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QUATERNARY GEOLOGY OF THE SPRINGDALE MAP AREA (12H/8)

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Terrain Sciences

ABSTRACT

The Springdale area is located in north-central Newfoundland (NTS 12H/8). The landscape and surficial deposits of the area have been strongly affected by the last glaciation. Ice flow over the south and west of the map area involved a single major flow, from the Topsails, parallel to the major valleys converging on Hall's Bay. Close to the coast, a two-phase ice-flow history is found, in which the initial flow was parallel to Hall's Bay (northeasterly), followed by a subsequent flow toward the bay. In coastal and low-lying areas, much of the sediment was deposited by marine processes during periods of raised postglacial sea level. Inland, a thick till cover was deposited mainly by a combination of basal melt-out and supraglacial melt-out processes. Much of the surface sediment has been modified by meltwater. Several sites show multiple diamictons, and these are interpreted as evidence of a late re-advance of Late Wisconsinan ice. Ice-wedge casts in the Indian Brook valley indicate a periglacial climate following initial deglaciation, possibly related to this re-advance.

INTRODUCTION

The Springdale map area (NTS 12H/8) is located in north-central Newfoundland (Figure 1). It is an area of moderate interest with regard to mineral exploration; the pulp and paper industry is also active in the area, and considerable reforestation takes place. A knowledge of the physical properties and distribution of surficial sediment, as well as the regional Quaternary geological history is important in using drift-exploration techniques, in locating groundwater resources, in the siting of waste-disposal sites, in civil engineering work, in planning reforestation, in soil mapping, and in land-use planning.

BEDROCK GEOLOGY

The bedrock geology of the 12H/8 map area was mapped by Dean (1977), Kean (1977), Hibbard (1983), Swinden (1987), Coyle and Strong (1987), and Bostock (1988). The bedrock is dominated by the Silurian Springdale Group, which outcrops over most of the central part of the study area (Figure 2). It consists of subaerial volcanic and clastic rocks including basaltic and andesitic flows, pyroclastic rocks, silicic ash-flow tuffs, rhyolite domes, volcanic-derived debris flows and breccias, and fluvial red sandstones and conglomerates (Coyle and Strong, 1987). The northwestern boundary of the Springdale Group is formed by the northeast-trending Lobster Cove—Chanceport fault, and by the Topsails Granite. The Catchers Pond Group (intermediate to felsic volcanic rocks) is exposed between the parallel Lobster Cove and Green Bay faults (Kean, 1977). Northwest of the Green Bay fault, the Mic Mac Lake group consists of subaerial silicic volcanic and pyroclastic rocks, associated with minor sandstone and conglomerate. It is intruded by the Burlington Granodiorite (Hibbard, 1983, 1989). The area around Indian Pond is underlain by Carboniferous sandstones and conglomerates (Dean, 1977). The east part of the map area is underlain by the Robert's Arm Group, consisting of pillow lavas, agglomerate and breccia, and minor rhyolite flows, and the Sansom Greywacke. A number of plutonic intrusions are found in this area, including the mafic to intermediate Hall Hill Complex, the granitic Mansfield Cove Complex and Loon Pond pluton, the granitoid South Pond pluton, and the mafic to intermediate Twin Lakes Complex (Swinden, 1987).

Economic interest has been restricted to the Roberts Arm Group, which hosts the Gullbridge deposit to the south of the map area, as well as numerous minor occurrences of base metals. The Catchers Pond Group contains minor mineral occurrences and mineralized base-metal float, possibly hosted by this Group, has been found south of Indian Pond (Alley and Slatt, 1975).

PREVIOUS WORK

O'Donnel (1973) studied boulder trains originating from the Gullbridge mine site (south of the field area), and postulated two ice-flow phases of the same advance, an earlier northeastward flow shifting to a later northwestward movement. Alley and Slatt (1975) and Alley (1976) discussed the glacial geology and sediment dispersal in the Sheffield Lake—Indian Pond area. Measurement of striae suggested a dominant northeastward flow, but with indications of later eastward flow. They identified two tills, an 'upper grey till' and a 'lower red till' and interpreted both to be lodgment tills deposited by separate advances.

Grant (1973, 1986) mapped the 12H/8 map area and located striae suggesting a northeastward flow. Ice-flow indicators have also been mapped by Lundqvist (1965), Tucker (1973), and Bostock (1988). Their data suggest valley-parallel flow in the southern half of the map area, and complex flow in the coastal areas. Liverman and Scott (1990) described a

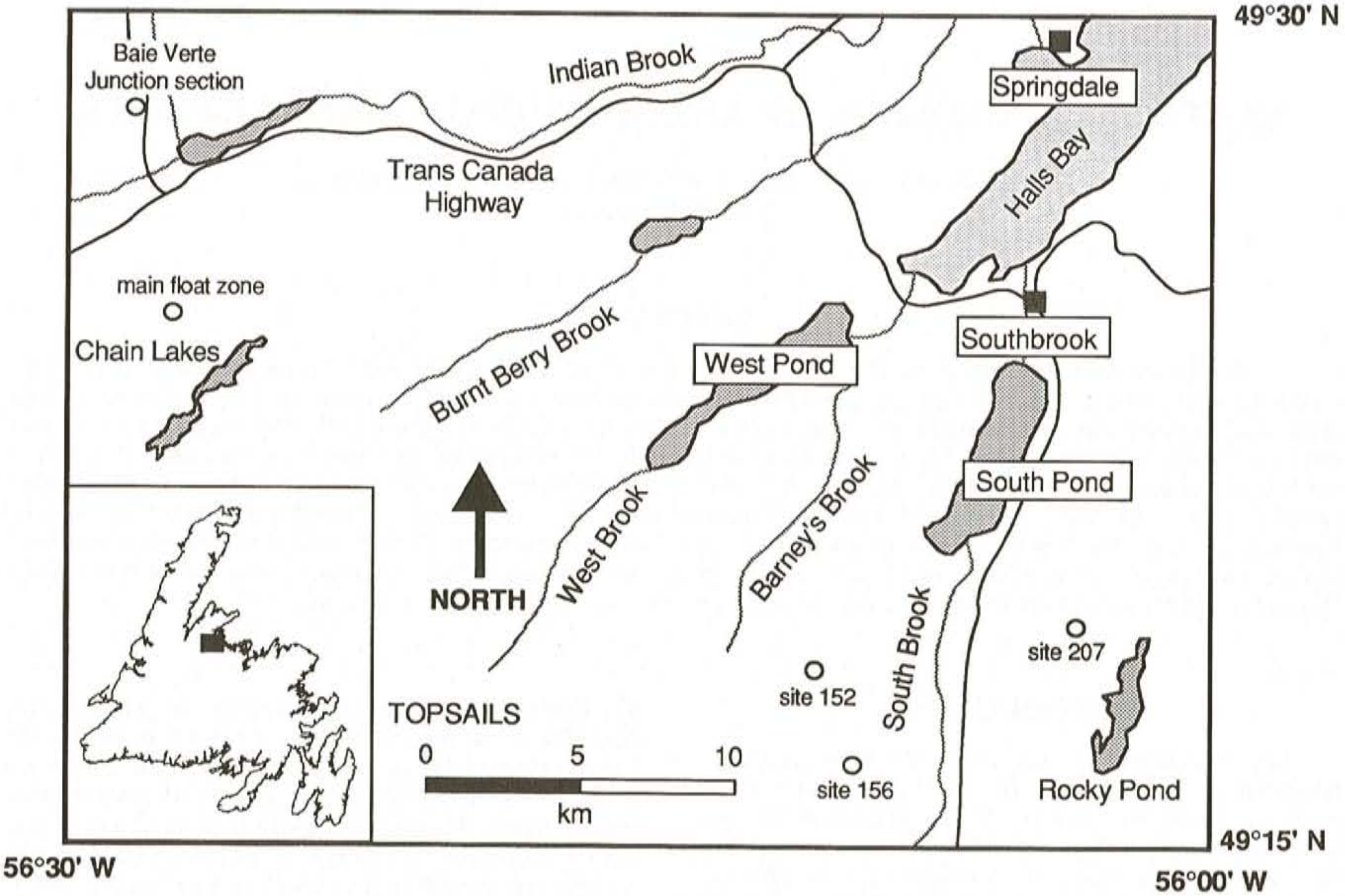


Figure 1. *Location and main features of the 12H/8 map area. Main float zone refers to the area of mineralized float described by Alley and Slatt (1975).*

two-phase ice-flow history on the King's Point map area (adjoining the Springdale map area to the north), with an initial northeastward ice flow overprinted by a later eastward to southeastward flow toward Hall's Bay.

Grant (1973, 1986) and Tucker (1973, 1974) mapped and described extensive marine deposits in coastal areas, with a marine limit defined at 75 m.a.s.l. on the basis of sediment distribution. Vanderveer (1977) evaluated marine clay deposits south of Springdale with regard to pottery and brickmaking. These sediments are further described by Scott and Liverman *(this volume)*.

FIELD METHODS

Access to the area is excellent due to the numerous logging roads built in the last thirty years. Most of these roads are still in good condition, and were traversed using truck or all terrain vehicle. Close to three-hundred sites were described in detail, including over 100 striation sites, and 16 backhoe pits. A total of 67 clast fabrics was obtained from diamictons exposed in sections and backhoe pits. Samples of matrix were analyzed for geochemistry and texture, and 80 to 120 pebbles were collected from diamictons to allow for clast lithology identification.

ICE FLOW

Over 100 striae sites were noted in the course of field work (see Liverman *et al.*, 1990 for locations). They suggest a relatively simple ice-flow history over the south and west parts of the map area, showing flow from the Topsails Hills, parallel to the major valleys of Indian Brook, Burnt Berry Brook, West Brook, Barney's Brook, and South Brook (Figure 3). This results in a pattern converging on Hall's Bay, which appears to have acted as a major conduit of ice away from adjacent central Newfoundland. Most multiple striation sites are found close to the coast (Plate 1) and indicate a two-phase ice-flow history, with initial flow, parallel to Hall's Bay (northeastward). Subsequent flow from the northwest side of the bay was eastward, but striae from the southeast side of the bay indicate late northwestward flow. Thus, late-stage local-ice-flow was toward Hall's Bay. Where clast fabrics from diamictons show strong unimodal orientations, generally, they parallel striations found in the same area (Liverman *et al.*, 1990).

Combining these results with other striation mapping in the area (Liverman and St. Croix, 1989a; Scott *et al.*, 1990: Liverman and Scott, 1990; St. Croix and Taylor, *this volume*) suggests that following initial flow from a major ice centre

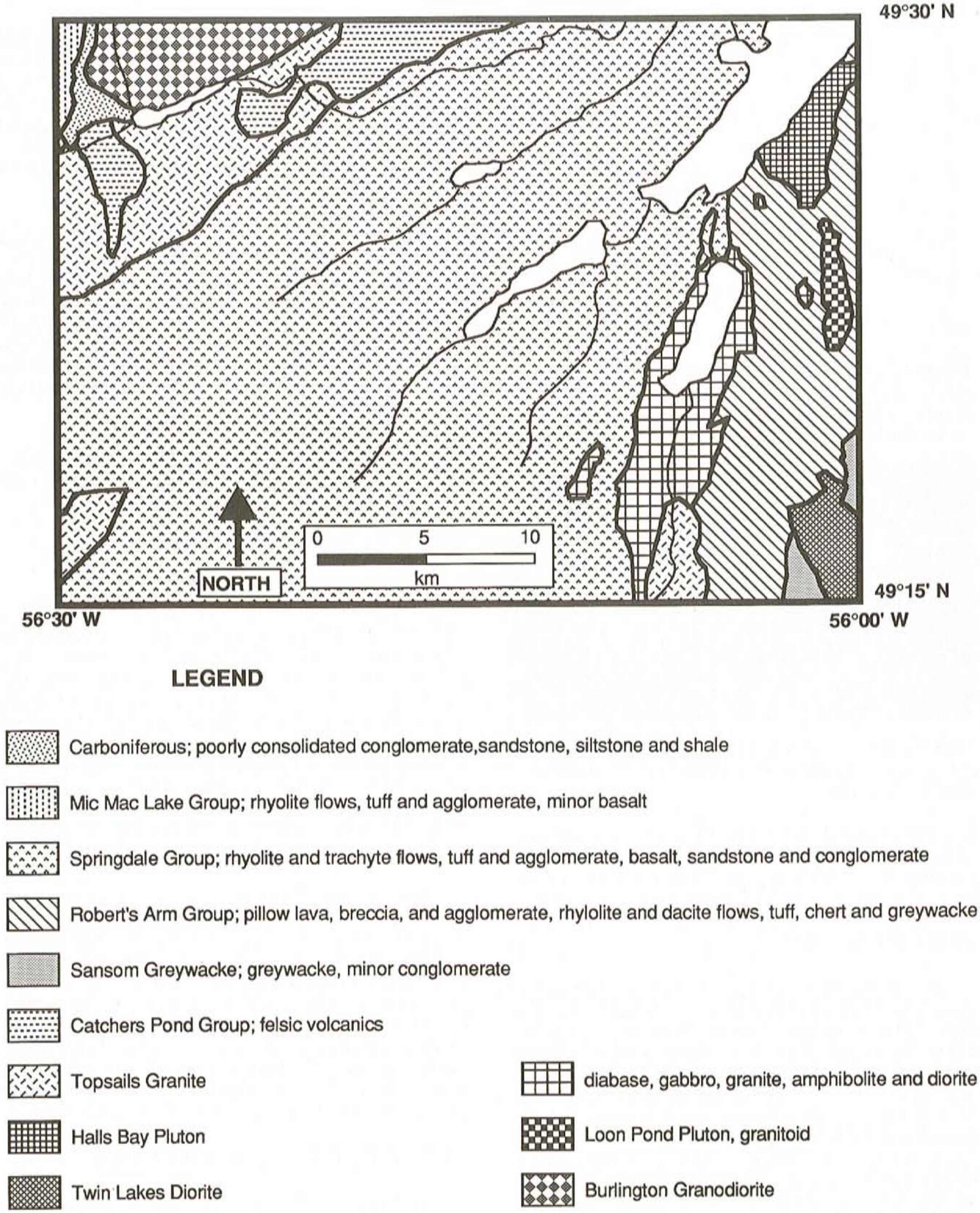


Figure 2. *Bedrock geology, 12H/8 map area, adapted from Dean (1977), Kean (1977), Hibbard (1983), Coyle and Strong (1987), and Swinden (1987).*

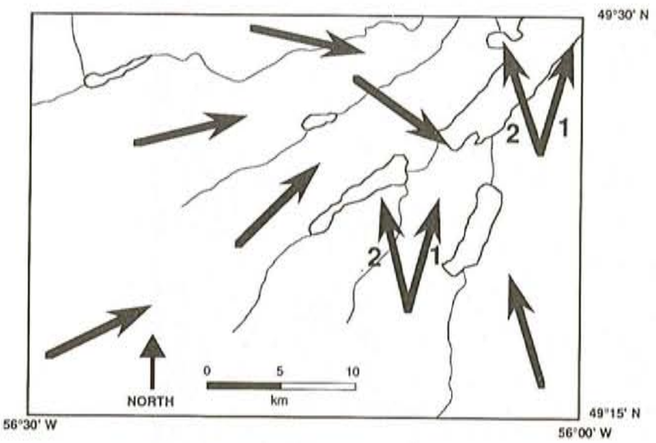


Figure 3. *Ice flow, Springdale map sheet. Arrows represent regional-flow directions deduced from numerous striation measurements, and numbers indicate age relationships (1 being oldest, 2 youngest).*

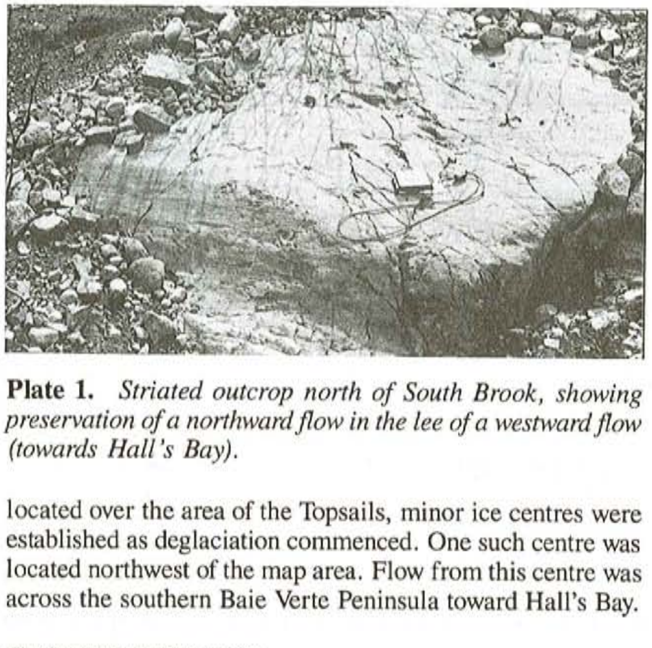


Plate 1. *Striated outcrop north of South Brook, showing preservation of a northward flow in the lee of a westward flow (towards Hall's Bay).*

located over the area of the Topsails, minor ice centres were established as deglaciation commenced. One such centre was located northwest of the map area. Flow from this centre was across the southern Baie Verte Peninsula toward Hall's Bay.

GEOMORPHOLOGY

The topography of the study area consists of a series of southwest-northeast-trending bedrock ridges, up to 200 m high, separated by the valleys of South Brook, Barney's Brook, West Brook, Burnt Berry Brook and Indian Brook (Figure 1). These brooks flow into Hall's Bay, a major embayment in the northeastern Newfoundland coastline. Both West Brook and South Brook enter lakes two to three kilometres inland from the coast (West Pond and South Pond). The southern Baie Verte Peninsula forms the northern boundary of the sheet, and the southern boundary is marked by the Topsails, reaching altitudes of 300 m in the southwestern corner.

The map area shows a geomorphological zonation from southwest to northeast. The southwestern part of the map sheet is dominated by a thick drift cover having a variety of geomorphological expressions. The most common landform is irregular hummocks up to 20 m high, and 50 to 150 m in diameter, which occur in wide areas of lowland between bedrock ridges. Resistant bedrock knobs in this area are common, and form rôches moutonnée and crag-and-tail landforms. In valley bottoms, a type of ribbed moraine is found, formed by alignment of hummocks perpendicular to the valley and presumably transverse to ice flow.

The central part of the map sheet shows inter-valley ridges dominated by rôches moutonnée, and featureless morainic plains. Valley sides are scarred by numerous meltwater channels, particularly noticeable in the upper West Brook valley, around Indian Pond, and in the valley of Barney's Brook. These channels range from 10 to 150 m wide, 3 to 20 m deep, and are up to 4 km long. The valley bottoms are filled with gravels, having distinct fluvial terraces along Barney's Brook and West Brook.

The northeastern part of the map sheet is dominated by marine sedimentation and numerous deltas and marine terraces (see Scott and Liverman, *this volume*).

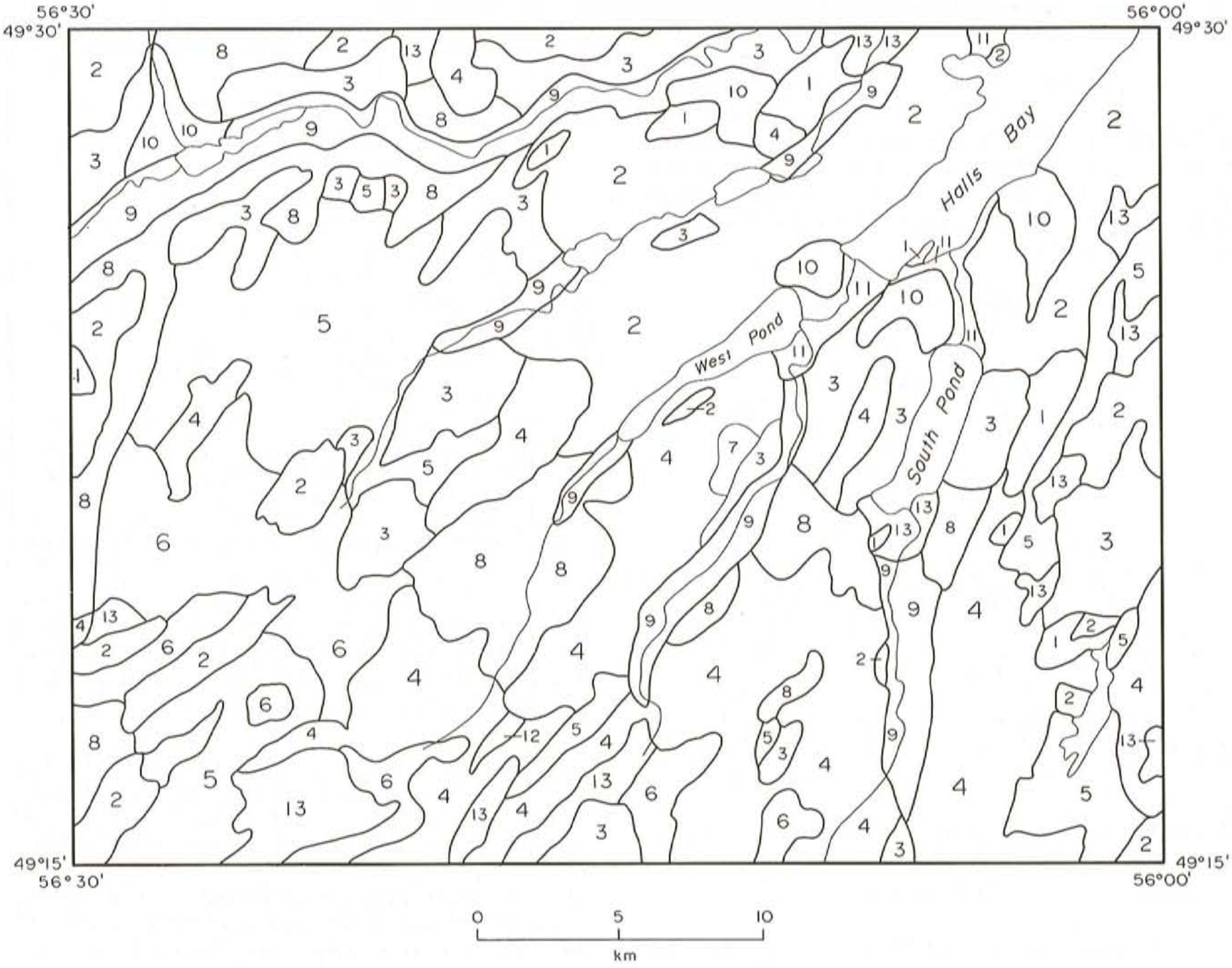
SURFICIAL SEDIMENT

Sediment cover over the area is variable (Figure 4). The coastal areas in the north and northeast have comparatively little surficial sediment cover over high areas; bedrock is intermittently exposed. However, the valleys have a thick surficial fill, related to marine incursion following deglaciation (Scott and Liverman, *this volume*) and deposition of outwash gravels. Large gravel bodies up to 75 m thick were deposited as ice-contact deltas at the mouths of the South Brook, West Brook, Burnt Berry Brook and Indian Brook valleys. Close to the coast, outwash and marine gravels are underlain by well-sorted marine clay and silt, up to 30 m thick (Scott and Liverman, *this volume*). Subsequent fluvial activity resulted in deposition of alluvial gravel, sand, and silt.

The centre and south parts of the study area have a thick surficial cover in low-lying areas, composed mainly of diamicton. Areas of exposed and vegetated bedrock are common on highs, and valley bottoms contain outwash gravel and alluvium. Topography is dominantly hummocky or ridged and areas between hummocks are commonly filled with bog. The eroded till unit is widespread on valley sides where common meltwater channels result in erosion of the diamicton surface, winnowing of fines, and concentration of cobbles and boulders as a lag in channel bottoms. Areas lying between channels consist of relatively undisturbed diamicton.

SEDIMENTOLOGY AND STRATIGRAPHY

Sedimentological work was largely confined to diamictons (described here), and marine sediments (see Scott and Liverman, *this volume*). The sedimentology of diamictons is of interest as the genesis of such sediments is difficult to determine without detailed examination, and the genesis has direct application to drift-prospecting studies.



LEGEND

1	Exposed bedrock: *exposed bedrock with little or no sediment or vegetation cover*
2	Concealed bedrock: *bedrock, mainly concealed by vegetation*
3	Till veneer: *thin (<1.5 m) discontinuous sheet of diamicton overlying bedrock*
4	Till blanket: *continuous diamicton cover having a smooth surface topography between 1.5 and 15 m thick*
5	Hummocky till: *a blanket of diamicton or sand and gravel, 1.5 to 15 m thick, having irregular hummocky topography*
6	Ridged till: *a blanket of diamicton having a topography consisting of irregular ridges transverse to valley axes*
7	Drumlinoid till: *diamicton having a topography consisting of streamlined elongate ridges*
8	Eroded till: *diamicton blanket having surface dissected by meltwater channels containing sand and gravel*
9	Glaciofluvial outwash: *consisting of gravel and sand*
10	Glaciofluvial deltas: *consisting of gravel and sand*
11	Marine sand and gravel: *moderately to well-sorted gravel and sand, found in marine terraces*
12	Alluvium: *Low-relief plains consisting of moderate to well-sorted gravel, sand, silt and clay*
13	Bog: *accumulations of degraded organic matter deposited in poorly drained low-lying areas*

Figure 4. *Surficial geology map, Springdale map area.*

Grain-Size Distribution

The grain-size distribution of diamictons in the area is variable, having a pebble and cobble component estimated to range from 30 to 70 percent. Figure 5 plots preliminary results for matrix texture of diamictons throughout the field area. The diamicton matrix composition averages approximately 38 percent granules, 44 percent sand, and 17 percent silt and clay.

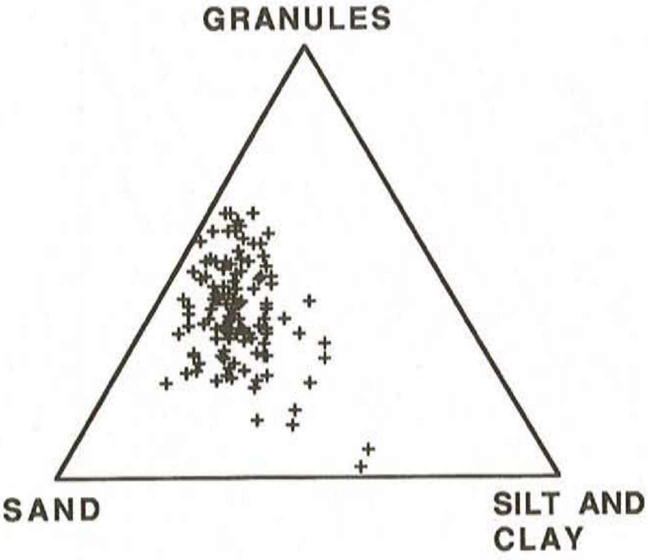


Figure 5. *Ternary diagram from sieve analyses of diamictons*

Clast Fabrics

Sixty-seven clast fabrics were obtained on diamictons throughout the area. Clast fabrics were analyzed on a Macintosh microcomputer using the Stereo™ program (MacEachren, 1989). Clast fabric is an important indicator of the environment of deposition in diamictons, as orientation of clasts is controlled by the processes depositing the diamicton. In lodgment till, strong orientations paralleling and transverse to glacial-flow direction are expected (Lawson, 1979, 1982; Dowdeswell and Sharp, 1986). In basal melt-out till, fabrics are also strong, but may be subsequently modified by reworking. Subaerial debris flow results in less well-oriented inconsistent fabrics, sometimes oriented parallel to local slope (Boulton, 1971; Lawson, 1979).

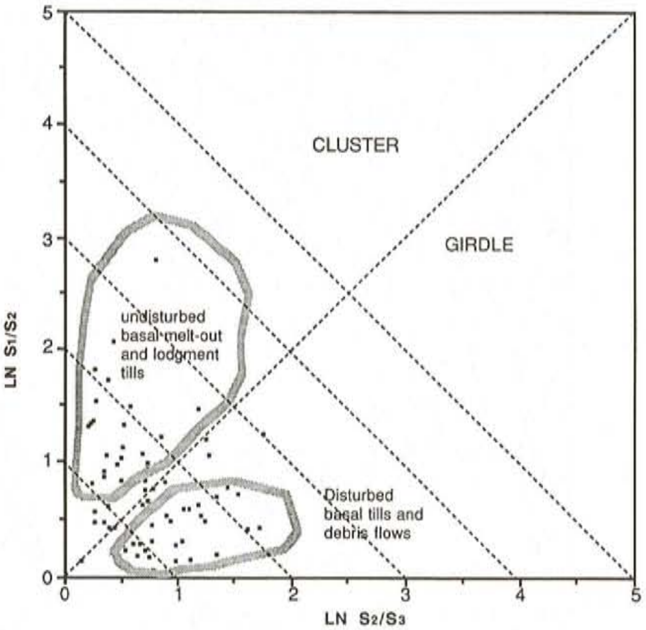


Figure 6. *Diagram of clast fabric eigenvalues, using the method of Woodcock (1977). The Y axis is the natural logarithm of the ratio between S1 and S2, and the X axis the natural logarithm of the ratio between S1 and S3.*

Clast fabrics must be evaluated using appropriate statistical techniques. Mean orientation, and strength of alignment were calculated by the eigenvector methods of Mark (1973, 1974) and Woodcock (1977). The S1 value measures the strength of the mean clast alignment, and ranges from 0.33 (weak) to 1.0 (strong). Figure 6 is a plot following the method of Woodcock (1977) and Rappol (1985). In this diagram, fabrics plotting in the upper left side of the diagram are considered to have a cluster distribution, whereas those in the lower right part have a girdle distribution. The parallel diagonal lines mark increasing values of a strength parameter (k), with weak fabrics plotting closer to the origin. Examination of the diagram shows that fabrics are very variable. About one third of the fabrics plot in the area that Rappol (1985) indicated as being typical of debris flow, one third in the area indicative of undisturbed basal till deposition and the remaining one third in the intervening area. Clast fabrics also show some very local variability, with, in some cases, fabrics from different areas of the same exposure showing different distributions. In such cases, however, it is usually found that one of the fabrics clearly indicates basal deposition, or debris flow; the other plots in the indeterminate region of the diagram.

Fabrics indicative of undisturbed basal tills were obtained sporadically from most areas sampled but are concentrated in two areas. The area northeast of Chain Lakes (Figure 1) is marked by irregular ridges transverse to the valley. Strong clast fabrics are obtained parallel to these ridges, and hence, transverse to ice flow. This suggests that these ridges were deposited by the action of active ice, rather than by stagnation processes. Similar ridges were described by Proudfoot *et al.* (1990), but clast fabrics in these examples were perpendicular to ridge axes. Cowan (1968) described till fabrics from ribbed moraine in Labrador and found that curved ridges showed ridge-parallel fabrics on their limbs. He suggests a subglacial origin for such landforms. The precise mechanism of formation of these ridges is unclear but is probably related to over-ride and shear of either debris-loaded ice, or deposited sediment.

The second area of fabrics indicating basal deposition lies between the Trans-Canada Highway and Rocky Pond (Figure 1). Sediments in this area are discussed in more detail below.

Sedimentary Structures

Diamictons in the area are dominantly massive, but in good exposures, interbeds, and lenses of silt, sand, and gravel are commonly found. Such structures are unlikely to be preserved in lodgment till, and suggest deposition as basal melt-out till, with lenses and beds produced by meltwater flowing in debris-poor areas of basal ice (Shaw, 1982; Haldorsen and Shaw, 1982). A poorly developed horizontal fissility is common in diamictons throughout the map area.

Rarely, more complex sequences are found, having interbedding of sand, gravel and diamicton. Site 152 (Figure 1), for example, shows interbedded diamicton, gravel, sand and silt (Plate 2). Bedding mainly dips to the north, but is deformed and disrupted. Diamicton beds contain some laminated silt intraclasts and compose 50 to 60 percent of the exposure. These interbeds have a similar colour and grain size to diamicton seen elsewhere in the area but have a higher proportion of fines. The abundant sorted sediment in this section indicates that current flow was important in the deposition of the sediment, and the laminated silt and clay suggest standing water. A likely environment of deposition for this sequence is supraglacial melt-out, having debris flow of diamicton, ephemeral ponds, and stream flow (Eyles, 1979). Similar sediments are found at site 156 (Figure 1) and elsewhere in the area.

Plate 2. *Sedimentary structures in diamicton, site 152.*

Clast Lithology

Clast lithology of diamictons is diverse, but is dominantly of local origin. No rock type in the area is sufficiently distinctive for use as an indicator lithology, so only gross trends are examined. Figure 7 plots the percentage of granite found in pebble samples from diamictons over the map area.

Comparison of the clast composition of pebble samples with outcrop of granitic rocks shows a close relation with the ice-flow history outlined above. Generally high proportions of granitic clasts are found overlying granitic bedrock, but some anomalies exist. High concentrations of granite are found up to 5 km east of the contact between the Topsails Granite and the Springdale Group, mapped by Dean (1977). It is possible that the exact position of this contact may be incorrectly inferred to the west of its actual position, as there is little bedrock exposure in this area. Alternatively, the clast lithology may be explained by dispersal by the eastward to northeastward ice flow in this area. These samples were obtained from hand-dug pits or small sections from an area mapped as hummocky moraine. The surface of such areas is likely composed of supraglacial melt-out till, which should contain high volumes of non-local material. Other anomalies may be explained, in part, by hand-dug pits not penetrating this surface supraglacial veneer (Plate 3).

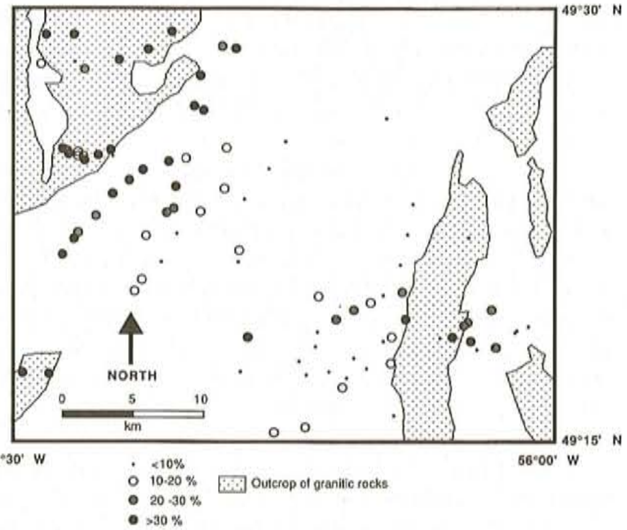


Figure 7. *Proportion of granitic clasts in pebble samples from diamictons; sample size ranges between 80 and 140.*

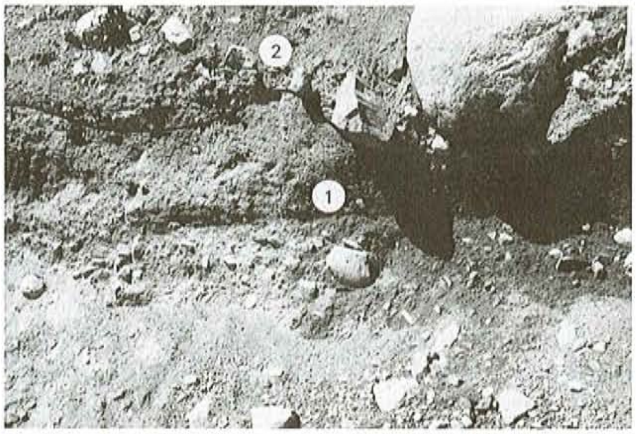


Plate 3. *Common stratigraphy in the south of the map area. A diamicton having clasts of mostly pebbles and granules, (1) is overlain by a cobble and boulder-rich veneer of sandy diamicton (2); section is 1.5 m high.*

STRATIGRAPHY

Multiple diamicton units are commonly interpreted as being deposited by discrete ice-flow events. In such cases, ice-flow direction and sediment provenance may differ for each unit, and thus, identification of such sequences is important in interpreting the results of drift prospecting surveys. A number of sections showed more than a single diamicton unit, and these are discussed in detail below.

Sections South of Indian Pond

Alley (1976) and Alley and Slatt (1975) reported a consistent two-till stratigraphy along the old Trans-Newfoundland highway, in the area east of Sheffield Lake and south of Indian Pond (Figure 1). This area is of particular interest as numerous mineralized floats of unknown origin are found on the surface. Six back-hoe pits were dug to re-examine this stratigraphy. The pits were spaced over 3 km along the old highway, and reached an average of 3 m below ground level (Figure 8). The pit at site 241 exposed mainly gravels, interpreted as glaciofluvial outwash. The other pits exposed diamicton units of varying properties and colour.

The most complex stratigraphy was found at site 242, where three diamicton units are overlain by well-sorted pebble gravel (Figure 8). The three diamicton units are of similar colour. The lowest unit has a Munsell colour of 7.5 YR 5/4 (brown) when moist and 10YR 6/2 (light brownish grey) when dry; the overlying diamicton is 10YR 5/3 (brown) when moist and 10YR 7/3 (very pale brown) when dry; the upper diamicton is 10YR 5/2 (greyish brown) when moist and 10YR 7/3 (very pale brown) when dry.

The lowest is distinguished by a high clast content, and numerous irregular sand and granule lenses. Overlying this is a diamicton having a lower clast content and numerous biconvex gravel lenses that are separated from the underlying diamicton by a bed of granule gravel. The uppermost diamicton is massive, and overlies a gradational contact. The upper contact with the gravel unit is very irregular. Clast lithology of all three diamictons is similar, with about one third granites, and two thirds locally derived andesites. Mineralized floats occur sporadically throughout, but are more common in the upper diamicton. Clast fabrics (Figure 9) are weakly to moderately oriented, decreasing in strength-up section. The lower two diamictons show a mean northward, and the upper a southeastward, clast orientation. The consistency of the lower two fabrics, and their moderate strength suggest that the clast orientation may reflect ice flow at the time of deposition.

The other sections show a diamicton of similar character to that seen at site 242, having weak to moderate fabrics, and variable mean clast orientations with the exception of site 244, which shows two diamicton units. The lower unit has a similar colour to the diamicton seen at site 242, but the upper is a distinctive reddish brown (10YR 5/8, dry; 10YR 6/6, wet). The clast lithology of the upper unit is dominated by volcanics, whereas clasts in the lower diamicton are mostly plutonic igneous rocks. Similar matrix colouration is seen in site 243, where weathered areas around float are a strong brown (7.5 YR 5/8, dry).

Examination of aerial photographs shows that the geomorphology of the area consists of irregular hummocks having a relief of 2 to 5 m, and a diameter of 50 to 100 m. Such topography is considered to be typical of the ice-stagnation environment (Gravenor and Kupsch, 1959). In such settings, ice melts in place during deglaciation, and the sediment held in the ice is deposited by basal and supraglacial melt-out. Considerable resedimentation of deposited diamictons occurs through debris flow as the buried ice melts. Probable sequences in these areas consists of supraglacial melt-out till, in part resedimented, overlying basal melt-out till, also possibly resedimented. The stratigraphy described in this study is compatible with the ice stagnation environment. The weak to moderate fabrics, which have inconsistent trends, are typical of debris flows (Lawson, 1979). The occurrence of sand and granule beds and lenses in the diamictons suggests that water flow was important in their deposition and thus, suggests that melt-out was the primary process.

Alley and Slatt (1975) describe the diamicton stratigraphy in the area as consisting of a 'lower red till' overlain by an 'upper grey till'; both are interpreted as being deposited by lodgement. Alley and Slatt (1975) and Alley (1976) differentiate the two till units by stating that the 'lower red till' is compact, fissile, possesses a strong northeast oriented clast fabric, and contains dominantly angular clasts of local derivation. The 'upper grey till', which is 'somewhat friable' and non-fissile, shows a strong northeast clast orientation at depths of 2 to 3 m, and a strong north to northwest orientation at depths of 1 m; and contains mostly sub-rounded clasts of a mixture of local and distal provenance. Alley and Slatt (1976) state that the presence of angular blocks of the 'lower red till' within a matrix of 'upper grey till' is diagnostic evidence of the lodgment origin of the upper till, and of two distinct ice advances in the area. Further, they conclude on the basis of ice-flow direction deduced from fabric measurements in the 'lower red till' and the shape of the dispersion fan, that the likely source of float is local, and situated close to the southern limit of float discoveries (Figure 8).

It is hard to reconcile the descriptions of Alley and Slatt (1975) with those made in this study. The 'lower red till' may be identified with the upper unit at site 244 and the 'upper grey till' is the diamicton seen elsewhere. Site 244 is located in the area mapped by Alley and Slatt (1975) as showing outcrop of the 'lower red till' at the surface. If the material seen at the surface at site 244 is the 'lower red till' then the presence of a diamicton resembling the 'upper grey till' below it is puzzling. The fabrics obtained from this area show S1 values from 0.46 to 0.60 (weak to moderately oriented) in contrast to the 'strong' fabrics reported by Alley and Slatt (1975) [without the benefit of statistical analysis]. Mean orientation varies from northeast to northwest, but the consistent stratigraphic trends described by Alley and Slatt (1975) were not found. It is possible the few backhoe pits dug

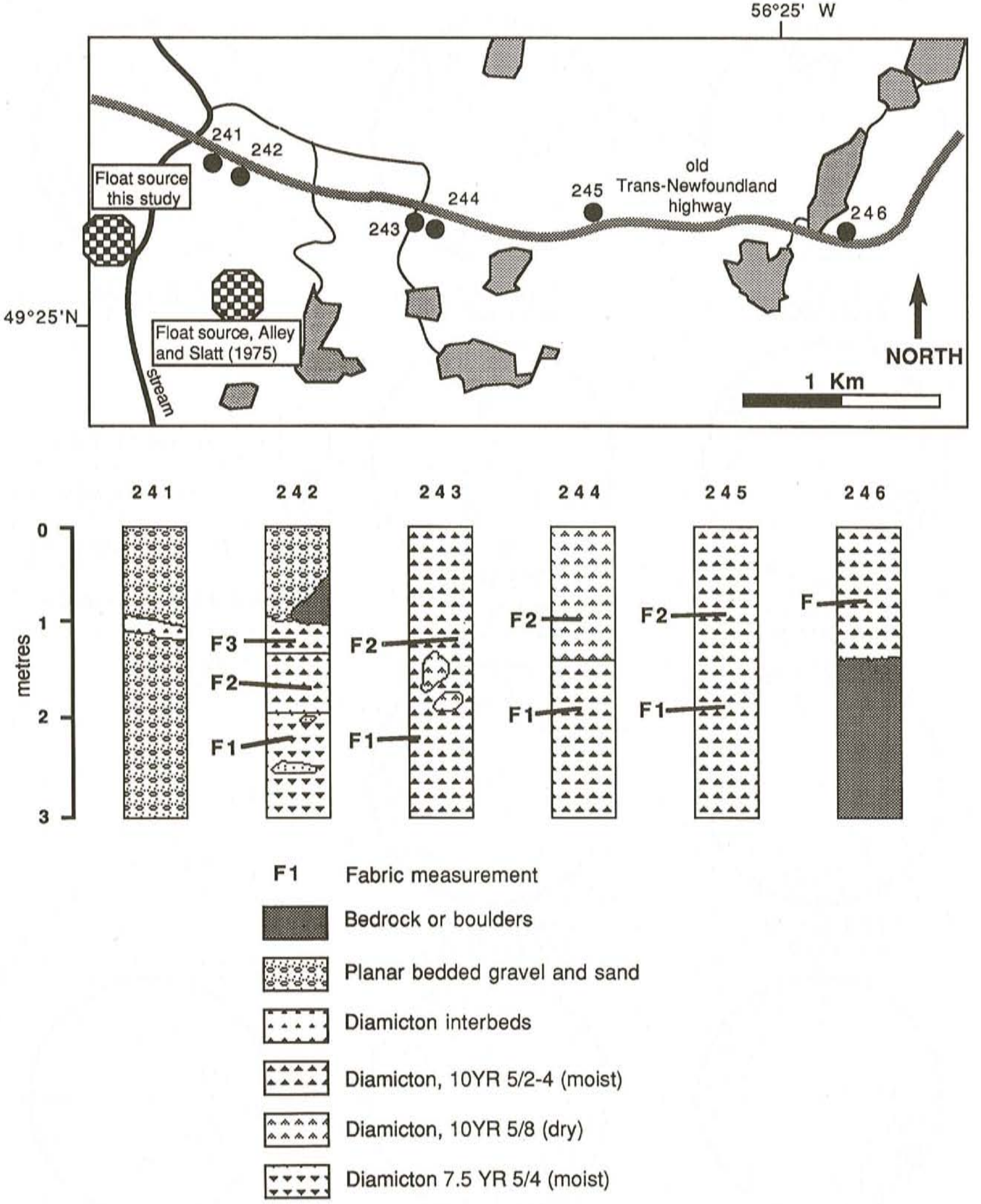
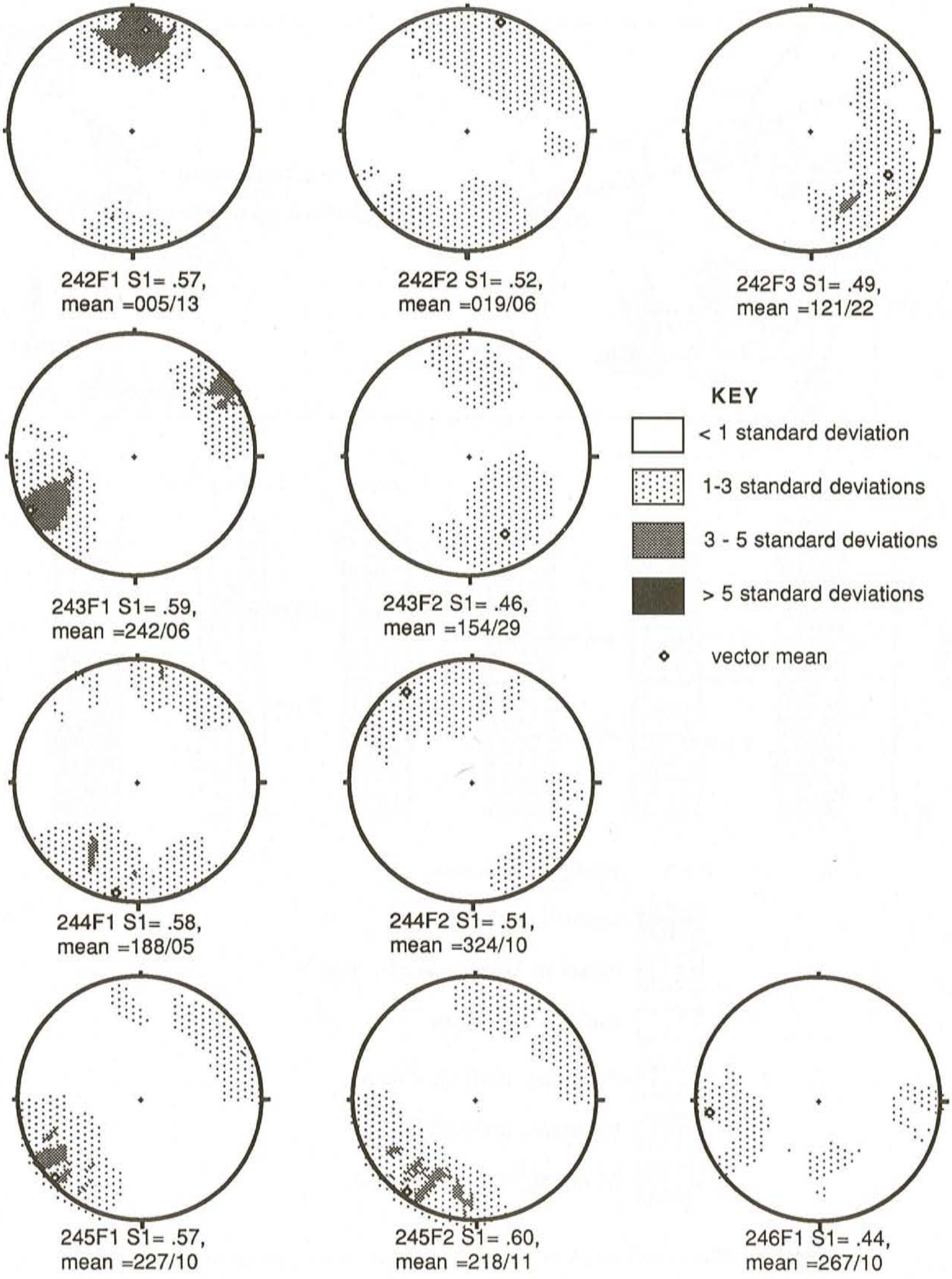


Figure 8. *Map of backhoe pits in the 'main float area' of Alley and Slatt (1975).*



242F1 S1= .57, mean =005/13

242F2 S1= .52, mean =019/06

242F3 S1= .49, mean =121/22

243F1 S1= .59, mean =242/06

243F2 S1= .46, mean =154/29

244F1 S1= .58, mean =188/05

244F2 S1= .51, mean =324/10

245F1 S1= .57, mean =227/10

245F2 S1= .60, mean =218/11

246F1 S1= .44, mean =267/10

Figure 9. *Clast fabrics from backhoe pits in the 'main float area' of Alley and Slatt (1975). S1 is the normalized principal eigenvalue, and the direction of dip and dip of the mean orientation is given as direction/dip. Contours are in standard deviations from the mean following the method of Kamb (1959).*

did not intersect the full stratigraphy described by them from more extensive trenching. The surface till over most of the area is, however, not a lodgment till, and the sections examined can be interpreted as showing deposition from a single advance and the surface material being of supraglacial origin.

The results of this study suggest that the work of Alley and Slatt (1975) should be re-evaluated. An alternative model of ice flow, based on regional striation trends and dispersal of granite clasts in the area east of the float zone (Figure 7), suggests a west-south-westward to east-north-eastward flow. The glaciofluvial gravels found in site 241 formed in a meltwater channel that truncates the dispersal fan on its westerly margin. Thus, an alternative source for the float may be adjacent to, or west of, this channel (Figure 8).

Site 207

This site (Figure 1) consists of an excellent exposure in a borrow pit that shows three distinct diamicton units (Figure 10 and Plate 4). The lowest has moderate to low compaction, about 40 percent pebbles and cobbles, and a moderately to poorly oriented northeast-southwest clast fabric. Sorted sand and silt laminae are common and impart a horizontal fissility to the unit. Overlying a sharp contact, the middle diamicton unit has a higher clast percentage (70 percent), is highly compacted, massive, and shows a strong north-south oriented clast fabric. The clast lithology of the lower two units is similar, dominated by mafic volcanic rock types (of local provenance), and containing about 20 percent granites. The uppermost diamicton unit is variable in thickness, contains many cobbles and boulders, and overlies a sharp undulating basal contact. The matrix is mostly poorly sorted, medium to coarse sand. The clast lithology of this unit is mixed, but it contains a high proportion of rounded granites (70 percent).

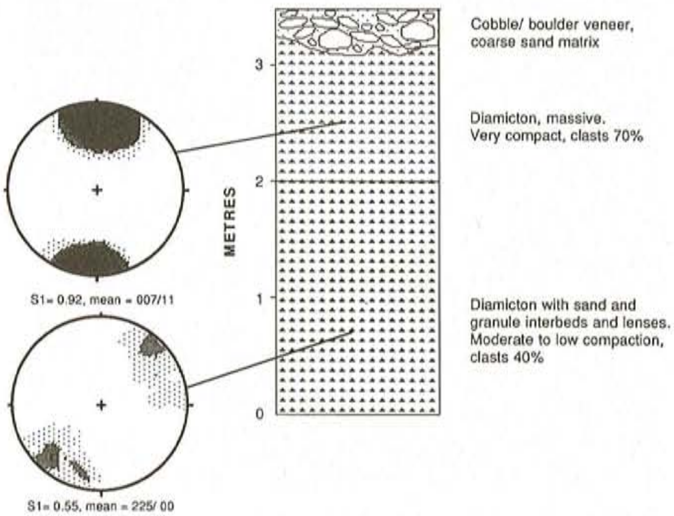


Figure 10. *Stratigraphy, site 207. See Figure 9 caption for explanation of fabric diagrams.*

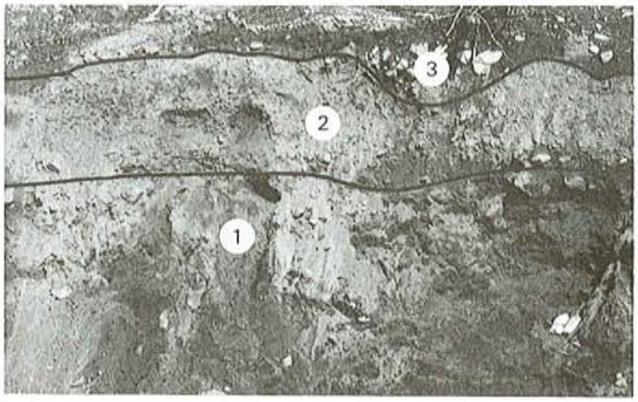


Plate 4. *Multiple diamicton section, site 207, west of Rocky Pond (see text for description; 1 being the lowest unit).*

This sequence of three units is interpreted as showing a basal melt-out till, overlain successively by a lodgment till, and a supraglacial melt-out till. A basal melt-out genesis for the lowest unit is suggested by the moderate clast fabric, the relatively low compaction, and the common sand laminae (Haldorsen and Shaw, 1982; Lawson, 1979; Shaw, 1987). The high compaction and strong clast fabric of the overlying unit is typical of lodgment tills (Dowdeswell and Sharp, 1986; Kruger, 1979; Lawson, 1979). The uppermost diamicton is thought to be of supraglacial origin due to the volume of coarser material, the numerous non-local clasts, and the coarse grain-size of the matrix (Eyles, 1979; Levson and Rutter, 1986). Thus, this stratigraphy indicates two distinct flow events. The clast fabrics suggest that an earlier northeastward flow deposited a basal melt-out till, which was over-ridden by a later northward flow, which deposited a lodgment till. Upon stagnation of this ice, supraglacial melt-out till was deposited at the surface.

This sequence is not seen in exposures 1 to 2 km away, where, generally, a sequence of a moderately compact diamicton, which contains some sand and silt laminae overlain by a cobble and boulder veneer, is found. Clast fabrics are variable, having indications of both northwestward and northward flow. These sequences are interpreted as showing deposition of supraglacial melt-out over basal melt-out till, having no evidence of lodgment. Striae in the area indicate a two-phase ice flow, having an early north to northeastward flow and a subsequent northwestward flow. Thus, the lower diamicton at site 207 was probably deposited by basal melt-out following the initial northeastward flow. Re-advance resulted in patchy deposition of lodgment till during a dominantly north to northeastward advance. Where lodgment till was not deposited, it is possible that melt-out tills of the early advance and re-advance cannot be distinguished. Such tills would be of similar character and provenance, and could clearly be separated only by intervening sediments. As the ice retreated, ice flow was dominantly to the northwest (as indicated by striae), and stagnation resulted in deposition of basal melt-out till overlain by a supraglacial melt-out veneer.

Baie Verte Junction Section

This section is exposed in a gravel pit adjacent to the Dorset Trail, 2 km north of its junction with the Trans-Canada

Highway (Figure 1). Recent clearing has exposed three units (Figure 11). The lowest is a diamicton, up to 1.8 m thick, moderately compact, reddish brown (5YR 4/4, moist), having many discontinuous sand and granule beds. Clast fabric is weak, and clast lithology is mixed. Red sandstones and conglomerate clasts are common. The likely source of these clasts is the local Carboniferous clastic rocks mapped by Dean (1977).

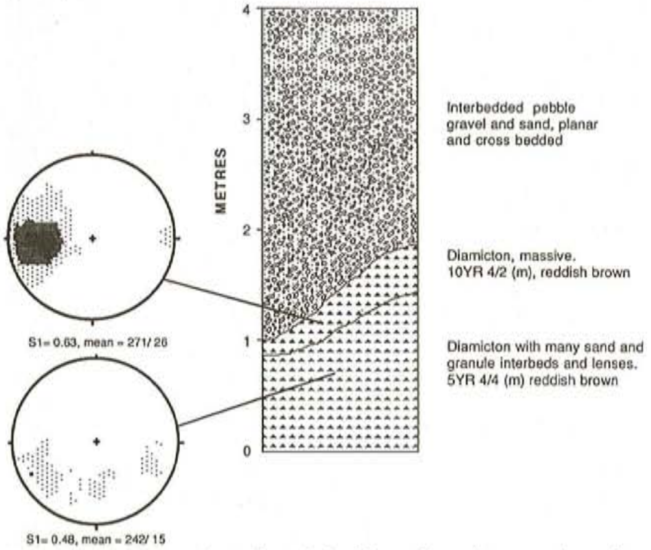


Figure 11. *Stratigraphy, Baie Verte Junction section. See Figure 9 caption for explanation of fabric diagrams.*

The middle unit is a diamicton separated from the lower unit by a sharp undulating contact. The contact has up to 0.5 m relief and in section forms a steep-sided trough. This diamicton is up to 0.4 m thick, and follows the slope of the underlying contact. It is dark greyish brown (10YR 4/2, moist), moderately compact, massive and contains many weathered mafic and ultramafic clasts. Granodiorite clasts are also common. Clasts are well-oriented east-west, parallel to the dip of the bed from which the fabric was measured. The uppermost unit consists of interbedded moderately sorted, pebble gravel and sand. The lower beds are contorted, and follow the contours of the underlying unit, but flatten-up section to lie close to horizontal (Figure 11).

The sequence is interpreted as showing diamictons deposited by two phases of ice flow, overlain by ice-contact outwash gravels. The poor clast fabric and interbedded sorted sediments suggest that the lowest unit is not a primary till. It may be a basal melt-out till that has undergone post-depositional resedimentation, or may have been deposited as a debris flow in ice-marginal positions. The contortion of the gravel unit suggests that the trough geometry of the lower contacts formed post-depositionally, probably as buried ice melted. The clast fabric of the upper diamicton is aligned parallel to the dip of the contact, and may have formed through debris flow of material following primary deposition. The upper diamicton contains fewer sandstone clasts of local provenance and the clast assemblage suggests a north to northwestern source for the sediment. Ultramafic rocks and gabbros in this area are only found north of the Green Bay fault (Hibbard, 1983). To deposit these rock types, ice must have moved south from the southern Baie Verte Peninsula into the Indian Brook valley, as suggested by Liverman and St. Croix (1989b). The lower diamicton has a similar clast assemblage to diamictons sampled south of the Indian Brook valley. Although it would be unwise to formulate major conclusions based on two small clast lithology samples, it is speculated that this area was initially glaciated by a northward ice flow (as suggested by ice-flow indicators south of the area). Following retreat of this ice sheet, ice flowed southward or southeastward into the Indian Brook Valley from the Baie Verte Peninsula. A similar ice-flow history was suggested for the King's Point map area by Liverman and Scott (1990) on the basis of striation mapping.

PERIGLACIAL STRUCTURES

A complex deformed sequence of sand and gravel is exposed in a small roadcut section on the north side of the Indian Brook valley. The main feature of this deformation is disruption of planar bedded, well-sorted, medium-grained sand by wedge-shaped units of poorly sorted coarse sand having some granules and pebbles (Plate 5). The wedges are 80 to 100 cm long, 40 cm wide at the surface, and narrow to less than 1 cm at the base. They show some internal stratification parallel to the sides of the wedge. The wedge structures are overlain by moderately to poorly sorted pebble gravel.

Plate 5. *Structure interpreted as an ice-wedge cast in sand and gravel, north of the Indian Brook valley.*

These structures are interpreted as resulting from periglacial action. The stratified filling, and its likely derivation from the overlying gravel bed suggest that these are ice-wedge casts, formed by infill of an ice wedge by sediment as it melted (e.g., Washburn, 1973; Eyles, 1977). Structures interpreted as ice-wedge casts exposed in a gravel pit near the Baie Verte Junction (14 km west of this section) were described by Liverman and St. Croix (1989b). These new discoveries confirm their conclusion of the existence of a periglacial climate following deglaciation of the Indian Brook valley.

DISCUSSION

QUATERNARY HISTORY

There is no local or regional evidence for pre-Late Wisconsinan glacial events. Despite the complex ice-flow history, and multiple diamicton sections, it is thought that all glacial events described here were Late Wisconsinan. The record of ice flow preserved is that of glacial retreat, as striae and sediments associated with advance are obliterated by erosion and thus, little can be said regarding the inception of glaciation. As deglaciation commenced, ice flow was from the area of the Topsails toward the coast. When ice retreated to close to the present coast line, topographic influence resulted in flow toward Hall's Bay in coastal areas, which acted as an outlet for most ice in the area. The deglacial chronology in north-central Newfoundland is based on radiocarbon dates from shells collected from marine sediments in coastal regions, and from organic matter in basal lake sediments (Dyck and Fyles, 1963; Lowdon and Blake, 1975; Blake, 1986, 1987, 1988). Shell dates range from 11,000 to 12,000 years BP, whereas basal lake-sediment dates span 11,800 to 10,400 years BP. However, Macpherson (1990) suggested that the basal lake dates were likely anomalously old, due to problems with aquatic photosynthesis. The shell dates have been assumed to date the formation of the large ice-contact deltas at the valley mouths (Tucker, 1974). It is not clear that the sediment from which these fossils were collected was deposited in association with the coastal marine limit deltas. During this study, shells for dating were collected from glaciomarine silt and clay, which is exposed up to 10 km inland from the ice-contact Springdale delta (see Scott and Liverman, *this volume*). If these shells are of equivalent age to those dated, then it is likely that initial deglaciation and coastal delta formation occurred earlier than 11,000 to 12,000 years BP, with the shell material related to a later still-stand or re-advance of ice.

The ice-wedge casts in the Indian Brook valley indicate the existence of a periglacial climate following initial deglaciation of the area. There is also stratigraphic evidence for a re-advance of ice at site 207. These may be related by postulating a period of cooling following the warming that initiated deglaciation. Evidence of a re-advance of ice was provided by MacClintock and Twenhofel (1940) on the Baie Verte Peninsula, who found marine silts lying between two tills. Brookes (1969, 1977) dated a re-advance of piedmont ice in southwestern Newfoundland at younger than 12,600 ± 140 years BP (GSC-2295). Macpherson and Anderson (1985) interpret radiocarbon dates and pollen from lake sediments in Notre Dame Bay as showing that following initial deglaciation at 13,400 years BP, a climatic deterioration occurred between 11,300 and 10,700 years BP. The structures indicating a periglacial climate described in this paper, and by Liverman and St. Croix (1989), lie close to, but below marine limit. Thus, a speculative sequence of deglaciation might be:

1. Climatic amelioration followed by retreat of ice to close to the present coastline, and construction of ice marginal deltas;
2. further retreat resulted in deglaciation of the major valley systems, and marine inundation. Ice remained on topographic highs inland from the modern coast, likely in the Topsails Hills, but also possibly on the southern Baie Verte Peninsula. This ice may have stagnated, and possibly meltwater channels on valley sides were formed at this time. Deposition of glaciomarine sediments commenced in the flooded valley systems;
3. climatic deterioration resulted in readvance of ice, continued deposition of glaciomarine sediments, and formation of ice wedges in the Indian Brook valley. This may be related to the Younger Dryas cooling event recognized around the North Atlantic, and dated at 11,000 to 10,200 years BP (Mott *et al.*, 1986); and
4. climatic warming, resulting in complete deglaciation. Large areas of ice stagnated on higher ground (the areas mapped as hummocky and ridged till on Figure 4), and provided meltwater to the valley bottoms, eroding the valley sides.

This sequence is very speculative at present. It may be tested in part, once the results of radiocarbon dating on shells collected in the Indian Brook valley are available (see Scott and Liverman, *this volume*). If these shells are of the same age as those collected in coastal areas, then it will substantiate the speculation that the marine limit deltas were deposited prior to 11,000 to 12,000 years BP. Scott and Liverman *(this volume)* further discuss sea-level change in this area.

Following complete deglaciation, sea level continued to fall, resulting in the construction of marine terraces. Rivers became established in their modern courses, depositing alluvium, and deltas at the coast. Vegetation rapidly spread eventually resulting in widespread bog development.

IMPLICATIONS FOR DRIFT PROSPECTING

Despite the simple ice-flow history, the problems encountered in the study of Alley and Slatt (1975) and the alternative interpretation discussed above illustrate the difficulty of using drift prospecting techniques in areas of thick drift. Such methods should be successful if used in conjunction with a sound understanding of the glacial geology. In this area, it is essential that the supraglacial boulder veneer is penetrated during soil sampling. The thickness of this veneer on a given property can only be evaluated by test pitting. The common washed areas (eroded till on Figure 4) will have areas where transport is largely by glaciofluvial processes, rather than ice flow, and this should be considered when evaluating results. The existence of multiple diamicton sections, and a relatively complex stratigraphy, indicate that conventional soil-sampling techniques should be augmented with back-hoe pits and consideration of the genesis of the surficial sediment.

ENVIRONMENTAL AND ECONOMIC GEOLOGY

The numerous sand and gravel areas mapped in the main valleys are likely highly permeable, and thus, may form a source of groundwater at depth. Such areas should be avoided in siting waste-disposal sites, as should the raised marine deposits in coastal areas. The low proportion of silt and clay in surface sediment over much of the area mapped as till, also suggests that the till may be porous and permeable, resulting in seepage problems if used as a waste-disposal site. The marine clays found in the lower Indian Brook valley are likely unstable on steep slopes, and may prove problematic if encountered in construction. They also form a source of clay for pottery and brick making (see Vanderveer, 1977). Mapping suggests that large volumes of such material exists. The sand and gravel bodies form a major source of granular aggregate, although further work on quality is required.

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