potential use as arable agricultural land is the flat ground between Exploits River and Northern Arm Brook valley. This area is presently being used for pastoral agriculture. The surficial deposits consist of a glaciofluvial veneer overlying marine silts and clays or till. This stratigraphy results in well-drained conditions, and podzols and Brunisols are developed.

There is one potential area for liquid waste disposal: the area of low relief north of Norris Arm. This impermeable material would prevent toxic waste from any disposal area from entering the local water table. Areas underlain by till or glaciofluvial sediments are not suitable for liquid waste disposal, due to their high permeability. Much of the local water supply is obtained from shallow surficial aquifers.

The area north of Norris Arm also appears to be suitable for commercial production of peat. Extensive deposits of organic material are present (>2 km^2). However, the lack of overland access into the area has precluded examination on the site. The interpretation is consequently based entirely on airphoto analysis. Access for the region has to be improved and on-site investigations conducted before the area could be developed. Peat is already being commercially exploited at Bishops Falls. The peat is fibrous and has a variety of economic uses including adsorbents and horticultural products.

CONCLUSION

During the Late Quaternary the study area was subject to at least two ice-flow events: an easterly ice flow and a northerly ice flow. This is based on sedimentological and geomorphological evidence. The ice-flow history is far more complex that that shown by the striation record (St. Croix and Taylor, 1991).

As deglaciation progressed, large amounts of water were released carving meltwater channels and depositing sediment. These deposits, which are essentially sorted sands and gravels, are important sources of aggregate. In the study area, several sites are currently being exploited and several other potential sites exist.

As the ice retreated, sea level in the study area was above present. The high stand occurred at 58 m asl; further stands were recorded at 48, 35, and 11 m asl. At this time, deltaic sediments and marine clays and silts were deposited. Due to a rapid fall in sea level from the high stand, the amount of reworking of the tills below 58 m was minimal.

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REFERENCES

Andrews, K.
1979: Mineral occurrence map of Sandy Lake (12H) map sheet. Newfoundland Department of Mines and Energy, Mineral Development Division, Map Number 80-4.

Boulton, G.S.
1976: The origin of glacially fluted surfaces: observation and theory. Journal of Glaciology, Volume 17, pages 287-310.

Brodzikowski, K. and van Loon, A.J.
1991: Glacigenic sediments. Developments in Sedimentology, 49, Elseveir, New York, 674 pages.

Broster, B. and Dremanis, A.
1981: Deposition of multiple lodgement till by competing glacial ice flows in a common ice sheet: Cranbrook, British Columbia. Arctic and Alpine Research, Volume 13, pages 279-299.

Dean, P.L.
1977: Geology of the Botwood map sheet (2E/03). Newfoundland Department of Mines and Energy, Mineral Development Division, Map Number 77-10.

Dowdeswell, J.A. and Sharp, M.J.
1986: Characterisation of pebble fabrics in modern terrestrial glacigenic sediments. Sedimentology, Volume 33, pages 699-710.

Dremanis, A.
1988: Tills: Their Genetic Terminology and Classification. *In* Genetic Classification of Glacigenic Deposits. *Edited by* R.P. Golthwait and C.L. Matsch. A.A. Balkema, Rotterdam, pages 17-83.

Dremanis, A. and Vagners, U.
1972: The effect of lithology upon the texture of till. *In* Research Methods in Pleistocene Geomorphology. *Edited by* A. Falconer and E. Yatsu. Geulph Symposium on Geomorphology, Geulph, Ontario, pages 66-82.

Emory-Moore, M.
1991: Gold placer potential of the northern Newfoundland Shelf. Contract Report for Atlantic Geoscience Centre, C-CORE Contract Number 91-C7, 8 pages.

Grant, D.R.
1980: Quaternary sea level change in Atlantic Canada as an indication of crustal deleveling. *In* Earth Rheology, Isostacy and Eustacy. *Edited by* N.A. Morner. John Wiley and Sons, pages 201-214.

Kirby, F.T. and Ricketts, R.J.
1983: Aggregate resource map, Botwood (2E) mapsheet. Newfoundland Department of Mines and Energy, Mineral Development Division, Map Number 83-13.

Kirby, F.T., Ricketts, R.J. and Vanderveer, D.G.
1988: Surficial geology map of the Botwood (2E/3) mapsheet. Scale 1:50 000. Newfoundland Department of Mines and Energy, Mineral Development Division, Map Number 88-156.

Lawson, D.E.
1979: A comparison of the pebble orientations in ice and deposits of the Matanuska Glacier, Alaska. Journal of Geology, Volume 87, pages 629-645.

Lundqvist, J.
1988: Glacigenic processes, deposits and landforms. *In* Genetic Classification of Glacigenic Deposits. *Edited by* R.P. Golthwait and C.L. Matsch. A.A. Balkema, Rotterdam, pages 3-16.

MacEachran, D.B.
1989: Stereo™, the Stereographic projection program for the Macintosh Computer. Distributed by Rockware Inc., Wheat Ridge, Colarado, U.S.A.

Meyer, J., Tomlin, S. and Green, R.
1984: Mineral occurance map of Gander Lake (2D) mapsheet. Newfoundland Department of Mines and Energy, Mineral Development Division, Map Number 84-45.

Quinlan G. and Beaumont, C.
1981: A comparison of observed and theoretical postglacial relative sea levels in Atlantic Canada. Canadian Journal of Earth Sciences, Volume 18, pages 1146-1163.

Scott, S., Catto, N.R. and Liverman, D.G.E.
1991: Quaternary marine deposits of the Springdale–Hall's Bay area, Newfoundland. Atlantic Geology, Volume 27, pages 181-191.

Shaw J. and Forbes, D.F.
1990: Relative sea level change and coastal response, northeast Newfoundland. Journal of Coastal Research, Volume 6, pages 641-660.

St. Croix, L. and Taylor, D.M.
1991: Regional striation survey and deglacial history of the Notre Dame Bay area, Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 91-1, pages 61-68.

Tuach, J.
1992: List of gold occurances on the Island of Newfoundland. Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File NFLD 2188.

Woodcock, N.H.
1977: Specification of fabric shapes using an Eigenvalue Method. Geological Society of America Bulletin, 88, pages 1231-1236.