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QUATERNARY GEOLOGY OF THE UPPER HUMBER RIVER AREA, WESTERN NEWFOUNDLAND

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ABSTRACT

Surficial geological mapping in the upper Humber River valley has shown that the area was affected by a single southward ice-flow event, from an ice centre in the Long Range Mountains. This flow merged with northwestward-flowing ice from the Topsail Hills to the south of Cormack, and the ice then flowed out to the coast through the Bonne Bay area. To the east of Birchy Ridge, which was also covered by ice derived from the north, ice flow was generally northward toward White Bay from a centre in the Topsail Hills.

Most diamictons in the study area have characteristics consistent with deposition at the base of a glacier, probably as melt-out tills. The colour, texture and clast provenance of diamictons are mainly controlled by the underlying bedrock geology. Glaciofluvial deposits are confined to the Humber River valley and associated tributary valleys. Marine muds adjacent to the Humber River are found below 50 m asl, and these are commonly covered by Holocene fluvial or organic deposits. No evidence was found for proglacial lake sediments or deltas.

Surficial mapping in this area has implications for mineral exploration by determining paleo ice-flow directions and suitable sampling media, and also for agricultural, water-resource and land-use planning by identifying surface and subsurface sediments and describing their physical characteristics.

INTRODUCTION

Surficial geological mapping of the Humber River valley was started in 1991, and has been continuous (Batterson and Vatcher, 1992; Batterson and McGrath, 1993). To date, three 1:50 000 map sheets have been completed (NTS 12A/13, 12H/3 and 4). Field work in 1993 concentrated on mapping the area of the Cormack map sheet (NTS 12H/6) in the upper Humber River valley.

The Humber River valley, stretching from Corner Brook in the west toward White Bay in the north, is a geologically significant area for the following reasons:

- it is situated in a lowland between two major ice dispersal centres, one on the Long Range Mountains to the north, and the other on the Topsail Hills to the east,
- it is within the area reported to have been covered by a large proglacial lake during deglaciation of the region (Batterson *et al.*, 1994),
- a large part of the basin is below the postglacial marine limit for the area, and it may therefore have been inundated by the sea,
- considering the above, the area may have a record, either erosional, depositional or both, of a complex series of events during the Quaternary, and
- the area contains several communities and supports agriculture and forestry, as well as having been an area of extensive mineral exploration.

An understanding of the Quaternary stratigraphy and its potential effects on development are therefore important.

In addition to preliminary mapping on the Cormack map area (NTS 12H/6), parts of the Sheffield Lake (NTS 12H/7), Hampden (NTS 12H/10) and Silver Mountain (NTS 12H/11) areas were also mapped in 1993 (Figure 1). This report will discuss ice flow, clast provenance in diamictons, surficial sediment units and present a discussion of the deglacial history of the area, and its potential implications to mineral exploration and land-use development in the area.

LOCATION AND ACCESS

The area spreads from Deer Lake in the south to Taylor Brook in the north, and Cormack in the west to Birchy Lake in the east (Figure 2).

Access to the area was by truck along the Trans Canada Highway and other paved roads, or by ATV along an extensive

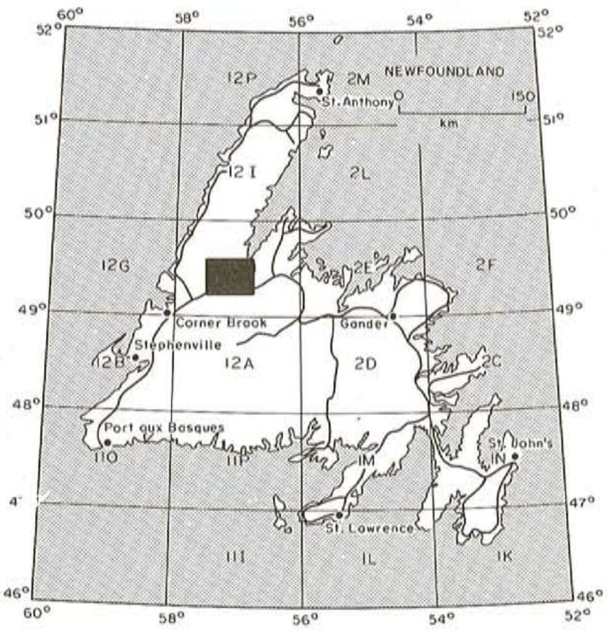


Figure 1. *Location of study area.*

network of logging roads, many of which have been abandoned. Active logging is currently underway in the Bridgers Pond and Taylor Brook areas.

BEDROCK GEOLOGY

The area contains Precambrian to Carboniferous bedrock (Hyde, 1984; Whalen and Currie, 1988; Williams and Cawood, 1989) (Figure 3), which is reflected in the physiography. The Humber River basin dominates the study area, of which about 60 percent lies below the 170 m contour and is underlain by soft Carboniferous clastic sedimentary rocks. The Long Range Mountains form the western margin of the study area, rising to over 600 m asl, and are underlain by gneisses, granitic gneisses and associated rocks of the Grenville basement. Birchy Ridge, a north-northeast–south-southwest-oriented bedrock ridge rising up to 300 m, separates the Humber River valley from the Sandy Lake basin to the east. Birchy Ridge is formed of Devonian–Carboniferous sedimentary rocks of the Anguille Group. The eastern part of the area (the Topsail Hills, extending up to 600 m asl) is underlain by felsic volcanic rocks of the Springdale Group, and granitic and peralkaline rocks of the Topsails intrusive suite.

The upper Humber River valley was an area of extensive exploration for uranium following the discovery of high-grade uranium boulders in 1978. Despite considerable activity by Westfield Minerals Limited, including diamond drilling, the source of the high-grade mineralization was not found. Small occurrences of base metals, mainly copper–lead, also occur in the area (Hyde, 1984).

Many rock types in the study area have distinctive physical properties and their distribution is important to the reconstruction of the regions ice-flow history. Red sandstones and siltstones are derived from Carboniferous rocks of the Deer Lake basin. Their widespread distribution in bedrock outcrop throughout the area (from Pasadena in the south up toward White Bay in the north) constrains their use to the interpretation of regional ice-flow patterns. Diamictons derived from the Long Range ice centre (to the north of the field area) should contain Precambrian gneisses having characteristic blue quartz inclusions, whereas diamictons related to ice flow from the Topsail Hills ice centre may contain flow-banded and porphyritic rhyolites (Springdale Group), one- or two-feldspar granites (some of which are peralkaline), and quartz-feldspar porphyry clasts.

PREVIOUS WORK

The surficial geology of the area has been mapped at a 1:250 000 scale (Grant, 1989) and at a reconnaissance level 1:50 000 scale (Vanderveer, 1987). Soil reports covering all or parts of the study area have been completed at a 1:250 000 scale (Kirby *et al.*, 1992), 1:50 000 scale (Button, 1983), and 1:12 500 scale (Kirby and Bouzane, 1993).

The glacial–deglacial history of the area has not been clearly defined by previous work. Vanderveer (1982) and Vanderveer and Sparkes (1982) suggested three phases of ice movement during the Wisconsinan. The first ice flow, identified by clast provenance data, was a southward advance that deposited a compact, fissile, reddish, silty-clay till. This was followed by an east to southeast flow from the Long Range Mountains that striated bedrock and deposited a grey-brown, loose, silty-sand till. The third phase of ice movement was again southward and is shown by surface geomorphology, mainly flutings. In contrast, Rogerson (1979), working in the Wigwam Brook area along the foot-slope of Birchy Ridge, suggested an early northeastward ice flow up the Humber River valley followed by a major flow to the northwest. Batterson and Taylor (1990) supported neither interpretation and instead proposed that an early northwest flow that crossed Birchy Ridge from the Topsail Hills was followed by a southward flow down the Humber River valley.

To the east of Birchy Ridge, MacClintock and Twenhofel (1940) suggested northward-flowing ice from the Grand Lake–Sandy Lake basin toward White Bay. This was supported by Lundqvist (1965) and Grant (1972) on the basis of striation and landform evidence. Taylor and Vatcher (1993), as a continuation of a regional ice-flow mapping project, confirmed the generally northward ice flow from an ice centre on the Topsail Hills, and also recognized an eastward ice flow toward White Bay in the northern part of the study area.

FIELD AND LABORATORY INVESTIGATIONS

Bedrock outcrops were examined for striae and other ice-flow indicators, such as nailheads, crescentic gouges, and stossed surfaces. Thirty-six striation sites were recorded to supplement those identified during previous projects (e.g., Taylor *et al.*, 1991). Detailed descriptions of surficial sediment

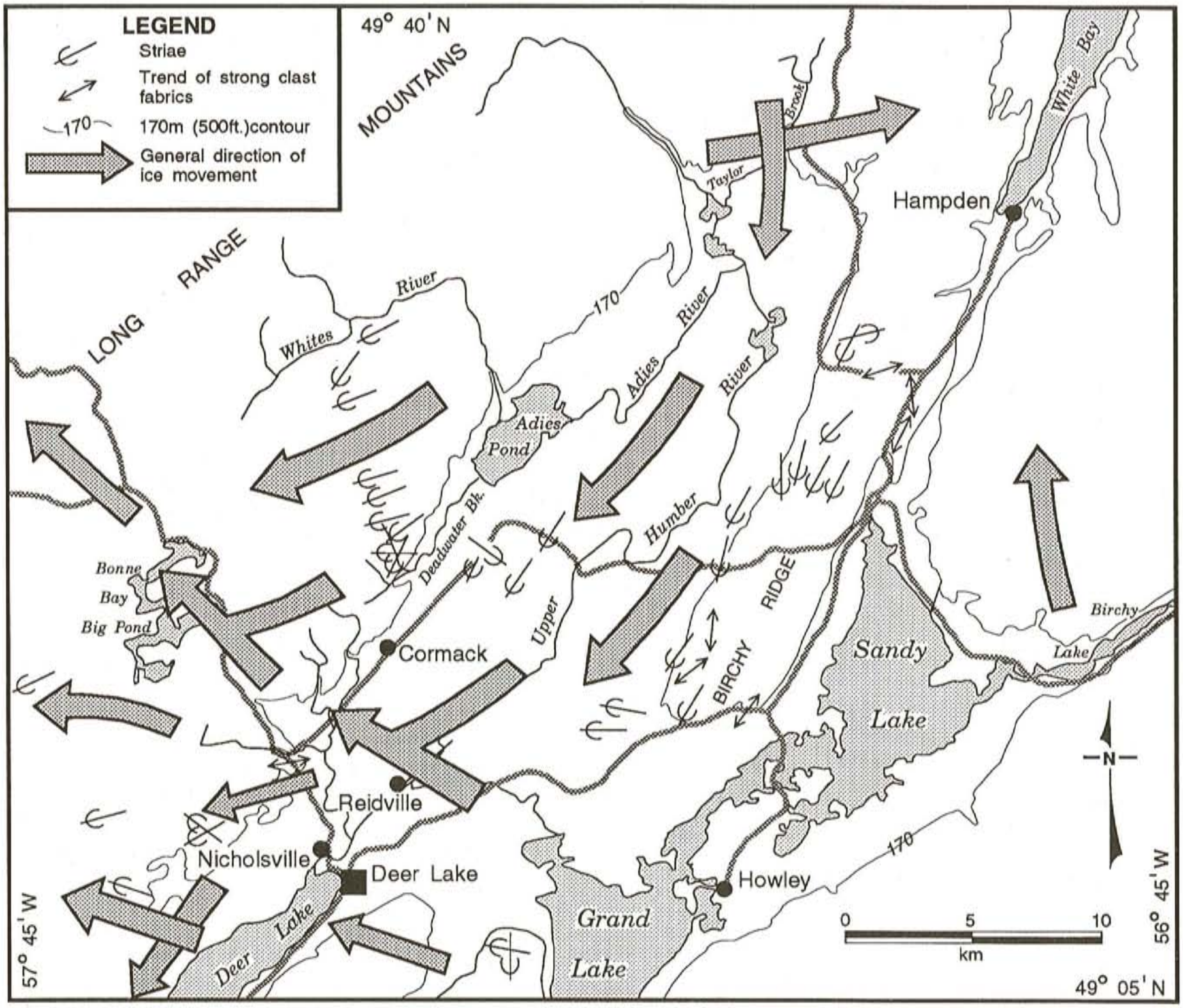


Figure 2. *Map showing location of places mentioned in text, and general direction of ice movement. Ice flow was mainly derived from striation measurement.*

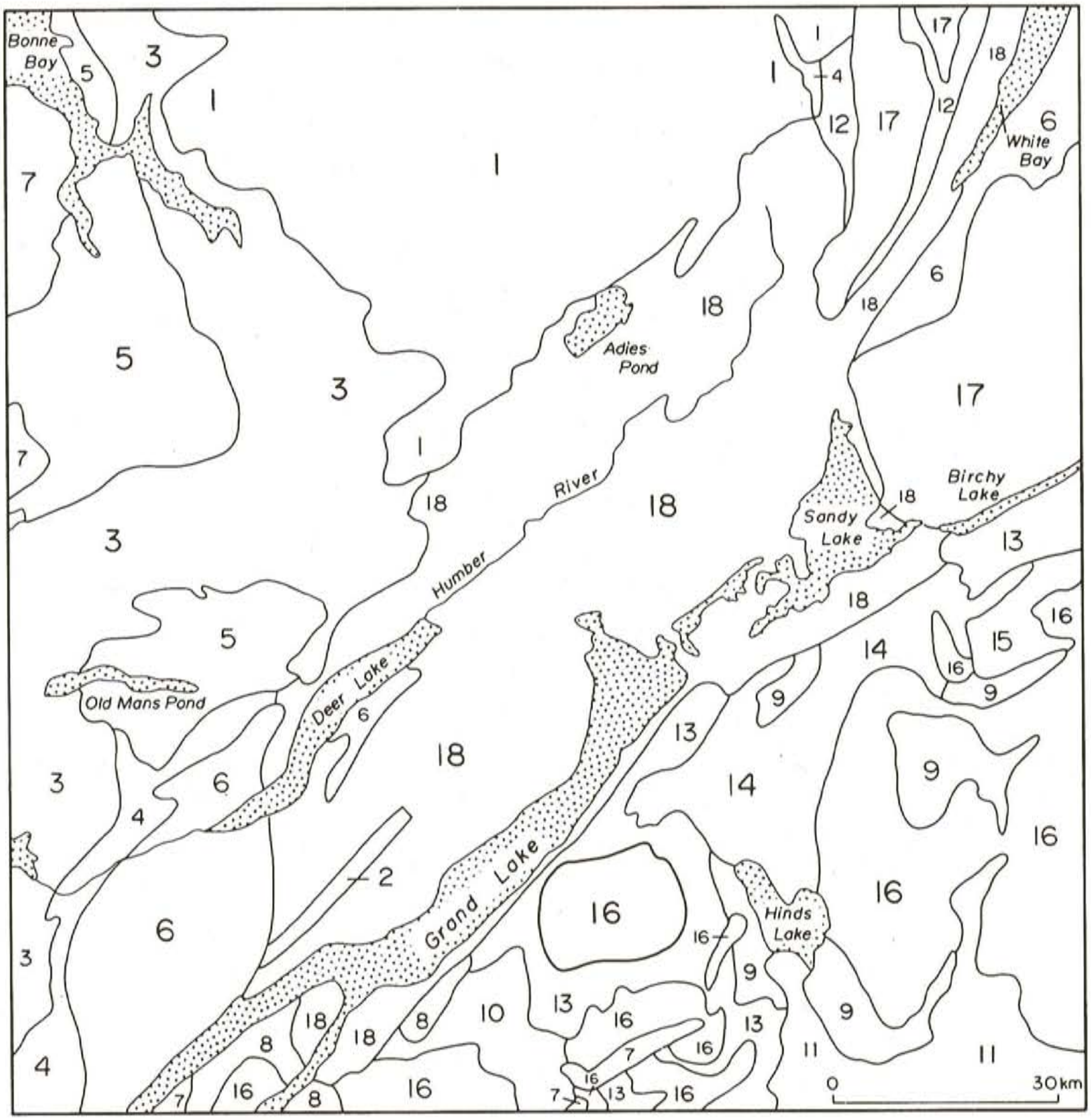
were made from natural or man-made exposures, including 28 backhoe test-pits. Sediment physical properties examined included texture, compaction, sedimentary structures and clast lithology (Plate 1). Clast fabrics were taken from 48 diamicton exposures. In each case, 25 elongate pebbles, with a length:breadth ratio of greater than 3:2 were measured. Results were plotted on a stereogram and analyzed using the Stereo™ software package for the Apple Macintosh microcomputer (MacEachran, 1990). Principal eigenvalues, which measure the strength of the fabric orientation, and K values, which estimate the distribution of the clast orientations (i.e., plunges), were produced using the method outlined by Woodcock (1977). Normalized eigenvalues (S1) can range between 0.33 (random) and 1.0 (unidirectional). K values of less than 1.0 suggest girdle distributions. In this paper, strong fabrics are defined as those with S1 > 0.6 and K > 1.0.

Matrix samples were taken from 133 locations for textural and possible geochemical analysis. Grain size and geochemistry results are not available, as yet. Samples (coarser than 64 mm/-6∅) of between 50 and 100 clasts were taken from 85 locations, and the rock types were identified.

RESULTS

ICE FLOW

Most ice-flow indicator sites only revealed one ice-flow direction. Sites were commonly from small bedrock surfaces where the preservation potential for striae was poor. In particular, soft Carboniferous sediments in the Humber River valley, were unsuitable for striation preservation, as they weathered rapidly when exposed at the surface. Also,



CARBONIFEROUS

18 *Carboniferous clastic sedimentary rocks*

SILURIAN

17 Wild Cove Pond and Gull Lake Intrusive Suites: *Biotite granite, granodiorite, diorite*

16 Topsails Intrusive Suite: *Rhyolite, one-feldspar and two-feldspar granites; some have peralkaline affinities*

15 *Quartz syenite, quartz monzonite, diorite, gabbro*

14 Hinds Brook Granite: *Massive to slightly foliated biotite granite to granodiorite*

13 Springdale Group: *Flow-banded rhyolite, tuff, basalt*

12 Sops Arm Group: *Felsic volcanic rocks, volcaniclastic rocks*

11 Buchans Group: *Pillow lava, volcaniclastic and felsic volcanic rocks, shale*

10 Rainy Lake Complex: *Gabbro, diorite, granodiorite*

ORDOVICIAN

9 Hungry Mountain Complex: *Moderately to strongly foliated gabbro to granite*

8 Glover Group: *Basalt, diabase, tuff and conglomerate*

7 *Gabbro, diorite, basalt*

6 Fleur de Lys Supergroup: *Pelite, psammite, schist; includes* Mount Musgrave Group

CAMBRIAN

5 *Grey to black shale and thin white quartzite*

4 *Crystalline limestone and phyllite*

3 *Shale, limestone, dolostone (includes* Reluctant Head Formation)

UPPER PROTEROZOIC TO LOWER CAMBRIAN

2 Hughes Lake Complex: *Metavolcanic rocks and granite*

PRECAMBRIAN

1 *Gneiss, paragneiss*

Figure 3. *Simplified bedrock geology map. Modified from Hyde (1984), Whalen and Currie (1988) and Williams and Cawood (1989).*

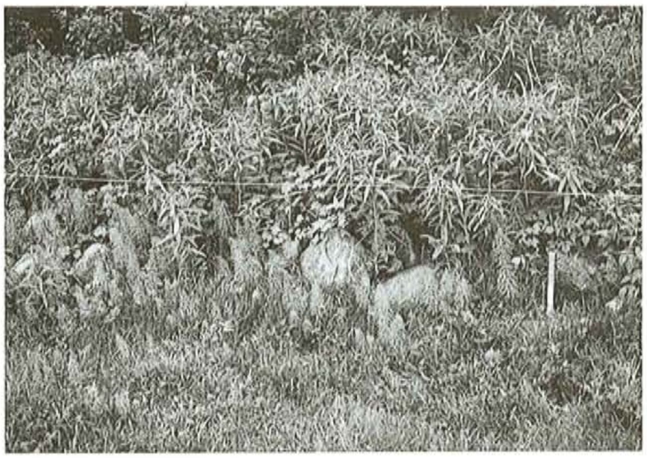


Plate 1. *A boulder pile adjacent to a ploughed field in Cormack. These piles were routinely examined as a representative sample of local rock types.*

Grenville basement bedrock, which is coarse grained, is unsuitable for striae preservation.

Ice flow over the Grenville basement was approximately west to southwestward, being southwestward in the Whites River valley area and westward on the highlands to the south of Adies Pond (Figure 2). In the upper Humber River valley, ice flow was southward down the valley (Plate 2). Several striation sites with no clear directional indicators were found along the western margin of the valley. No striae with similar directions were found farther east in the basin, suggesting that they were formed by a local flow originating in the Long Range Mountains. Ice-flow indicators on Birchy Ridge again show southward ice flow, although some westward-oriented striae are found on the eastern flank of the ridge. To the east of Birchy Ridge, ice flow was generally northward toward White Bay, although, as Taylor and Vatcher (1993) reported, some sites record a southward ice-flow event.

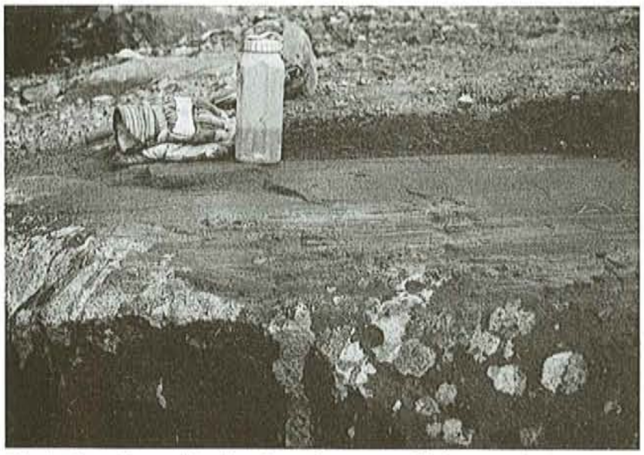


Plate 2. *Rat-tails developed on a pebble conglomerate in the Dancing Point area, upper Humber River. This site shows clear evidence of southward ice flow down the valley toward Deer Lake.*

Of the 48 clast fabrics recorded from diamictons only 13 had an Sl > 0.6 and K > 1.0, and could therefore be interpreted as representing ice flow. In all cases, directional trends were consistent with adjacent or regional striation sites. This suggests that these diamictons were emplaced by the last flow event to have affected the area, and that the diamictons are likely of subglacial origin.

CLAST PROVENANCE

The provenance of rock types from diamictons is consistent with the ice-flow directions outlined previously. In the area south and west of Birchy Ridge, and in the Sandy Lake lowlands to the east of Birchy Ridge, diamictons commonly contain clasts derived from the Topsail Hills. In particular, flow-banded and porphyritic rhyolites from the Silurian Springdale Group are found throughout the area. Similarly, Ordovician granites that outcrop between Hinds Lake and White Bay, and a Silurian yellow-weathered peralkaline granite, are all diagnostic of westward to northward ice flow from the Topsail Hills.

No clasts from the Topsail Hills were identified in the upper Humber River valley, north of a line running from the southern tip of Birchy Ridge through Cormack to the southern extension of the Grenville basement. In this area, clasts were either Carboniferous sediments, or gneisses, basalts and granitic gneisses from the Grenville basement.

On Birchy Ridge, diamictons contained mostly locally derived clasts. Some clasts from the Grenville basement were found on the west flanks and on the ridge crest. On the east side of the ridge, clasts derived from the Topsail Hills were found. This pattern is consistent with the deduced ice-flow record.

GLACIAL AND POSTGLACIAL SEDIMENTS

The sediments in the study area are dominated by glacial diamictons, although glaciofluvial and postglacial fluvial sediments are found adjacent to the modern Humber River and along tributary valleys. Much of the low-lying parts of the valley are covered by bog and fen.

Diamictons

Many of the characteristics of glacial diamictons within the field area, especially colour, texture and clast provenance are mainly controlled by the composition of the underlying bedrock. In the west, diamictons are thin and discontinuous over a rugged Grenville basement surface. The sediment is light greyish-brown (Munsell colour 10YR 6/2) when moist, to dark greyish-brown (10YR 4/2) when dry. The matrix is poorly consolidated, very poorly sorted and sand dominated, with about 10 to 15 percent silt and clay. Irregular shaped lenses of moderately sorted, medium to coarse sand are common beneath clasts. The clast component is mostly granules, cobbles and occasional boulders, all of local provenance; between 50 and 70 percent of the sediment is clasts. Clast fabrics are generally weak, and show girdle distributions. Some clasts are striated.

Within the upper Humber River valley, thicker glacial sediments are found overlying soft Carboniferous bedrock. Diamictons are light grey to light reddish-brown (Munsell colour charts, 10YR 7/1 to 5YR 6/3) when dry, and dark brown to reddish-brown (10YR 3/3 to 5YR 4/3) when moist. The diamicton matrix is poorly consolidated, very poorly sorted to unsorted, sandy to silty having 15 to 20 percent fines, including rare lenses of sorted sediment. Clasts compose about 40 to 50 percent of the sediment and are subrounded to subangular granules, cobbles and occasional boulders. Clast types and matrix colour varies rapidly over short distances, in response to changes in bedrock colour and texture. The dominant clast type is the underlying bedrock, which also determines matrix colour. Clast fabrics are generally weak with girdle distributions. Where strong fabrics are found, they are parallel to the local striation record.

Over Birchy Ridge, diamictons are thin and discontinuous. They are grey to light brownish-grey (2.5Y 6/0 to 2.5Y 6/2) when dry and dark greyish-brown to very dark greyish-brown (2.5Y 4/2 to 10YR 3/2) when moist. The matrix is poorly to moderately compact, very poorly sorted to unsorted, sandy to silty having 20 to 25 percent fines. Clasts are granules, cobbles and occasional boulders, subrounded to subangular, commonly of local provenance, except on the east side of the ridge where clasts originating in the Topsail Hills are found. Some clasts are striated. Clast fabrics are similar to those found elsewhere.

To the east of Birchy Ridge, in the area mainly underlain by Ordovician granites, diamictons are light grey to light brownish-grey (10YR 7/2 to 10YR 6/2) when dry, and dark greyish-brown to very dark greyish-brown (10YR 4/2 to 2.5Y 3/2) when moist. The matrix is poorly to moderately compact, very poorly sorted to unsorted, sandy to silty and having 15 to 20 percent fines. Irregularly shaped, moderately sorted medium to coarse sand lenses are common beneath clasts. Clasts are granule to cobble, plus occasional boulders and are dominated by local rock types. Some clasts are striated.

Within each area described, there is considerable local variation, related to changes in the underlying bedrock. There are no diagnostic characteristics of the diamictons found in the field area that unequivocally constrain them to a single depositional environment. The characteristics of the diamictons described previously and those found elsewhere in the study area are consistent with a glacial origin (Dowdeswell and Sharp, 1986; Dreimanis, 1988; Haldorsen and Shaw, 1982; Lawson, 1981; Shaw, 1982). The striated clasts, their subrounded form and clast fabrics are consistent with glacial transport. The presence of sorted layers beneath clasts suggests the presence of water during deposition. Clast fabrics are variable across the field area. Statistical data was graphed using the methods of Mark (1974) and Woodcock (1977) (Figure 4). Rappol (1985) suggests that fabrics that cluster on the top left of the graph are consistent with undisturbed basal melt-out and lodgement tills, whereas those that have girdle distributions and plot on the lower right are consistent with disturbed basal tills and debris flows. Figure 4 shows that disturbed and undisturbed sediments are found in the field area. In lodgement tills, well-oriented clast fabrics result from friction with the substrate, whereas in melt-out tills, clast fabric is inherited from the glacial transport process (Dreimanis, 1988). In both cases, the resulting fabric is commonly parallel to ice movement. The inconsistent, weak fabrics with girdle distributions suggest that some resedimentation following deposition may have occurred (Lawson, 1981). It is likely that both primary and secondary tills are found in the area. Precise depositional environments may be determined following further analysis.

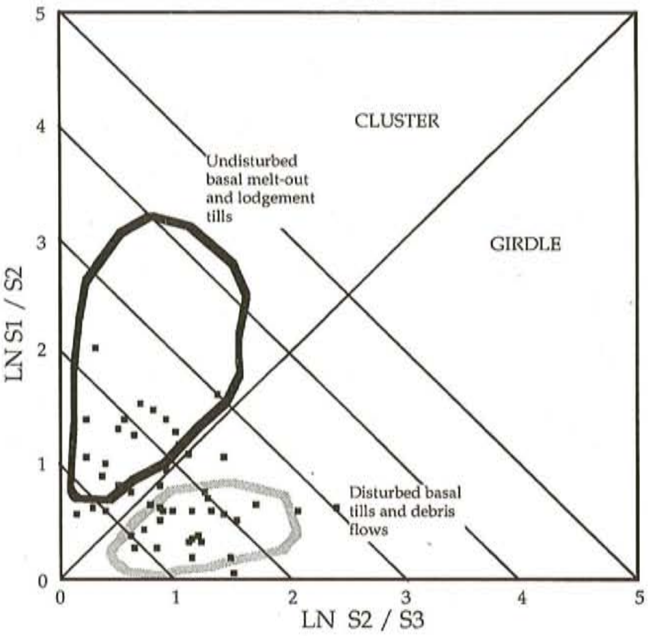


Figure 4. *Graph of fabric data following the method of Mark (1974), Woodcock (1977) and Rappol (1985). The graph may be used to suggest potential depositional environments for glacial diamictons in the area.*

Glaciofluvial

In the southern part of the study area, in the Rocky Brook valley (Plate 3), and in the area to the southwest of Adies Pond, glaciofluvial sediments are exposed. A series of esker ridges, up to 20 m high and 4 km long are found near Adies Pond (Plate 4). Sections expose mostly sand, with minor amounts of gravel, and sedimentary structures show water movement to the southwest. In the Rocky Brook valley, sandy glaciofluvial sediments form a 1 to 2 m veneer over diamicton. Both the Adies Pond and Rocky Brook sediments are currently the sites of small-scale aggregate extraction. In the area between Rocky Brook and Adies Pond, other small glaciofluvial deposits occur. They are associated with the numerous meltwater channels that are found along the western margin of the Humber River valley. Most meltwater channels are 10 to 20 m deep, 10 to 20 m wide with flat bottoms, and

Plate 3. *Rocky Brook from the air. In the central part of the photo a terrace is clearly visible. This is part of a delta sequence that formed during marine inundation in the area following deglaciation.*

Plate 4. *An esker near Adies Pond. This feature shows that ice retreated up the valley in this area. The esker is currently being exploited for aggregate.*

are approximately oriented down the valley, and were likely carved by meltwater from waning glacier ice within the Humber River valley.

Postglacial Sediments

Rhythmically bedded to massive silt and clay are common in the Humber River valley below about 50 m asl. In places they are exposed at the surface, but more commonly they occur beneath a veneer of postglacial fluvial sands. These muds are similar to those described farther down the valley (Batterson and Vatcher, 1992; Batterson and McGrath, 1993), and are consistent with deposition in the sea that inundated the Deer Lake basin during deglaciation (Batterson *et al.*, 1994). Fluvial sand and silt are common along the Humber River, and are exposed as either a veneer over diamicton, marine sediments or bedrock, or as thicker accumulations of overbank sediment. These sediments are commonly poorly drained and the Humber River flood plain is covered by extensive areas of fen and bog.

QUATERNARY HISTORY: PRELIMINARY OBSERVATIONS

Striae and clast provenance of diamictons suggest a major, single, south to southwestward phase of ice movement in the Humber River valley and over the southern part of the Grenville inlier to the west. This ice flow deposited glacial diamictons across the area whose colour and texture are controlled by the underlying bedrock. No evidence was found for ice-flow events crossing Birchy Ridge from the Topsail Hills or from the Long Range Mountains eastward across the basin or northward up the valley, in contrast to the findings of Rogerson (1979), Vanderveer and Sparkes (1982), and Batterson and Taylor (1990). The single, southward ice flow extended as far south as a northwest-trending line extending from the southern part of Birchy Ridge through Cormack to the southern extension of the Grenville basement. South and west of this line, evidence of ice originating in the Topsail Hills dominates. It is likely that the southward flow merged with the northwestward flow from the Topsail Hills and ice then flowed out to the coast through the Bonne Bay area. To the east of Birchy Ridge, evidence from ice-flow indicators and glacial sediments show a northward ice flow from a centre in the Topsail Hills. Birchy Ridge was likely occupied by glacier ice derived from the north, impeding the ability of Topsail Hills ice to overtop it.

During deglaciation, ice retreated up the Humber River valley and onto the Long Range Mountains. This is indicated by the orientation of eskers near Adies Pond and meltwater channels in the Cormack area. No evidence was found in the study area for the existence of the large proglacial lake described by Batterson *et al.* (1994), and it may therefore be speculated that the upper Humber River valley was ice covered during the existence of the lake to the south and east. However, the phase of marine inundation described by Batterson *et al.* (1994) is found in the upper Humber River valley in the form of muds below about 50 m asl adjacent to the modern Humber River. Following sea level fall, the Humber River established itself in the valley, reworking some of the existing sediments into fluvial deposits. Low-lying areas in the valley are commonly covered by bog and fen.

IMPLICATIONS FOR MINERAL EXPLORATION

Ice flow in the upper Humber River valley was generally southward, although the presence of ice on Birchy Ridge may have led to the flow of residual ice into the basin during deglaciation. Glacial diamictons are characteristically variable in texture and clast provenance, but these properties are mainly controlled by the underlying bedrock. Most diamictons contain greater than 90 percent local clasts and are therefore likely short transported (<2 km but generally between 1 and 2 km). The diamictons have properties consistent with deposition at the base of the ice, although the clast fabrics suggest some resedimentation. Nonetheless, the diamictons are a suitable sampling medium for mineral exploration. Care must be taken to avoid areas underlain by glaciofluvial, marine or fluvial sediments as their transport histories are unrelated to glacial flow.

IMPLICATIONS FOR LAND-USE PLANNING

Potential aggregate deposits occur in several areas throughout the upper Humber River valley. The deposits in the Adies Pond area are large, but are sand dominated and have clasts largely derived from the Grenville basement. Petrographic qualities are likely unsuitable for some applications e.g., concrete, but may be suitable for fill and other lower quality uses. Other deposits are small and are currently being exploited.

Forestry and farming are the two main land-based industries in the upper Humber valley, with farming in the Cormack area and forestry active in the Taylor Brook area, and being re-established in the Whites River valley. The effects of the removal of trees and the development of logging roads on surface-water runoff, and consequently, erosion are factors that should be incorporated into forest-management plans, particularly in areas of steep slopes and thin overburden. Similarly, the proper disposal of animal waste from farms needs to be monitored to avoid contamination of local rivers and water supplies. Some farms are underlain by permeable sand and gravel, whereas others have tills with numerous sand lenses. Contaminant migration toward streams and rivers is likely, and proper containment of animal waste is therefore required. This becomes more acute in areas adjacent to modern rivers, which have silt and clay exposed at, or near, the surface. These sediments are generally impermeable and therefore contaminant migration rates are probably rapid.

Most areas in the study area have no slope stability problems. However, several areas were noted to have experienced slope failures. Opposite the Viking Trail–Cormack intersection, along the West Rocky Brook valley, a small landslide occurred in 1993 (Plate 5). The stratigraphy here is 1 to 2 m of gravely sand over compact till. Failure was along the contact between the two units. Small landslides were also noted along the Humber River, mostly in areas underlain by marine clays. Construction should be avoided in areas adjacent to steep slopes underlain by poorly drained sediment.

Plate 5. *A small landslide opposite the Cormack intersection on the Viking Highway. The slide occurred during heavy rains when fluvial sands overlying a compact diamicton became saturated and failed along the contact.*

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REFERENCES

Batterson, M.J., Liverman, D.G.E. and Kirby, G.E.
1994: Glacial lake development and marine inundation, Deer Lake area, Newfoundland, Canada: topographically controlled deglaciation of an interior basin. Journal of Quaternary Science, Volume 8, pages 327-337.

Batterson, M.J. and McGrath, B.
1993: Quaternary geology of the Deer Lake and Pasadean map areas (NTS 12H/3 and 12H/4). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 103-112.

Batterson, M.J. and Taylor, D.M.
1990: Glacial history of the Humber River basin. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 90-1, pages 1-6.

Batterson, M.J. and Vatcher, S.V.
1992: Quaternary geology of the Corner Brook–Pasadena area (NTS 12A/13 and 12H/4). *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 92-1, pages 1-12.

Button, R.G.
1983: Soils of the Cormack–Deer Lake area, Newfoundland. Newfoundland Soil Survey, Report No. 5, 83 pages.

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

Dreimanis, A.
1988: Tills: their genetic terminology and classification. *In* Genetic Classification of Glacigenic Deposits. *Edited*

by R.P. Goldthwait and C.L. Matsch. A.A. Balkema, Rotterdam, pages 17-86.

Grant, D.R.
1972: Surficial geology, western Newfoundland. *In* Report of Activities, Part A. Geological Survey of Canada, Paper 72-1A, pages 157-160.

1989: Surficial geology, Sandy Lake—Bay of Islands, Newfoundland. Geological Survey of Canada, Map 1664A, scale 1:250 000.

Haldorsen, S. and Shaw, J.
1982: The problem of recognizing melt-out till. Boreas, Volume 11, pages 261-277.

Hyde, R.S.
1984: Geology of Carboniferous strata in portions of the Deer Lake Basin, western Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 79-6, 43 pages.

Kirby, G.E. and Bouzane, D.C.
1993: Soils of the Cormack extension area, Newfoundland. Report No. 93-2. Agriculture Branch, Department of Forestry and Agriculture.

Kirby, G.E., Guthrie, K.T.L. and Hender, F.
1992: Soils of the Sandy Lake—Bay of Islands area, western Newfoundland. Newfoundland Soil Survey, Report No. 11, 113 pages.

Lawson, D.E.
1981: Distinguishing characteristics of diamictons at the margin of the Matanuska Glacier, Alaska. Annals of Glaciology, Volume 2, pages 78-84.

Lundqvist, J.
1965: Glacial geology in northeastern Newfoundland. Geologiska Foreningens i Stockholm Forhandlingar, Volume 87, pages 285-306.

MacClintock, P. and Twenhofel, W.H.
1940: Wisconsin glaciation of Newfoundland. Geological Society of America Bulletin, Volume 51, pages 1729-1756.

MacEachran, D.B.
1990: Stereo™, the stereographic projection software program for the Apple Macintosh® computer. Distributed by Rockware Inc., Wheat Ridge, Colorado, U.S.A.

Mark, D.M.
1974: On the interpretation of till fabrics. Geology, Volume 2, pages 101-104.

Rappol, M.
1985: Clast-fabric strength in tills and debris flows compared for different environments. Geologie en Mijnbouw, Volume 64, pages 327-332.

Rogerson, R.J.
1979: Drift prospecting in the Deer Lake lowlands. Westfield Minerals Limited, Reidville, Newfoundland. Newfoundland Department of Mines and Energy, Mineral Development Division. Unpublished report, 12 pages, Open File 12H (559).

Shaw, J.
1982: Melt-out till in the Edmonton area, Alberta, Canada. Canadian Journal of Earth Sciences, Volume 19, pages 1548-1569.

Taylor, D.M. and Vatcher, S.V.
1993: Late Wisconsinan deglacial ice-flow patterns in west-central Newfoundland. *In* Current Research. Newfoundland Department of Mines and Energy, Geological Survey Branch, Report 93-1, pages 175-179.

Taylor, D.M., St. Croix, L. and Vatcher, S.V.
1991: Newfoundland Striation Database. Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File NFLD (2155).

Vanderveer, D.G.
1982: Quaternary mapping—upper Humber River area. *In* Current Research. Newfoundland Department of Mines and Energy, Mineral Development Division, Report 82-1, pages 192-194.

1987: Surficial and glacial geology for the Deer Lake-Hampden area, Newfoundland (NTS 12H/3, 6, 10, 11). Newfoundland Department of Mines and Energy, Geological Survey Branch, Open File 12H/0945.

Vanderveer, D.G. and Sparkes, B.G.
1982: Regional Quaternary mapping: an aid to mineral exploration in west-central Newfoundland. *In* Prospecting in Areas of Glaciated Terrain-1982. *Edited by* P.H. Davenport. Canadian Institute of Mining and Metallurgy, Geology Division, pages 284-299.

Whalen, J.B. and Currie, K.L.
1988: Geology, Topsails Igneous Terrane, Newfoundland. Geological Survey of Canada, Map 1680A, scale 1:200 000.

Williams, H. and Cawood, P.A.
1989: Geology, Humber Arm Allochthon, Newfoundland. Geological Survey of Canada, Map 1678A, scale 1:250 000.

Woodcock, N.H.
1977: Specification of fabric shapes using the eigenvalue method. Bulletin of the Geological Society of America, Volume 88, pages 1231-1236.