THE GLACIAL GEOMORPHOLOGY OF WEST-CENTRAL NEWFOUNDLAND: HALLS BAY TO THE TOPSAILS

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THE GLACIAL GEOMORPHOLOGY OF WEST-CENTRAL NEWFOUNDLAND; HALLS BAY TO THE TOPSAILS

by

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science.

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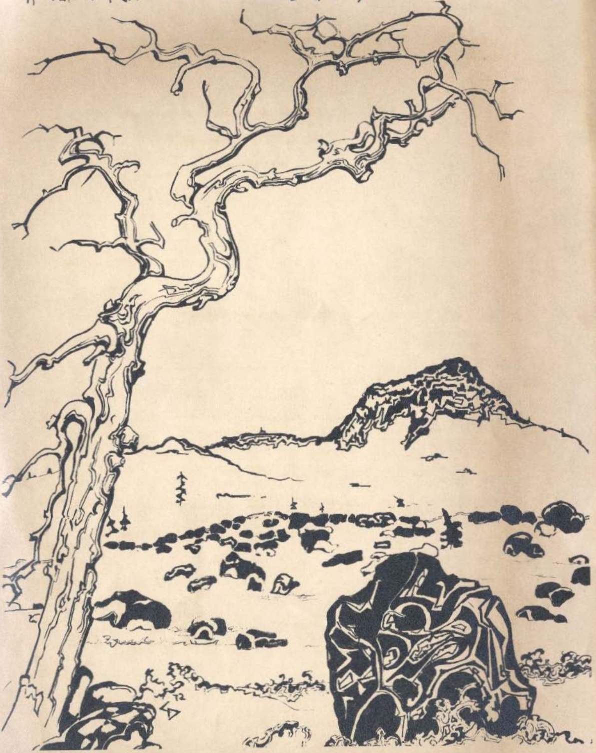
August 1973

THE FORETOPSAIL - CENTRAL NEWFOUNDLAND



ABSTRACT

THE GLACIAL GEOMORPHOLOGY OF WEST-CENTRAL NEWFOUNDLAND; HALLS BAY TO THE TOPSAILS

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During the late Wisconsin glaciation, ice flow in west-central Newfoundland was to the north-northeast and northeast, sub-parallel to structural lineations. Constructional forms at this stage included drumlins, drumlinoid forms and ribbed moraine.

The coast of Halls Bay was deglaciated about 12,000 B.P. in a relatively short period during which glaciomarine deltas were formed at Springdale, Dock Point, White Point, Barney's Brook, West Pond, South Brook and Sugarloaf; the latter three being remnants of a continuous terrace. Subsequent net isostatic and eustatic change positioned the deltas approximately 250 feet (75 meters) above present sea level.

After the initial coastal stage of deglaciation, ice withdrew inland by stagnating in the valleys and lowlands leaving ridged ablation moraine and kettle topography.

Ice receded in this manner to a plateau level 19 miles (30 kms.) from the coast, where a pause in retreat occurred. During this stage a series of recessional moraines was built and a zone of eskers formed.

near Barney's Brook and southeast of Sheffield Hill. Surficial crevasse fillings are also found within this zone. A final, topographically controlled flow into the Kitty's Brook - Chain Lakes valley system followed by stagnation, resulted in the fabrication of a series of recessional-ablation moraines.

Last ice in the field area was situated to the southwest of Gaff Topsail and is evidenced by an area of hummocky, disintegration moraine.

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ACKNOWLEDGEMENTS

The writer wishes to thank several individuals and organizations who aided in the preparation and writing of this thesis.

Mr. R. J. Rogerson, Department of Geography, Memorial University of Newfoundland, supervised the research and writing of the thesis and provided advice that was of benefit at all stages of preparation.

Dr. D. R. Grant of the Geological Survey of Canada in Ottawa supplied logistical support early in the field season (through a D.R.E.E. - D.M.A.R.* glacial geology-geochemical survey), and advice during the preliminary thesis preparation including permission to use radiocarbon date G.S.C.-1733.

Dr. J. B. Macpherson, Department of Geography, Memorial University of Newfoundland, gave counsel in the initial planning stages of the thesis and ongoing discussion throughout the study.

Dr. R. Slatt, Department of Geology, Memorial University of Newfoundland, advised the writer on sedimentological techniques and made laboratory facilities available for the analyses.

Mr. M. Crane, Department of Geography, Memorial University of Newfoundland, advised in the preparation of diagrams and aided in the reproduction of the glacial map.

Ms. C. Deorksen contributed her excellent sketch of the Foretopsail which appears as the frontispiece of the thesis.

Newfoundland and Labrador Forestry Service provided facilities including airphotos for an initial analysis of the terrain.

Canadian National Railways arranged transportation in the

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* For these and other abbreviations, see Appendix 3, p. 131.

southern sections of the area, without which the field work involved in Chapters III and IV would have been difficult to accomplish.

INTRODUCTION

Objectives

The raised Pleistocene deltas at Halls Bay and the inland glacial features of west-central Newfoundland have been described by several authors in the past fifty years. Much of the early literature is qualitative in its approach and tends only to identify problem areas and speculate on solutions. A detailed analysis of the morphology and chronology of the various deposits is required to complement related studies of the north coast (Grant, 1969, 1970) and west coast (Brookes, 1969) and to determine in particular whether the inner-outer drift zones described by Jenness (1960) in eastern Newfoundland and by Lundqvist (1965) in the field area do in fact exist. Lundqvist also raises the possibility of invasion of the Halls Bay area by early Wisconsin Labrador ice, which he bases on evidence from the Jenness 1960 isobase map and southeast-oriented striae.

The present study involves an overall air photo analysis and the production of a glacial map plus the detailed analysis of three specific problem areas defined by previous literature and the preliminary air photo interpretation. It is hoped that a more rigorous approach than formerly attempted will provide some specific answers, or will at least re-define problems with new information.

Location of Study Area

The field area of 624 square miles (1597 square kms.) is located in west-central Newfoundland and extends from Springdale in the north to

PLATE 1. THE FIELD AREA

1. Halls Bay
2. Springdale
3. Town of South Brook
4. Howley
5. Burnt Berry Pond
6. West Pond
7. South Pond
8. Chain Lakes
9. Little Sandy Pond
10. Gull Pond
11. Indian Brook

For completer identifications refer to the Glacial Map, Chapter V. The light area between Chain Lakes and Little Sandy Pond shows a recent snowfall on the High Central Plateau.

SCALE: 1 CM. = 10 KMS.
1 INCH = 16 MILES

EARTH RESOURCES TECHNOLOGY SATELITE IMAGE 5, 11, 72 just south of the C. N. R. line at the Topsails on the High Central Plateau (Plate 1). Twenhofel and MacClintock (1940) identify the plateau as "that part of the Atlantic Upland between the Grand Lake - White Bay Basin and a line extending from Hall[s] Bay to the head of Red Indian Lake" (p. 1702).

To the southwest, a section of the upper Kitty's Brook and Chain Lakes drainage system is included in the field area.

Organization of the Thesis

Chapter I serves as an introduction to the field area; the topography, general bedrock geology, drainage, climate, vegetation, access and human geography of west-central Newfoundland are discussed briefly.

Chapter II describes the Springdale and lower Halls Bay delta systems. It examines the various unconsolidated deposits in Indian Brook valley and several marine shell samples found in the area. A description of the deglaciation process and chronology of the coastal section of the field area is tendered.

Chapter III is concerned with a zone of esker-like features in the south-central portion of the study area that were identified by Lundqvist (1965) as open crevasse fillings and " of limited value to interpreting ice flow " (p. 296). A morphological and textural analysis was conducted on specific deposits and a reinterpretation based on these results is presented.

Chapter IV examines a series of ridges located in the southwest corner of the field area at Kitty's Brook and Chain Lakes. The features were briefly described by MacClintock and Twenhofel (1940) as being recessional moraines. They are a significant part of the overall study since it is deduced that last ice melted in this vicinity and, as such, the deposits might indicate a late, topographically controlled ice flow. Till fabric and textural analyses were completed and a method of formation is suggested for the deposits.

Chapter V presents a glacial map of the area based on a detailed interpretation of 1:15,840 and 1:50,000 air photos. An explanation of the legend is included and it is hoped that this, in conjunction with the map, will be of some practical value in future glacial chronologies and glacial drift studies for mineral exploration.

Chapter VI summarizes the work presented in the previous chapters and synthesizes a chronology of the last stages of Wisconsin glaciation and the sequence of deglaciation. Several comments are made pertaining to previous studies and a note is made of possibilities for future research within the field area and in tracts peripheral to it.

Techniques, Field Instruments and Analyses are discussed in Appendix I. They outline the basic procedures used in analyzing sediment characteristics and landforms discussed in the various chapters.

A brief second appendix presents graphs of the unconsolidated sediment data plotted in several texturally descriptive combinations.

Logistics

The initial part of the field season (May) was spent in Springdale and around the lower Halls Bay area. Travel was by car while foot traverses were completed to less accessible areas. Camp was established near Riverhead Brook for study around lower Halls

Bay and the Department of Mines base camp was used for a period of about three weeks while in Springdale and vicinity. The writer was employed for a period during the field season with a Department of Regional Economic Expansion - Department of Mines, Agriculture and Resources, glacial drift project under the direction of Dr. D. R. Grant of the Geological Survey of Canada, (Grant 1973).

The second part of the field season involved work on the High Central Plateau. Access to the Kitty's Brook - Chain Lakes area was by C.N.R. "speeder" from Howley; camp was set up near the southern end of Chain Lakes and foot traverses were completed over a radius of about three miles. Various stops were made along Kitty's Brook valley on the return journey.

The Topsails area was approached from the east. Again a C.N.R. "speeder", this time from Millertown Junction, was the initial mode of transport. From Gaff Topsail, the area was covered extensively on foot with a base camp being established at Foretopsail from which traverses were made to Barney's Brook and Sheffield Hill (Chapter IV).

A final foray was made around Springdale, Halls Bay and the major valleys in the northern part of the field area. All secondary roads were driven to field check the air photo analysis. Several of the private roads, that is, to Gull Bridge Mines and the Price (Newfoundland) Pulp and Paper Ltd. road to Dawes Pond and Lake Bond were also covered to check interpretations further.

CHAPTER I

THE FIELD AREA

Topography

The field area (Fig. 1-1 and Plate 1) may be generally divided into two physiographic regions; (1) the Halls Bay - Gull Pond lowlands, (2) the High Central Plateau.

1. The Halls Bay - Gull Pond area is characterized by a north-northeasterly structural-topographic trend which is emphasized by glacially scoured bedrock ridges. Halls Bay proper is a fjord with a 150 fathoms (270 meters) threshold close to shore. In this northern section of the field area, summit elevations slope from 750 feet (225 meters) southwest of Gull Pond to about 500 feet (150 meters) just north of Springdale. Prominent bedrock peaks occur at 456 feet (137 meters) at Springdale and 855 feet (257 meters) at Rowsell Hill behind the town of South Brook.

Neale and Nash (1963) map a tight synclinal axis following the western shore of West Pond in a northeasterly direction to the mouth of Indian Brook. Within the central section of the Halls Bay - Gull Pond lowlands, the authors describe a broad synclinal trough with its axis roughly paralleling the upper reaches of West Brook. The synclinal folds reach altitudes of 800 feet (240 meters) northeast of Sheffield Lake and 974 feet (292 meters) at Nutmeg Hill northwest of Gull Pond. Elevations of 500 feet (150 meters) are typical of the axial area of the trough.

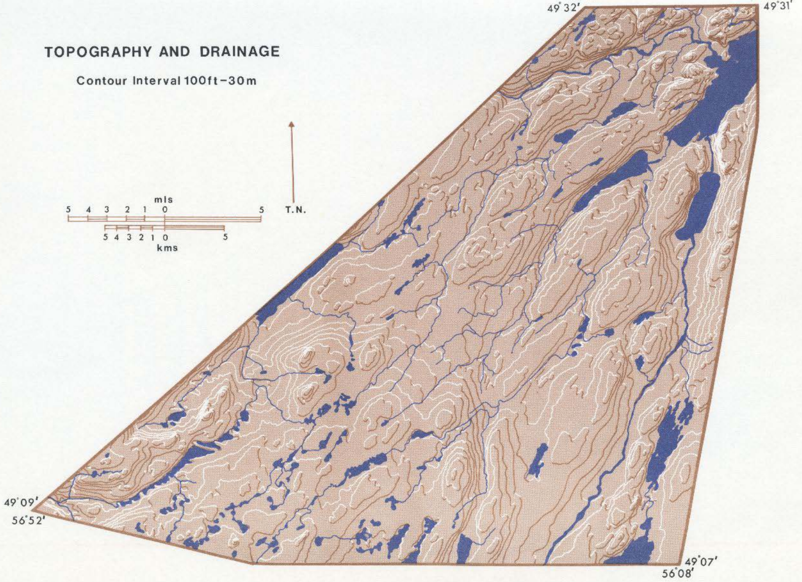

TOPOGRAPHY AND DRAINAGE
Contour Interval 100ft-30m
mls
5 4 3 2 1 0 5
5 4 3 2 1 0 5
kms
T.N.
56°15′
49°32′
56°00′
49°31′
49°09′
56°52′
49°07′
56°08′

Figure 1-1

2. The second topographic subdivision includes the area south of Gull Pond in the east, Sheffield Lake in the west and extends beyond the southern limit of the field area. This is the High Central Plateau as described by Twenhofel and MacClintock (1940). The boundary between the two physiographic units is sharply defined by a break in slope at the 900 feet (240 meters) contour. Solifluction lobes and thick drift cover the break in slope. Plateau elevations slope gently from 1500 feet (450 meters) in the south to 1000 feet (300 meters) at the northern edge of the plateau. West-east tilt is from 1500 feet (450 meters) near Chain Lakes to 800 feet (240 meters) at Little Sandy Pond. The terrain between Little Sandy Pond and the eastern border of the field area may be included in the first physiographic subdivision.

The Topsails are prominent hills on the High Central Plateau which are referred to as monadnocks by Twenhofel and MacClintock (1940). The authors propose that before glaciation the ridges were probably "high places," with graded slopes, on the plateau, and that jointing in the granite bedrock facilitated plucking which led to their becoming crags. In view of their description of the Topsails being formed by glacial action rather than by long term circumdenudation, it seems rather inappropriate that they refer to the peaks as monadnocks. The Topsails are all elongated 040-045 and rise 200-250 feet (60-75 meters) above the surrounding topography. Sheffield Hill may be included with the granite Topsails though it is located further west. Elevations of the peaks are as follows: Sheffield Hill, 1639 feet (492 meters); Foretopsail Hill, 1610 feet (483 meters); Main Topsail, 1822 feet (547 meters); and Gall Topsail, 1650 feet (495 meters).

General Bedrock Geology

The bedrock geology of the field area has been mapped in part by Kalliokoski (1953) and more completely by Neale and Nash (1963). The following generalizations have been made from Neale and Nash; numbers on Figure 1-2 indicate bedrock type and are identified in the text.

The High Central Plateau is underlain by Devonian Topsails granite (18); pale red equigranular granite, quartz, monzonite and granodiorite. The central synclinal troughs including the area as far north as Springdale consist of the Springdale Group (15), that is, zones of (a) red sandstone and conglomerate, red and greenish grey shale and minor limestone, (b) red sandstone, conglomerate, limy siltstone and shale, (c) silicic flow and pyroclastic rocks and (d) basic flow and pyroclastic rocks. The Ordovician Lush's Bight Group (5), located north of Springdale, is formed of schistose basalt and andesite, minor pyroclastic rocks, greywacke, slate and chert. The area around Gull Pond is part of the Ordovician Exploits Group (6); the Roberts Arm Formation includes basalt, minor pyroclastic rocks, silicic flow rocks and basic sills. The Crescent Lake Formation contains shale, minor chert, greywacke and rhyolite. The area between Little Sandy Pond and Halls Bay comprises various patches of granite, granodiorite and syenite similar in age to the Topsails granite (18), as well as Devonian quartz diorite, diorite and gabbro (17). Southwest of Sheffield Lake there is a zone of Silurian andesite, basalt flow and pyroclastic rocks (11).

The field area is part of the Central Mineral Belt of

Figure 1 - 2

Legend

Number of rock type	Group or general description
5	Ordovician - Lush's Bight group.
6	Ordovician - Exploits group
11	Silurian andesite
17	Devonian diorite
18	Devonian Topsails granite

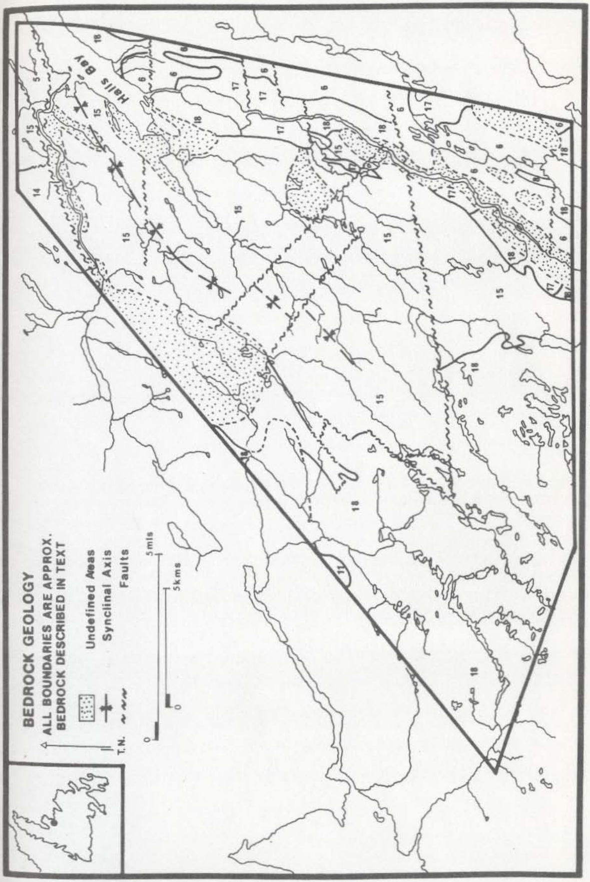

BEDROCK GEOLOGY
ALL BOUNDARIES ARE APPROX.
BEDROCK DESCRIBED IN TEXT
Undefined Areas
Synclinal Axis
Faults
T.N.
0
5mls
0
5kms
Halls Bay

Figure 1-2

Newfoundland, (Rose *et al.*, 1970), and as such has been subject to extensive mineralogical exploration by the American Smelting and Refining Company in the south and British Newfoundland Exploration Limited and Noranda Exploration towards the northeast. While a number of shortlived mining operations were located in the Belt, Gullbridge Mines at Gull Pond was the only one within the field area. Neale and Nash (1963) state that a headframe and mining plant were first constructed in 1956 but after an initial run, production ceased in 1971. Rose *et al.* (1970) note that the occurrence of sulfide minerals on Gull Pond has been known since 1905. Pyrrhotite, pyrite, chalcopyrite and magnetite as well as quartz, chlorite, sericite, biotite, cordierite and tremolite-actinolite occur in lenticular masses in sheared zones of the Roberts Arm Group. Many of the above minerals are found in erratic boulders of unknown provenance and have been studied by Boliden Mining Company of Sweden in an attempt to discover their specific origin.

Drainage

For the most part drainage in the central and northern sections of the field area is to the northeast in drift-filled valleys following structural lows (Fig. 1-1 and Plate 1). Streams are not well incised in their courses except for Indian Brook which is deeply entrenched and flows over bedrock in its lower sections. Between the T.C.H. and Springdale, meander scars are visible over a broad terrace. These however may relate to a much larger deglacial river flowing within Indian Brook valley, and graded to a higher sea level.

On the High Central Plateau the drainage pattern is deranged (typical of glaciated old plateaus) though a haphazard northeast trend predominates across the bouldery surface. Near the southwest corner of the plateau, flow is southwest down Kitty's Brook valley and to the northwest in the upper Chain Lakes valley to Sheffield Lake. A drainage divide from which water flows southeast to Red Indian Lake is located just south of the field area.

Although ponds are numerous throughout the field area, most are small, less than 2 square miles (5 sq. kms.) in area. The largest, West Pond 3.4 square miles (8.8 sq. kms.) and South Pond 3.6 square miles (9.1 sq. kms.) are confined to deep valleys with areas of thick till and glaciofluvial material. To the west and east, Sheffield Lake and Gull Pond are located in structural basins. The Chain Lakes system, at the southwest corner of the area, is dammed by a series of morainal deposits (see Chapter IV).

Vegetation

The vegetation of west-central Newfoundland can be related to physiographic subdivisions. The plateau level is devoid of forest cover; vegetation consists of alder thickets (*Alnus*) and occasional patches of stunted white spruce (*Picea glauca*) in poorly drained, sheltered areas. Generally, plant species are limited to low bushes on the morainal cover and grasses on the numerous string bogs. On the terrain north and below the High Central Plateau, where drainage is well defined and soils more fully developed, forest cover is extensive.

Damman (1964) states that balsam fir (*Abies balsamea*) occupies all soils except the extremely dry and wet ones in undisturbed forests of central Newfoundland. These are covered with either black spruce *(Picea mariana)* or alder. Hardwood forests are always of fire origin and contain white birch, *(Betula papyrifera* Marsh) trembling aspen, *(Populus tremuloides)* and pin cherry *(Prunus pennsylvanica)*. Black spruce is also a dominant burn species and is prominent around Halls Bay.

Climate

Obtaining long term climatic data for the field area is difficult since no stations have been in operation for extended periods on this section of the island. Long term statistics from Buchans (50 miles (80 kms.) southwest of Springdale) are used as being indicative of climatic conditions on the High Central Plateau and monthly averages for Springdale (1971) describe coastal conditions (Table 1-1). While the two groups of figures are not strictly comparable, they do suggest variations in climate between the two main zones of the field area.

Precipitation is well distributed throughout the year with a slight maximum in the fall: November generally being the wettest month, (Hare, 1952). Winters are relatively mild, though colder on the inland plateau. Snowfall is moderately heavy over the whole field area with more than 100 inches (254 cms.) being experienced on average. Total annual precipitation is slightly higher at Buchans, 36.7 inches (91.8 cms.) compared with 34.7 inches (90.8 cms.) at Springdale. August is slightly warmer than July at the coast but inland the reverse is true. This is probably a result of lingering Arctic ice and the Labrador Current which delays or moderates summer warmth on most of the coastal sections of the island.

Hare (1952) states that the vegetative season starts between the 15th-20th of May, more than a month behind Montreal or Ottawa. The frost free season is about 100 days, from early June to mid September, in the southern part of the field area; in the coastal zone the season is probably longer, again due to the modifying marine influence.

Access and Human Geography

Access to the perimeters of the field area is excellent. The Trans Canada Highway follows the east termination and northerly margins and the Canadian National Railway cuts the southern boundary; access to the plateau is available from either Howley in the west or Millertown Junction in the east. Both settlements were used as starting points on traverses to the High Central Plateau.

Springdale, the largest town in the field area and the economic hub of Green Bay, is located 73 miles (117 kms) west of Grand Falls and 118 miles (189 kms.) east of Corner Brook by road. Until recently, Springdale was a dormitory town for a population working at Whalesback and Little Bay mines which have since been closed. Employment in the town is generated by service establishments for the populus of Green Bay, a provincially operated Vocational School, a D.M.A.R. geochemical laboratory and several diamond drilling operations. Much of the population is employed in the woods operations of Price (Newfoundland) Pulp and Paper and Bowaters, Ltd. both of which have extensive cutting rights in the field area. Springdale also provides a link with Notre Dame Bay and Labrador on the C.N.R. coastal boat service.

TABLE 1-1

CLIMATOLOGICAL RECORDS FOR BUCHANS AND SPRINGDALE

Buchans Long Term (1942-1971) Climatological Record

	J	F	M	A	M	J	J	A	S	O	N	D
Mean Daily Temp °F.	16.9	15.7	21.0	31.5	42.1	52.6	60.0	59.0	51.8	41.5	32.5	22.2
" Max. " " "	23.3	22.5	28.1	38.1	50.9	62.5	70.0	67.7	60.4	48.4	38.1	28.3
" Min. " " "	10.5	8.9	13.8	24.8	33.3	42.6	49.9	50.3	43.2	34.5	26.9	16.0
Snowfall (inches)	23.2	21.0	18.1	9.6	1.3	0.9	0	0	0	1.7	9.9	20.6
TOTAL PPTN.	3.31	2.92	2.35	2.10	2.42	2.60	2.94	3.68	3.57	3.33	4.11	3.40

Springdale 1971 Climatological Record

	J	F	M	A	M	J	J	A	S	O	N	D
Mean Daily Temp °F.	20.6	15.8	30.0	37.9	50.1	53.8	62.0	65.3	52.8	4.24	35.6	16.1
" Max. " " "	24.8	28.1	37.9	44.6	60.3	63.8	73.3	72.9	62.3	49.6	42.5	25.6
" Min. " " "	13.9	13.5	22.1	31.2	39.8	43.8	50.7	57.7	43.3	35.1	28.6	6.5
Snowfall (inches)	39.8	6.5	30.0	8.0	0	0	0	0	0	0	13.0	19.8
TOTAL PPTN.	4.21	1.46	3.05	3.46	1.65	2.78	2.76	3.97	3.03	2.19	4.04	1.13

South Brook, located 15 miles (24 kms.) south of Springdale was a shipping center for copper concentrate from the now defunct Gullbridge Mines. Its economic viability is derived from the logging operations of private contractors for the paper mills at Grand Falls and Corner Brook.

The Halls Bay area is presently undergoing some small economic revitalization with the development of its natural tourist facilities. Both provincial and private campsites have been opened during the past few years.

CHAPTER II

THE HALLS BAY DELTA SYSTEMS

Introduction

Halls Bay contains a number of raised Pleistocene deltas at various locales from Springdale in the north to South Brook and West Bottom at the head of Halls Bay. The deltas have been described by Lundqvist (1965) who proposes a general scheme for construction of the system following the Jenness (1960) theory of an inner-outer drift zones. He hypothesizes individual ice lobes protruding from an inland ice sheet and filling the valleys which feed into Halls Bay. Jenness argues that the inner-outer drift zones in northeast Newfoundland resulted by either a still-stand at a position of discontinuous end moraine or a final major advance from farther inland. He identifies the outer drift zone (coastal side) by ground moraine and the inner drift zone by "slightly younger eskers, kames and ground moraine" (p. 161). Supposedly, final melting produced the glaciofluvial deposits that radiate coastward to form deltas.

Despite the Jenness argument, Lundqvist mentions that no end moraine could be distinguished at the zone boundary in west-central Newfoundland. To substantiate the theory he describes the inner-outer boundary on the basis of thick, almost continuous, inner drift and thin outer drift where--". . . bedrock structure is clearly visible through the thin overburden, even where bedrock is not exposed" (p. 299). The deltas at Springdale and South Brook, as well as Kings Point and Botwood (the latter two being located outside the field area) are interpreted by Lundqvist as being contemporaneous and part of the boundary between inner and outer drift, since such a halt would allow the deposition of much thicker glaciofluvial sediments than would a continuous recession of the ice. The possibility of the deltas being deposited in ice-dammed waterbodies as described by Jenness is also suggested by Lundqvist.

Jenness proposes a series of isobases from elevations of former marine levels, based on his work on the northeast coast and that of Flint (1940) for the west coast. He assumes contemporaneous deglaciation for the whole north coast, although unproven, and envisages a 0 isobase of no net postglacial emergence passing through the isthmus of Avalon, 100 feet (30 meters) of uplift at Eastport in Bonavista and 250 feet (75 meters) at Halls Bay relative to present sea level. Since rebound is proportional to ice thickness, the values indicate late Wisconsin ice concentrated over the west-central section of the island.

A glacial study completed by Damman (in Wilton, 1957) portrays the Halls Bay delta deposits as being similar in origin to those of St. Georges Bay (MacClintock and Twenhofel (1940) and Brookes (1969)). The process as presented in the Wilton report would have an extensive glaciofluvial period with a readvance of ice depositing till 1-2 feet (0.3-0.6 meters) thick on top of the deltas. Damman continues by hypothesizing a gradual isostatic rise of the land which resulted in rivers flowing into Halls Bay cutting their way through old deltaic deposits, leaving some parts of the deltas as high terraces.

Several authors have studied the Halls Bay deltas as individual units within the system. MacClintock and Twenhofel (1940) describe the Springdale terrace as an emerged Pleistocene delta of sand and gravel that has scattered boulders strewn on top at 260 feet (78 meters) a.s.l. They depict the delta as being over 1500 feet (450 meters) long, 800-900 feet (240-270 meters) wide, about 200 feet (60 meters) thick and resting against a bedrock hill northwest of Springdale which is situated on a 30 feet (9 meters) terrace at the foot of the main scarp. The authors state that the deposit is an eroded remnant of a once extensive deposit of much-pitted outwash that filled all the valleys draining into Halls Bay and that terraces in the South Brook valley at 15, 55 and 240 feet (4.5, 16.5 and 72 meters) are fragmented remains of the continuous "Halls Bay delta." The lower two terraces are wave-cut in drift while the third is the original depositional surface of the delta.

The Springdale delta is also described by Lundqvist (1965). He suggests it was formed, particularly in its eastern section, by meltwater flowing south, noting that the beds dip slightly away from the hills northwest of the town. Similarly, bedding in other deposits in the area slopes outward from local centers. Unlike MacClintock and Twenhofel, Lundqvist visualizes the 240 feet (72 meters) terrace at South Brook as being an isolated terrace formed in front of West Brook valley.

Since theories and morphological descriptions abound for the Halls Bay deposits, an attempt has been made to quantify and qualify the characteristics of the system and present some conclusions as to their method of formation.

THE SPRINGDALE DELTA

Morphology

In actual size the Springdale delta is somewhat larger than described by MacClintock and Twenhofel (1940). On its eastern face the delta is over 3600 feet (1080 meters) long, while the southwest scarp (Plate 2) is 2500 feet (750 meters) in length from the bedrock cliff northwest of the town to its southern spit-like extremity.

The highest point on the delta surface was measured at 252 feet (75.6 meters) a.s.l. The surface of the deposit is hummocky and shows some dissection. Near the eastern edge of the scarp there is a kettle remnant at 200 feet (60 meters).

Several terraces and raised shorelines are visible on the eastern face of the delta (Plate 3). A weakly developed terrace is visible, which varies in elevation from 209 feet (62.7 meters) at the top southern end, to 220 feet (66 meters) further east. Towards the extreme south-east end of the delta a reading of 181 feet (54.3 meters) was obtained on a raised shoreline, while further north near Huxter's Brook a height of 150 feet (45 meters) was measured at the edge of the scarp. This variation in height may be a result of erosion by the brook at location 2 (Figure 2-1).

As previously mentioned, the town of Springdale is built on a lower terrace of the delta though it is approximately 50 feet (15 meters) rather than 30 feet (9 meters) a.s.l. as reported by MacClintock and Twenhofel (1940). Near the government wharf, elevations of 35-40 feet (10.5-12 meters) are probably a result of erosion and slump along Huxter's Brook. A break in slope occurs at 68 feet (20.4 meters) on the east side of the delta and at 89 feet (26.7 meters) in the gravel pit near the Department of Highways Depot (location 3, Plate 4).

PLATE 2. THE SPRINGDALE DELTA, SOUTHWEST SCARP.

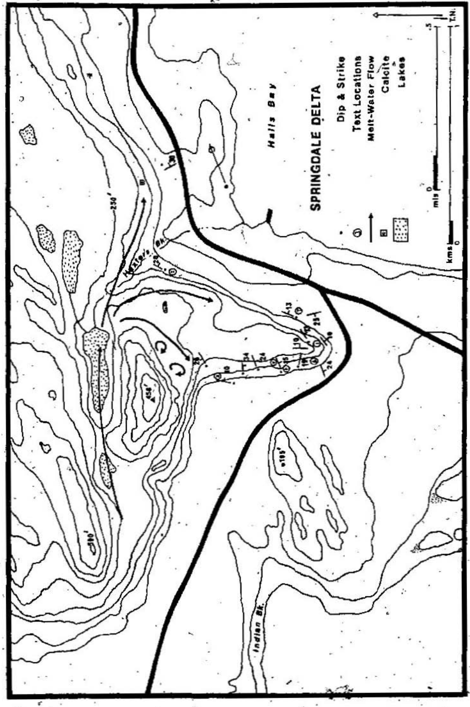

SPRINGDALE DELTA
Halls Bay
Dip & Strike
Text Locations
Melt-Water Flow
Calcite
Lakes
kms
mls
T.N.
Indian Bk.
250'
590'
456'

Figure 2-1

PLATE 3. THE SPRINGDALE DELTA, EAST SCARP.

PLATE 4. LOCATION 3, ZONE OF SANDS AND GRAVELS, SPRINGDALE DELTA.

Sedimentary Structure

Exposed bedding in the delta is chaotic; however, descriptions are made with reference to various plates (especially Plate 2) and Figure 2-1.

At location 3 there is a mass of highly dissected silty material at 78 feet (23.4 meters) on which a strike of 010° and dip of 10° R was recorded. From the location and mélange of material it would appear that this was a zone of turbidity or deposition of fines related to a period of lower melt-water discharge.

Large bouldery deposits at location 4 are 118 feet (35.4 meters) a.s.l. and contain well rounded clasts up to 3 feet (0.9 meters) in diameter cemented with a gravel matrix. Thirty feet (9 meters) of foreset material above the boulder zone contains rounded stones ½-3 inches (1.3-7.6 cms.) in diameter and has strike and dip of 010°, 10° R.

Near the southwest end of the delta at point 6 (Plate 5) there are excellent exposures of foreset gravels at 130 feet (39 meters). Bedding planes, measured at various points, strike 060-070° with dips of 15°-25° R. Texturally, the deposits are finer than the foresets noted at location 5; the size range being ½-1½ inches (1.3-3.8 cms.).

At the southeast corner of the delta at a height of 85 feet (25.5 meters) (location 7, Plate 6) there is a mass of slightly indurated sandy sediment striking 346° and dipping 25° L. While the bedding plane does not correspond to location 3, the deposits may be related in that they represent similar depositional environments.

Bedding northeast of Huxter's Brook is indicative of a flow of material through the stream gap; north of the delta, chaotically bedded

PLATE 5. LOCATION 6, FORESET BEDDING ORIENTED 060-070, 15°-25° R, SPRINGDALE DELTA.

PLATE 6. LOCATION 7, INDURATED SILT, ORIENTED 346, 25° L, SPRINGDALE DELTA.

sands and silts are visible 81 feet (24.3 meters) a.s.l.

Northwest of the above location at an elevation of 178 feet (53.4 meters) a large mass of calcite is visible (Plate 7). D.M.A.R. sources indicate that the calcite is Ordovician and related to the Lush's Bight Group. The height of the exposure corresponds favorably to the previously mentioned 180 feet (54 meters) erosional terrace.

An attempt was made to relate lateral meltwater or kame terrace levels on the north side of Indian Brook valley to deposition of the Springdale delta, however breaks in slope were poorly defined and no specific correlations were possible.

Discussion

From the data outlined above and presented in Figure 2-1 it is suggested that the Springdale delta was deposited in Halls Bay from meltwater flowing through the designated route and along what is now Huxter's Brook. The modified kettle hole on the eastern edge of the delta and the bedrock meltwater channel indicate that ice blocked Indian Brook valley during deposition and was close to the western face of the delta. Recorded dips and strikes signify that while initial flow was down the north side of Indian Brook valley, meltwater involved in delta deposition also flowed to the east-northeast and deposits wrapped around the massive bedrock outcrops.

Tides and currents in the bay modified the delta and elongated its southern tip into the spit-like shape shown in the plan view (Figure 2-1).

Volumes of meltwater varied considerably during delta deposition. This is implied from the mass of bouldery material at location 4,

(Plate 8), indicative of a period of very high discharge. Further deposition of large amounts of fines onto the boulder layer would signify a substantial slowing of meltwater flow.

It is further suggested that the delta was at no time much more extensive in a north-south direction than it is now. British Admiralty Chart, No. 4591, does not indicate deposition of large quantities of sediment outside Indian Brook Arm, rather the 100 fathoms (180 meters) threshold is close to shore at this point.

Ice later retreated in Indian Brook valley. During this time the delta was elevated by isostatic rebound, with subsequent 210 feet (63 meters), 180 feet (54 meters) and 50 feet (15 meters) still-stands occurring after initial delta deposition. No correlations between still-stands and glacial retreat are envisaged, rather the term is interpreted as meaning a point in time when the rates of isostatic and eustatic change were briefly comparable resulting in the cutting of terraces on the original delta.

Indian Brook Valley Sediments

On traverses along Indian Brook valley, fine silt-clay deposits were noted at various locations (Figure 2-2). For the most part the deposits are 1-3 feet (0.3-0.9 meters) thick and are covered by varying amounts of glaciofluvial gravels, however, one deposit 5 miles (8 kms.) west of Springdale and north of the Indian Brook Bridge is more than 41 feet (12.3 meters) thick from its thin glaciofluvial cap to the stream bed. The sediment mass is bedded (Plate 9), and shows varying pink and grey colorations.

PLATE 7. CALCITE DEPOSIT
AT NOTCH, 180 FEET (54 METERS)
A.S.L. SPRINGDALE, NORTH.

PLATE 8. HIGH DISCHARGE BOULDER
ZONE CAPPED BY FORESET GRAVELS,
SPRINGDALE DELTA.

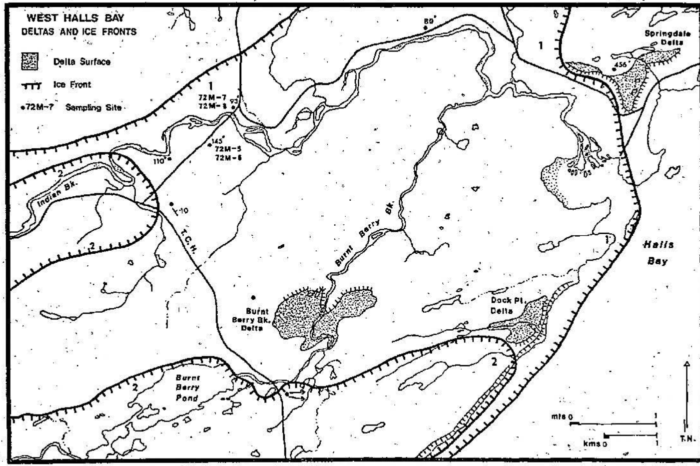

WEST HALLS BAY
DELTAS AND ICE FRONTS
Delta Surface
Ice Front
•72M-7 Sampling Site
1
72M-7
72M-8
93
145
72M-5
72M-6
110
2
Indian Bk.
10
T.C.H.
89
Burnt Berry Bk.
Burnt Berry Bk. Delta
Burnt Berry Pond
Dock Pt. Delta
Springdale Delta
456
Halls Bay
mls 0
1
kms 0
1
T.N.

Figure 2-2

Two possibilities exist for the origin of the deposits.

1. The clays may be marine. This would suggest rapid deglaciation and marine transgression up the valley which at that time was isostatically depressed (as was the whole area), followed by considerable glaciofluvial deposition from inland sources, with delta construction at the mouth of the valley. The level area west of the T.C.H. - Springdale highway intersection would thus be interpreted as alluvial fill over a flat marine sediment base.

2. The sediments may be lacustrine in origin. They would then have been deposited in ponded water at various locales and elevations along the valley system. This need not have occurred in direct association with delta deposition at Springdale but rather as ice retreated up valley, or in any body of postglacial ponded water.

In an attempt to decide the method of deposition, several analyses were completed. Four samples were chosen; two were obtained from the massive deposit north of Indian Brook Bridge. Sample 72 M-7 was from a grey silty lens while 72 M-8 seemed visually finer in texture and had a pinkish hue. Two samples were taken from a meander-scar cut, 0.3 mile (0.48 km.) further west, south of the Springdale highway. Sample 72 M-5 was dug from a 6-8 inches (15-20 cms.) thick lens that sloped in an easterly direction and sample 72 M-6 was removed from a 1 foot (0.3 meter) thick lens of sediment 4 feet (1.2 meters) higher and 50 feet (15 meters) further west. By comparing the two sets it was hoped to be able to relate them more clearly; (a) in a total morphological context in Indian Brook valley and (b) as individual sediment samples within specific deposits.

Textural Analysis

Initially wet sieve and pipette analyses of the sections finer than 4φ (phi) were completed as described in Appendix 1. The results were plotted on Cumulative Curves and Frequency Curves (Figures 2-3 and 2-4). The mean, inclusive graphic standard deviation, kurtosis and inclusive graphic skewness were calculated as outlined and the results tabulated in Table 2-1.

Results

TABLE 2-1

CALCULATED DATA FOR INDIAN BROOK VALLEY
SAMPLES 72 M5 – 72 M8

SAMPLE	MEAN	INCLUSIVE GRAPHIC STANDARD DEVIATION	KURTOSIS	INCLUSIVE GRAPHIC SKEWNESS
72 M5	7.73φ	2.21φ very poorly sorted	0.93 mesokurtic	0.21 fine skewed
72 M6	7.28φ	2.69φ very poorly sorted	0.87 platykurtic	0.17 near symmetrical
72 M7	4.62φ	1.70φ poorly sorted	1.67 very leptokurtic	0.52 strongly fine skewed
72 M8	6.70φ	2.06φ very poorly sorted	1.05 mesokurtic	0.32 strongly fine skewed

Samples 72 M-5 and 72 M-6 contain more clays than the final two samples. 72 M-6 has a greater percentage of coarser (3-4φ) material, thus explaining its near-symmetrical platykurtic curve. Because of its high very fine sand content, sample 72 M-7 is leptokurtic. A secondary mode in the 10-12φ range has the effect of producing a strongly fine skewed Frequency Curve. All samples have a visible secondary mode in the clay fraction though percentages are considerably higher for samples 72 M-5 and 72 M-6.

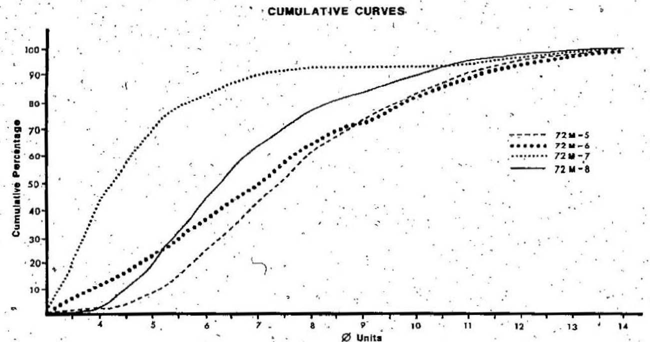

CUMULATIVE CURVES
Cumulative Percentage
100
90
80
70
60
50
40
30
20
10
4
5
6
7
8
9
10
11
12
13
14
Ø Units
72 M-5
72 M-6
72 M-7
72 M-8

Figure 2-3

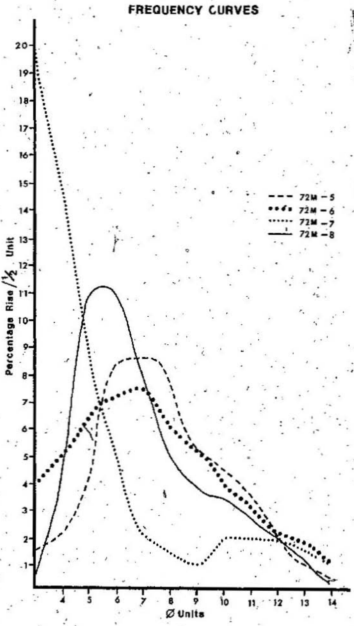

FREQUENCY CURVES
Percentage Rise/½ Unit
Ø Units
72M – 5
72M – 6
72M – 7
72M – 8
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
4
5
6
7
8
9
10
11
12
13
14

Figure 2 – 4

A section was cut from the massive Indian Brook deposit and the following sequence was measured.

TOP
0.70 inches (2 cms.) grey
0.60 inches (1.7 cms.) pink
1.85 inches (4.7 cms.) grey
0.90 inches (2.2 cms.) pink
4.10 inches (10.5 cms.) grey
0.55 inches (1.5 cms.) pink
1.9 inches (5 cms.) grey
BOTTOM

X-Ray Analysis

To test the differences in composition of the various samples, an X-ray analysis of the sections finer than 8ϕ was attempted, as explained by Carroll (1970) and outlined in Appendix 1. The initial patterns run from 2-30 degrees 2θ have been drafted and are presented as Figure 2-5 a, b, c and d.

Results

Compositionally the samples were similar. All contained chlorite (14A° (001), 7A° (002)), amphiboles (8.42A°), mica-illite (10A° (001), 5A° (002)), quartz (3.33A°, 4.21A°) and feldspars (3.17-3.19A°). No montmorillonite or kaolinite was present. The samples did vary in the amounts of specific minerals they contained. Related to the textural analyses; sample 72 M-5 and 72 M-6 contained greater proportions of clay, thus their patterns are disturbed and have more background "noise." Peaks are not as sharp as those of 72 M-7 and 72 M-8 which are pointed and in many cases 3-4 times the height of the background pattern.

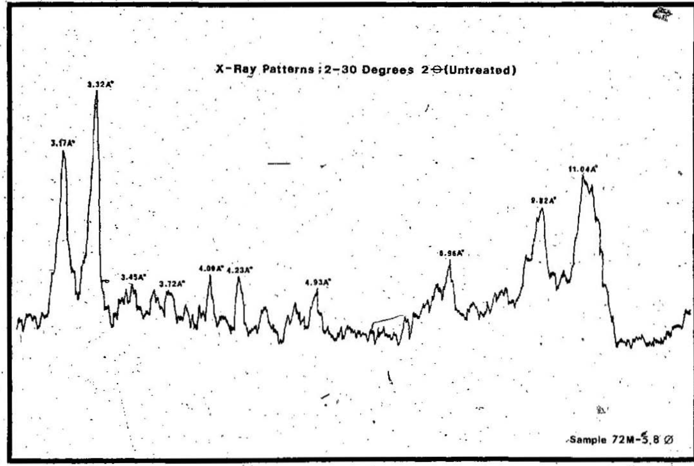

X-Ray Patterns ; 2-30 Degrees 2 Θ (Untreated)
3.32A°
3.17A°
3.45A°
3.72A°
4.09A°
4.23A°
4.93A°
6.96A°
9.82A°
11.04A°
Sample 72M-5,8 Ø

Figure 2-5a

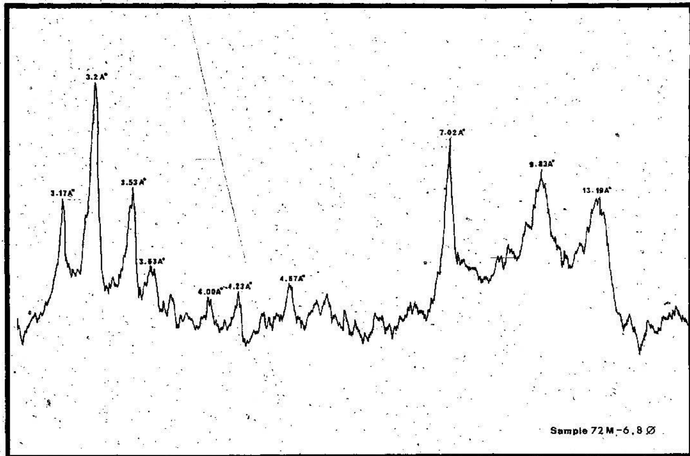

3.17A°
3.2A°
3.53A°
3.63A°
4.00A°
4.23A°
4.57A°
7.02A°
9.83A°
13.19A°
Sample 72M-6,8 Ø

Figure 2-5b

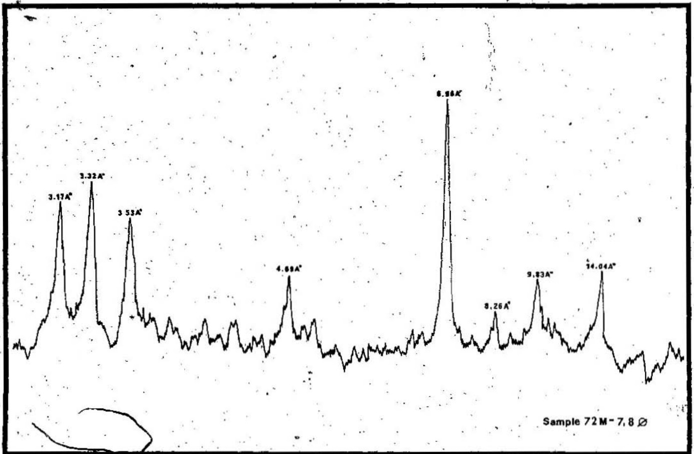


Figure 2-5c

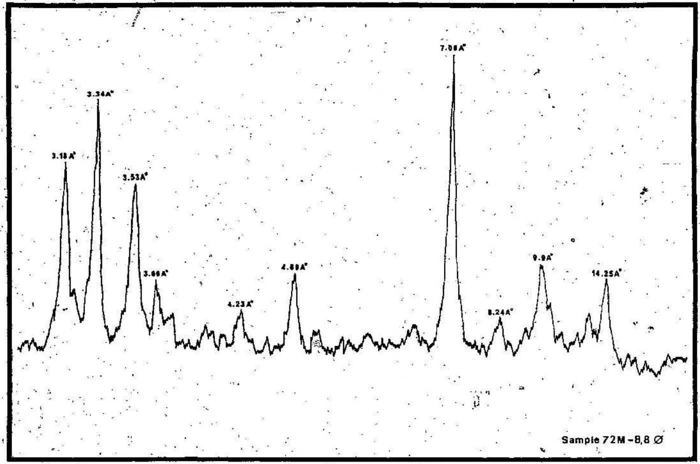


Figure 2-5d

Stereo Microscope Analysis

A stereo microscope analysis was completed on samples 72 M-7 and 72 M-8. No grey-pink color differentiation was visible. A search was made of all samples under 4ϕ for foraminifera and diatoms, however none were found.

Conclusions

For the following reasons it is concluded that the sediments are lacustrine in origin.

1. The textural variations in samples 72 M-7 and 72 M-8, and the sedimentary section indicate probable varving.

2. The laminated bedding of gravels and silts in the meander scar describes non-marine depositional environments.

3. The absence of foraminifera and diatoms, while not necessarily proving a lacustrine environment, certainly is evidence for non-marine deposition.

The altitudinal differences in 72 M-5-6 and 72 M-7-8 might explain the higher proportions of clay in the former two samples. At the point of higher elevation, (Fig. 2-2) and thus later deposition, meltwater flow had probably slowed and sediment transported to the same locale would have been considerably finer. No other compositional variations were noted; this is logical since it is assumed that meltwater flowed over bedrock and outwash of the same derivation, that is, down the upper reaches of Indian Brook valley and Burnt Berry Pond valley. Since samples 72 M-7 and 72 M-8 were obtained from only the top few feet of an extensive mass of sediment, it may be that the lower sections of the deposit are marine in origin. Based on the rather superficial analyses presented, it is obvious that the possibility should not be ruled out and that further work is needed to properly evaluate the problem.

THE LOWER HALLS BAY DELTAS

Burnt Berry Brook and Dock Point

A raised delta remnant is located 1.4 miles (2.3 kms.) northeast of Burnt Berry Pond. Islands on the delta surface are 250 feet (75 meters) a.s.l., however the dissected scarp is nearer 180 feet (54 meters) in elevation. No field data were collected on this feature, but from an air photo analysis it appears that the delta was deposited by melt-water issuing from an ice front located in or near Burnt Berry Pond; terrain around the delta remnant is hummocky and kettled, suggesting stagnant ice.

Two miles (3.2 kms.) east of the above deposit there is a raised delta at Dock Point. Scarp and surface heights are similar to those of the Burnt Berry Brook delta. A 50 feet (15 meters) erosional terrace is visible near the bottom of the Dock Point scarp and continues along the southwest coast of Halls Bay.

West Pond

A raised delta remnant, immediately due west of Riverhead Brook was the subject of field analysis (Fig. 2-6). Various elevations were taken on the main delta scarp; near the easternmost edge (Plate 10) a height of 200 feet (60 meters) was recorded. Several kettles are located on the surface of the feature; the bottom of the east-west

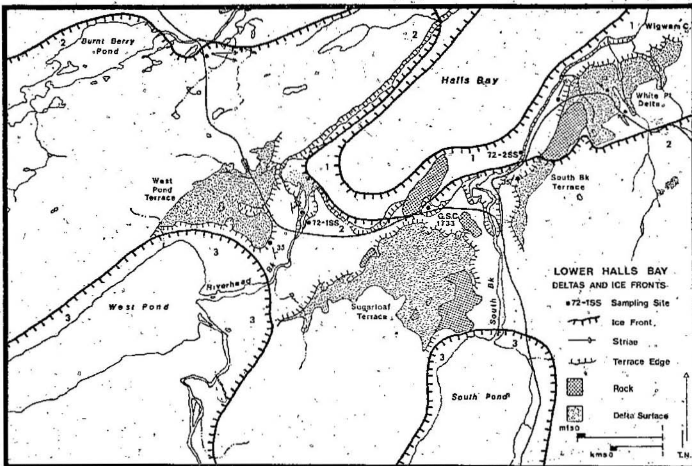

LOWER HALLS BAY
DELTAS AND ICE FRONTS
•72-1SS Sampling Site
Ice Front
Striae
Terrace Edge
Rock
Delta Surface
m150
kms0
T.N.
Burnt Berry Pond
Halls Bay
Wigwam C.
White Pt Delta
South Bk Terrace
72-2SS
West Pond Terrace
72-1SS
G.S.C. 1733
Riverhead
Bk
West Pond
Sugarloaf Terrace
South Bk
South Pond
1
2
3

Figure 2 - 6

PLATE 9. BEDDED SILTS AND CLAYS NORTH OF INDIAN BROOK BRIDGE, 93 FEET (27.9 METERS) A.S.L.

PLATE 10. THE WEST POND TERRACE SHOWING 210 FEET (60.3 METERS) AND 53 FEET (15.9 METERS) LEVELS. RIVERHEAD BROOK IS INCISED IN THE LOWER LEVEL.

trending kettle nearest the T.C.H. is 109 feet (32.7 meters) a.s.l. The slopes of the kettle are rounded and show indications of fluvial or marine action.

North of the highway and southwest of Eaton Point a 178 foot (53.4 meters) level was recorded. The top of the northern section of the delta is hummocky and was measured at various points as 200-210 feet (60-60.3 meters). The base of the main delta scarp, southwest of Eaton Point is 53 feet (15.9 meters) a.s.l.

Major cuts in the delta are thickly covered with scree making strike and dip measurements difficult to obtain, however one orientation of 345°, 35° R was recorded on the main West Pond terrace at an elevation of 100 feet (30 meters). This coincides with a strike and dip of 345°, 32° R obtained in the 50 foot (15 meters) terrace at the mouth of Riverhead Brook. Foreset gravels exposed in the 50 feet (15 meters) terrace are loosely compacted with sub-rounded to rounded pebbles ½-6 inches (1.3-15.3 cms.) in diameter. On top of the 50 feet (15 meters) terrace there are 9 feet (2.7 meters) of postglacial lag gravels that contain rounded stones 1-12 inches (2.5-30 cms.) in diameter.

<u>Sugarloaf</u>

A traverse was completed from west to east across the Sugarloaf terrace (Fig. 2-6, Plate 11) and elevations have been recorded from several locations. No bedding planes were visible, however. At the break in slope on the west side of the terrace a height of 58 feet (17.4 meters) was noted while on the eastern end, towards South Brook, a break in slope occurs at 49 feet (14.7 meters). Outcrops are visible on the delta surface at 309 feet (92.7 meters). The main delta scarp is 212 feet (63.6 meters) a.s.l. while further back on the terrace a recording of 245 feet (73.5 meters) was made. Modern stream dissection of the delta scarp is extensive, but despite this, the surface is quite even and no major kettle depressions were encountered either during the traverse or from air photo analysis.

South Brook

Directly east of the town, the main scarp of the South Brook terrace is 249 feet (74.7 meters) a.s.l. Further south near the T.C.H., the height of the delta drops to 218 feet (65.4 meters). Two erosional terraces are located within the town. The upper is 58 feet (17.4 meters) a.s.l. at the main break in slope and the lower was measured as 29 feet (8.7 meters) at the town wharf. Only one cut was visible on the main scarp (Plate 12). The six feet (1.8 meters) of topsets or lag gravels which cap the terrace at this point are well rounded and contain stones up to 1.5 feet (.45 meters) in diameter. One orientation of 020° dipping 35° L was obtained, however, it is thought that this conforms to slope bedding rather than true delta foresets.

In the South Brook and Riverhead Brook valley bottoms, bedded glaciofluvial material was noted. No specific orientations were obtained and the texture of the deposits altered with location. In certain cuts, the glaciofluvial material was capped by varying thicknesses of postglacial lag gravels.

White Point

The top of the delta at White Point (Fig. 2-6) is 220 feet

PLATE 11. THE SUGARLOAF TERRACE AND SUGARLOAF. PHOTOGRAPHED FACING NORTH. TERRACE HEIGHT IS 250 FEET (75 METERS) AT THE LEFT.

PLATE 12. THE SOUTH BROOK TERRACE WITH BEDDING ORIENTED 020°, 35° L.

(66 meters) a.s.l. A break in slope occurs at 110 feet (33 meters) with an erosional scarp at 54 feet (16.2 meters). A third level was noted at an elevation of 20 feet (6 meters). No bedding was visible on the face of the White Point delta, however a newly opened borrow pit on the highway midway across the terrace has good exposures of topsets and foresets. Orientations of 330-345° were obtained with dips ranging from 7°-13° R. It is not possible to be more specific in describing sediment texture in this pit since material varied from sandy cross-bedding to foresets with stones up to 10 inches (25.4 cms.) in diameter.

Shell Samples

In early summer 1972, D. R. Grant recovered a sample of *Balanus* which was subsequently dated at 12,000 ±220 B.P. (G.S.C. - 1733). The shells were located 55 feet (17.5 meters) a.s.l. in a stony pelite located at the front of the Sugarloaf terrace.

Two shell samples were collected in the Halls Bay area by the writer. Sample 72-1SS, *Mytilus edulis*, was located in a sand lens in foreset gravels on Riverhead Brook (Fig. 2-6) 29 feet (8.7 meters) a.s.l. Sample 72-2SS contained perfect specimens of *Hiatella arctica* (Plate 13). The sample was removed from a cut in stony pelite 15 feet (4.5 meters) a.s.l. in Spring Cove at the eastern end of Halls Bay (Fig. 2-6). Pieces of the shells were visible on the surface of the cut but most were dug from the compact silt. Both these samples are estimated to be similar in age to G.S.C. - 1733 and are significant in that they date the innermost series of glaciomarine deltas of the north east coast of the island.

Henderson (1963) obtained three shell samples north of the field area which were subsequently dated. Sample G.S.C. – 55 (11,520 ± 180 B.P.), *Macoma calcarea*, *Mya truncata* and *Hiatella arctica*, was obtained from a silty clay 160 feet (48 meters) a.s.l. in the Baie Verte River. G.S.C. – 75, collected from till-like material 35-42 feet (10.5-12.6 meters) a.s.l. in Middle Arm, Green Bay, was dated at 11,950 ± 170 B.P. At Southwest Arm, Green Bay, a sample of *Hiatella arctica* and *Mya truncata* was deposited 11,880 ± 170 B.P. The shells were located in silty bottomset clays 40 feet (12 meters) a.s.l.

Conclusions and Discussion

The shell dates from Green Bay and Halls Bay are roughly equivalent. No one date falls outside the upper or lower statistical error of the other samples. Excluding sample G.S.C. – 55 all were less than 60 feet (18 meters) a.s.l. and thus represent deep water growth in delta bottomsets. The dates indicate that Green Bay and Halls Bay were deglaciated within a fairly narrow interval of time approximately 12,000 B.P., and that the deltas were not, as has been suggested by Jenness (1960) and Lundqvist (1965), deposited in ice dammed lakes. The following sequence is proposed for the deglaciation of Halls Bay.

A calving ice front rapidly deglaciated Halls Bay until it became land fast in Indian Brook and in the valleys to the south where it remained while delta deposition took place at Springdale and lower Halls Bay. Bottomsets of the deltas fronting on Halls Bay are equivalent in time and were deposited at ice recessional position 1 (Figs. 2-2, 2-6). Construction of the Springdale delta occurred from lateral meltwater in Indian Brook valley and deposition across the bedrock ridge northwest of the main terrace, (Fig. 2-1). Material was derived from the valley systems to the west and along the north side of Indian Brook valley.

The silt units throughout Indian Brook valley may represent a lacustrine environment during this retreat or later, though the possibility of a marine origin for the lower portions of the large mass of sediment near Indian Brook Bridge is not discounted. Marine waters certainly penetrated some distance up the Indian Brook - Burnt Berry Brook valley for delta deposition to occur southwest of Springdale. Further analysis is necessary for complete clarification of this problem.

As ice retreat continued, major marine delta deposition took place at Burnt Berry Brook, Dock Point and White Point with continued minor deposition at the head of Halls Bay (Position 2, Figs. 2-2, 2-6). Although there is little remaining evidence to confirm the idea, it is possible to speculate that at Position 2, a 250 feet (75 meters) terrace was constructed just southeast of the T.C.H. - Springdale highway intersection. This would have paralleled the existing terraces at Burnt Berry Brook, Dock Point and White Point.

Finally, meltwater from ice located in West Pond and South Pond valleys (Position 3, Fig. 2-6) was responsible for the larger proportion of West Pond, Sugarloaf and South Brook terrace construction. Greatest amounts of ice recession between positions 1 and 3 took place on interfluves with relatively slow retreat in the valleys. Kettle holes and hummocky moraine on the highlands around the deposits indicate that ice fronts were near the deltas during their construction.

It is also concluded that the delta system at the head of Halls Bay which includes the West Point, Sugarloaf and South Brook terraces, completely filled the lower perimeter of the bay. Continued glaciofluvial and postglacial erosion removed large portions of the delta from the two valleys (Plate 14). British Admiralty Chart No. 4591 shows depth soundings of 30-40 fathoms (54-72 meters) in lower Halls Bay with a sudden drop to 103-120 fathoms (185-216 meters) immediately north of Dock Point. This suggests major fjord infilling by the eroded deltaic material.

During and after the process of ice removal from the field area, isostatic rebound caused the terrain to be uplifted. From recorded elevations of the Halls Bay deltas the marine limit or limit of post-glacial emergence relative to present sea level is 250 feet (75 meters). Various sources cite sea levels for 12,000 B.P. as being about 172-224 feet (52-68 meters) below present levels. Walcott (1972) suggests a level of -224 feet (-68 meters) based on Grant's (1970) work on the Great Northern Peninsula of Newfoundland. Flint (1971) indicates a sea level of -182 feet (55 meters). Andrews (1970) quotes Godwin *et al.* (1958) as predicting general sea levels of -172 feet (-52 meters) at 12,000 B.P. All the above values are based on curves constructed from radiocarbon-dated shells and material assumed to have been existing at sea level. This is a major weakness in that certain species subsisted at considerable depths depending on the temperature and salinity of the water.

For this reason eustatic curves may overestimate the amount

PLATE 13. SAMPLE 72-255, OF *HIATELLA ARCTICA*, LOCATED AT SPRING COVE 15 FEET (4.5 METERS) A.S.L.

PLATE 14. LOWER HALLS BAY SHOWING; SOUTH BROOK TERRACE, LEFT, SUGARLOAF TERRACE, CENTER, AND THE SUGARLOAF, LEFT CENTER.

of sea level change by as much as 60 feet (18 meters). However from the approximate eustatic data it may be that c. 440 feet (133 meters) of isostatic uplift has taken place since 12,000 B.P. of which 190 feet (57 meters) has been obscured by a eustatic rise in sea level during the same postglacial interval.

Erosional terraces occur at 220, 200, 180, 50 and 30 feet (66, 60, 54, 15 and 9 meters), (Table 2-2). All except the 50 foot (15 meters) level are poorly defined and do not appear on all deposits in Halls Bay. The 50 foot (15 meters) terrace is continuous throughout the area and represents a major still-stand. This is not to suggest that the other still-stands were not important but that evidence for them is scanty, having been removed by later marine erosion or mass wasting of unconsolidated material.

TABLE 2-2

ELEVATIONS OF TERRACES AND RAISED SHORELINE FEATURES ON THE HALLS BAY DELTA SYSTEMS

Springdale	Burnt Berry Brook	Dock Point	White Point	West Pond	Sugarloaf	South Brook
252' (75.6 m.) (U.M.L.)	250' (75 m.) (U.M.L.)	250' (75 m.) (U.M.L.)	250' (75 m.) (U.M.L.)	250' (75 m.) (U.M.L.)	245' (73.5 m.) (U.M.L.)	249' (74.7 m.) (U.M.L.
220' (66 m.)			220' (66 m.)			218' (65.4 m.)
210' (63 m.)				200' (60 m.)	212' (63.6 m.)	
180' (54.3 m.)	180' (54.3 m.)			178' (53.4 m.)		
50' (15 m.)		50' (15 m.)	54' (16.2 m.)	53' (15.9 m.)	49' (14.7 m.)	58' (17.4 m.)
			20' (6 m.)			29' (8.7 m.)

*U.M.L. - approximate upper marine limit

CHAPTER III

ESKERS AND CREVASSE FILLINGS

Introduction

The purpose of this chapter is to relate a zone of eskers and crevasse fillings (Fig. 3-1) to the overall pattern of deglaciation of the Hafls Bay - Topsails area. The central part of the field area is marked by a number of ridges of apparent glaciofluvial origin. Air photo analysis reveals that while some of them appear to be crevasse fillings, as suggested by Lundqvist, (1965), others bear a greater similarity to true eskers.

Generally, all the deposits studied are on the High Central Plateau with the larger and more prominent ones being located at the northern boundary, specifically near Barney's Brook and Sheffield Hill. The larger ridges near the edge of the plateau are up to 3 miles (4.8 kms.) long while further south lengths are about 0.8 mile (1.3 kms.).

Lundqvist (1965) describes one of the features lying outside the present study area as "a low but sharp ridge of a type that in Sweden is considered to have been formed in open-crevasses in the ice . . . and is of limited value for the determination of ice flow" (p. 296). He observes that all "eskers" in the current field area are of this origin. In order to interpret the High Central Plateau deposits adequately, it is necessary to describe various possible methods of formation.

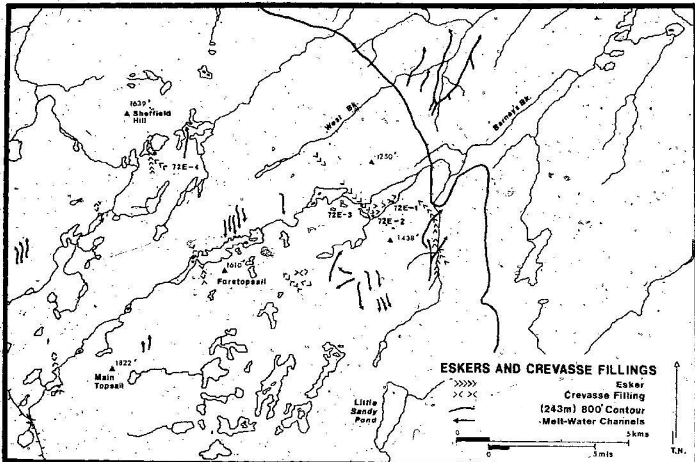

ESKERS AND CREVASSE FILLINGS
Esker
Crevasse Filling
(243m) 800' Contour
Melt-Water Channels
0
5kms
0
5mls
T.N.
1639'
Sheffield Hill
72E-4
West Bk.
Barney's Bk.
1250'
72E-1
72E-2
72E-3
1438'
1610'
Faretopsail
1822'
Main Topsail
Little Sandy Pond

Figure 3-1

Eskers

While englacial and supraglacial processes have been suggested, Flint (1971) favors a subglacial origin for the deposition of esker material, whereby, in a late phase of deglaciation, surface meltwater seeps through the ice seeking the lowest possible channelways. Water and sediment transported via this route is deposited partly along the beds of such channels and partly into ponded bodies of water at the glacier terminus.

Lewis (1949) suggests that externally ponded water is not necessary for frontal or near-frontal esker deposition. He observed an esker in the process of formation at a location where a contemporary valley glacier terminates on a gentle slope covered with solifluction debris. Since the valley had not contained water recently, Lewis explains that ponding necessary for esker development had occurred under the glacier and deposition had taken place in stagnant water dammed in ice caves.

Embleton and King (1970) envisage a similar method of esker construction. Instead of requiring ponded water near the glacier terminus, they maintain that a reduction of terrain gradient under the ice or blocking of stream channels by the collapse of decaying ice may be instrumental in initiating the deposition of material in subglacial channels.

A variant of the frontal and normal eskers mentioned above is the beaded esker which is formed by the annual addition of small mounds of sediments as an ice front retreats. The summer period of rapid water flow adds to each bead, while winter is represented by the intervening gap.

Crevasse Fillings

Doornkamp and King (1971) describe a process of crevasse filling on west Baffin Island where they observe that the irregularity of the deposits, in plan and profile, indicates that they are not formed by flowing water but that they represent the filling of cracks in dead ice by material being accumulated from the surface above. The slow washing down into the hollows would account for diminution of ridge height towards the distal end of the ridge. From several publications (esp. Flint, 1928) the following summary of variations in esker and crevasse filling morphology is tendered (Table 3-1). The table is self-explanatory and will not be elaborated on at this point.

Morphology

Barney's Brook

The Barney's Brook "esker" is located 4 miles (6.4 kms.) north-east of Foretopsail (Fig. 3-1) and is approximately 2.9 miles (4.6 kms.) in length. The feature trends 130° on its main section while near what appear to be distal distributuries the orientation is 070-080° (Plate 15).

On the section of the deposit east of Barney's Brook, perched erratics are numerous. The granite boulders are 3-5 feet (0.9-1.5 meters) in diameter and often have numerous smaller erratics stacked atop them (Plate 16). The crest of the feature is sharp and hummocky. Slope angles taken at sample points varied from a minimum of 16° to a maximum of 22°. Towards the ice-marginal end, near sample point 72 E-1, the deposit is 28 feet (8.4 meters) above the general terrain, while at

TABLE 3-1

DISTINCTIVE FEATURES OF ESKERS AND CREVASSE FILLINGS

ESKERS	CREVASSE FILLINGS
1. Situated within and tributary to terminal or recessional moraines.	1. Closely associated with recessional moraines and pitted outwash; lie beyond the former and incorporated within the latter.
2. Commonly several miles in length; height of 12-45 feet (3.6-13.5 meters).	2. Most are short, less than 0.25 miles (0.4 kms.) and range from 12-15 feet (3.6-4.5 meters) in height.
3. Usually (not always) trend parallel to the direction of ice movement and may be discontinuous.	3. Trend in any direction regardless of ice direction and are continuous rather than broken.
4. Commonly sinuous in plan and arranged in distributary-tributary systems.	4. Are not arranged in distributary systems but where associated with lake deposits marginal to ice edge may merge with them; are generally straight though may bend sharply around kettle rims.
5. Trend uphill and cross divides with no change in the volume of the deposit. Crests are knobby and hummocky or undulating, rarely level for long distances.	5. Tops are horizontal and the features do not pass over divides.
6. Crest elevations not related to surrounding deposits.	6. Crest elevations are similar to surrounding kame and kettle rims.
7. Material coarse, lacks sands and clays; predominance of gravels and cobbles. Visible bedding in transverse sections parallels slope at angle of rest, 18-30 degrees.	7. Composition is similar to that of eskers; side slope angles also similar.

TABLE 3-1 (CONTINUED)

ESKERS	CREVASSE FILLINGS
8. Bedding variable with semistratified to non-stratified lenticular masses. Sections of till may cover esker--ascribed to collapse of tunnel roofs and melt of debris-laden ice.	8. Bedding is moderately foreset to horizontal. Sections never show coatings of till.
9. Ridge crests trend upwards in the direction of former ice flow to reach a maximum at the distal end.	9. Gradient slopes down in the direction of water flow indicating slow accumulation, i.e., ridge heights diminish towards the distal end of the deposit.

PLATE 15. THE BARNEY'S BROOK ESKER, PHOTOGRAPHED FACING SOUTH. FORETOPSAIL IS SHOWN ON RIGHT CENTRAL HORIZON.

PLATE 16. PERCHED ERRATICS ON THE BARNEY'S BROOK ESKERS. LICHENS COVER THE UPPER SURFACES.

sample point 72 E-3, about 0.9 mile (1.3 kms.) further west, height decreases to 16 feet (4.8 meters).

The crests are devoid of vegetation with heathland and scrub covering the sides and surrounding low areas. In general the terrain slopes gently to the north east and is bouldery in nature. Well weathered, pale red, equigranular "Topsails granite" (Neale and Nash, 1963) bedrock is visible and erratics of the same lithology litter the area. Near Barney's Brook "esker" the terrain becomes more hummocky, indicative of ablation moraine (Glacial Map, Chapter 5), though towards the northeast end of the feature the hummocks have a transverse linearity suggesting highly dissected recessional moraines.

Although a more detailed textural analysis will be presented ~~later in~~ this chapter, it was observed that surface material of the deposit appeared well sorted with a distinct lack of clasts over 1-2 inches (2.5-5 cms.) in diameter. The possibility exists that sorting was not a result of glaciofluvial deposition but rather of postglacial or periglacial action, however since sediment size did not increase substantially with depth, the initial assumption is probably correct.

Sheffield Hill

A prominent glaciofluvial ridge located 0.9 mile (1.4 kms.) southeast of Sheffield Hill, is morphologically similar to the deposit described at Barney's Brook. It is 1.1 miles (1.8 kms.) in length, oriented 355, and increased in breath and height towards the north-northwest (Plate 17).

of rounded to sub-angular granite and granodiorite 1-2 inches (2.5-5 cms.) in diameter. Similarly, from an initial inspection, there seemed to be a lack of argillaceous material or large boulders within the deposit, though as was noted at Barney's Brook, erratics litter the surface. In places several smaller erratics are perched on the larger base boulders.

At the low southern end of the "esker" heights vary from 17-18 feet (5.1-5.4 meters). Near the center of the feature height increases to 23 feet (6.9 meters) and slope angles are 25° (west) and 26° (east). The northernmost section has steep sides and a sharp crest about 10 feet (3 meters) wide while height was leveled as 41 feet (12.3 meters). The surface of the deposit is devoid of vegetation at its southern extremity but is covered with scrub spruce and juniper towards Sheffield Hill. Valley axial gradient is poorly defined at this location. Minor valley slopes are oriented northeast and southwest, though major topographic slope is to the northwest.

Foretopsail

0.6 mile (0.96 kms.) west of Foretopsail there is a smaller esker or crevasse filling remnant 0.5 miles (0.80 kms.) in length (Plate 18). It is oriented 355, has a low, broad crest and side slope angles of 19° (south) and 18° (north). Although the feature is 11 feet (3.3 meters) above the immediate terrain, surrounding ablation moraine is generally of the same, or greater, height. There are no surface boulders and vegetation is minimal. A pit was dug to a depth of 2.5 feet (0.75 meters) and no bouldery material was encountered, rather the

PLATE 17. THE SHEFFIELD HILL ESKER, PHOTOGRAPHED LOOKING NORTH.

PLATE 18. THE FORETOPSAIL AREA SHOWING THE CREVASSE FILLING REMNANT (LEFT) AND BOULDERY TERRAIN OF THE HIGH CENTRAL PLATEAU.

sediment was well sorted and sub-rounded containing clasts from 0.80-1.3 inches (2-3 cms.) in diameter.

Air Photo Deduced Morphologies

A ridge situated in the valley north of Little Sandy Pond appears from air photo analysis to be morphologically similar to the Barney's Brook "esker," 1.5 miles (2.4 kms.) to the west. The deposit follows the valley axis at 340° and is dissected by meltwater channels and existing streams (Fig. 3-1). Its overall length (1.2 miles, 1.9 kms.) and orientation further indicate a relation to the Barney's Brook complex. The Little Sandy Pond valley is filled with glaciofluvial material and surrounding drift is abundant.

Two miles (3.2 kms.) east-southeast of Foretopsail there is a deposit which may be a true crevasse filling as described by Lundqvist (1965). It is approximately 0.8 miles (0.98 kms.) in length and branches at various points. Part of the feature trends 355° while other sections are oriented 010° and 035°. The ridges are highly dissected and pitted with kettle holes.

Prominent meltwater channels have been plotted from the air photos (Figure 3-1). Near Sheffield Hill the pattern indicates a northerly flow of meltwater, while in the Barney's Brook area flow was radial from the surrounding summits with final flow to the north-northeast down Barney's Brook and West Brook.

Textural Analysis

Samples were collected from the deposits at Barney's Brook and Sheffield Hill. All were taken unsieved from a depth of 2.5-3 feet

(0.75-0.9 meters) on the slopes of the features. Four samples were analyzed; three from Barney's Brook "esker," 72 E-1 (most easterly), 72 E-2, 72 E-3, and one, 72 E-4; from the Sheffield Hill "esker." (Fig. 3-1)

A standard sieve analysis was completed at whole ϕ intervals as outlined in Appendix 1. Individual percentages were calculated for the sample weights and the results were plotted on Cumulative (Arithmetic Ordinate) Curves (Fig. 3-2) and Frequency Curves (Fig. 3-3). A pipette analysis was not completed on the fractions less than 4ϕ since only a general indication of (or lack of) glaciofluvial action was required as a result, which would be obvious from the standard sieve analysis. A fabric analysis was attempted at sample point 72 E-4 (Plate 19) but the sediment was neither well consolidated nor were the pebbles elongated enough to complete an analysis with any degree of accuracy.

Results

The following results were obtained from the textural analysis (Table 3-2).

CUMULATIVE CURVES

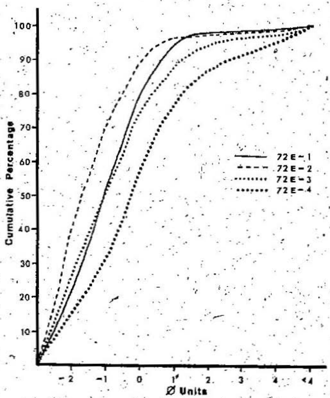


Figure 3-2

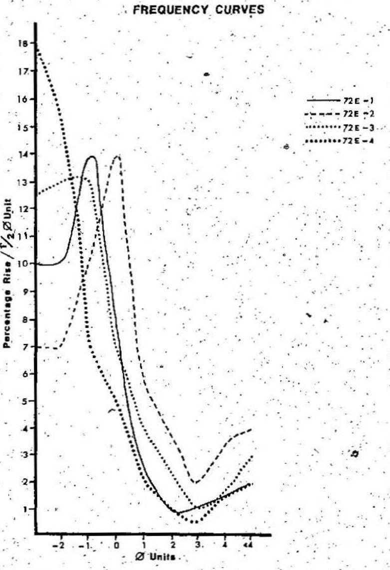

FREQUENCY CURVES
72E-1
72E-2
72E-3
72E-4
Percentage Rise / 1/2 Ø Unit
Ø Units

Figure 3-3

TABLE 3-2

CALCULATED DATA FOR HIGH CENTRAL PLATEAU
SAMPLES 72 E-1 - 72 E-4

Sample	Inclusive Graphic Standard Deviation	Mean	Kurtosis	Inclusive Graphic Skewness
72 E-1	1.24ϕ Poorly Sorted	+1.07ϕ	0.95 Mesokurtic	0.06 Near Symmetrical
72 E-2	1.96ϕ " "	-0.13ϕ	1.21 Leptokurtic	0.23 Fine Skewed
72 E-3	1.53ϕ " "	+0.97ϕ	1.11 Leptokurtic	0.25 " "
72 E-4	1.09ϕ " "	-1.58ϕ	0.91 Mesokurtic	0.30 " "

All four samples have primary modes occurring in a zone of very coarse sand, with an abrupt break in slope on both sides of the modal peak (Fig. 3-3). It is possible that the primary modes may have been influenced by the upper limit placed on the sieving, though in three of the four samples analyzed a distinct absence of material greater than -2ϕ occurs. Notably, though, there is a lack of fine sand (2-3ϕ) with a slight increase in very fine sand (2-4%) in all samples (Fig. 3-3).

From the Cumulative Curves (Fig. 3-2), one may observe that at least 90% of the sediment is confined to material coarser than 2.6ϕ, that is, with a sharp break in slope of the curves within the sand categories (Table 3-3).

PLATE 19. SAMPLE PIT 72 E-4 SHOWING SUB-ROUNDED, GLACIOFLUVIAL SEDIMENT IN THE SHEFFIELD HILL ESKER.

TABLE 3-3

TEXTURAL BOUNDARY (ϕ UNITS) AT 90% CUMULATIVE WEIGHT

SAMPLE	ϕ UNITS
72 E-1	+0.60ϕ
72 E-2	+2.60ϕ
72 E-3	+1.20ϕ
72 E-4	0.00ϕ

Since the samples were not obtained from contiguous bedding planes, it would be unwise to intimate any spatial relations for deposition, however the lack of very fine sand and silt is a notable general feature.

Samples 72 E-2 and 72 E-3 may be described as leptokurtic. Possibly this is a result of the large amount of material in the -2ϕ - 0ϕ range. Samples 72 E-1 and 72 E-4 are mesokurtic and thus have more even sediment distributions. All except 72 E-1 are fine skewed. This does not imply that they contain a large amount of silt or very fine sand but rather, indicates a skewing of the frequency curve to the fine section; however all samples are in a closely defined range and are comparable in the general scope of positive or fine skewness.

Stereo Microscope Analysis

From an examination of the 2ϕ sections of the samples under a stereo microscope, it was noted that samples 72 E-1, 2 and 3 had roundness values of 0.30 (Powers (1953) scale); that is, they were sub-angular with a high degree of sphericity. Sample 72 E-4 was more angular (0.20) with a high sphericity. A tarnish, probably due to postglacial chemical weathering, was present on most grains though a slight polish was visible on the quartz fraction, the latter being indicative of abrasion by water transport.

As a general result of the analyses there would seem to be a certain amount of sorting by water and a lack of fines and very coarse material in the samples.

Conclusions and Discussion

From the textural analysis, morphologies and literature, it is concluded that the two features at Barney's Brook, which includes the deposit in Little Sandy Pond valley, and the Sheffield Hill formation are true eskers. The reasons for deciding so are:

1. The high number of undisturbed perched erratics on the deposits at Sheffield Hill and Barney's Brook. If the material had been deposited in open crevasses it is unlikely that boulders would have lodged as shown in Plate 16. The erratics were probably deposited from englacial and supraglacial debris as ice stagnated *in situ*.

2. The well washed granular material and lack of a very fine sand-silt fraction would also indicate esker-like composition. These signify flow deposition and a removal of specific sediment fractions rather than infilling and poor sorting of material.

3. The dimensions of the features are greater than those outlined by Flint (1928) for crevasse fillings (Point 2, Table 3-1).

4. In each of the locations the area surrounding the eskers is free of large amounts of ablation moraine and kettles, the presence of which would imply crevasse fillings (Point 6, Table 3-1).

5. While no bedding was discovered, this does not preclude

classification of the deposits as eskers since Flint (1928) notes that they may be semi-stratified to non-stratified (Point 8, Table 3-1).

6. The association of the Barney's Brook - Little Sandy Pond valley complex with an area of recessional moraine conforms with point 1 (Table 3-1) which defines esker location as being within, and tributary to, terminal or recessional moraine. This is possibly the weakest of the criteria listed for deciding the feature origins. While the point is valid for smaller localized valley eskers, deposits the size of Munro esker (lat. 48° N, long. 80° W) which is 250 miles (400 kms.) long and 1-4 miles (1.6-6.4 kms.) wide (Lee, 1965) would obviously be associated with multi-variate glacial deposits.

The orientation of the eskers seems unusual, since in an overall field context ice movement was to the northeast; however it may be explained with relation to more localized flow. Following an initial stage of coastal delta construction, ice retreated steadily until a pause occurred at the 800 feet (243 meters) contour delineating the High Central Plateau (Chapter 1 and Fig. 3-1). South and southwest of this line ice remained long enough for esker formation.

Neale and Nash (1963) map west-east stoss and lee forms near the Barney's Brook source area indicating late east and west ice flow. Within this zone, however, the terrain is flat. Any strong hydrological gradients would have been confined to major valleys. Ice at this stage of deglaciation was thin and major hills presented barriers to the movement of subglacial waters.

From the criteria outlined by Doornkamp and King (1971), thickening of an esker towards its ice marginal or distal end, (Point 9,

Table 3-1), it appears that for the Barney's Brook esker hydrological gradient was to the southwest and then northeast at its terminus. Major topographic obstacles were avoided and final flow was confined to the Barney's Brook Valley. Flow in the Little Sandy Pond - Barney's Brook esker was to the northwest. Orientation of the deposit conforms with the long-valley axis; roughly north with a northwest component at the distal end. Meltwater flow in the Sheffield Hill esker was to the north, in a shallow valley context and with a localized hydrological gradient.

These orientations are logical since ice was thicker several miles southwest of the eskers and in the case of the Sheffield Hill vicinity there had been a westerly component to ice flow at a late stage of deglaciation (Chapter IV). Further east at Barney's Brook topographic gradients and valleys would have been pronounced enough to control late ice flow in an approximate northerly direction.

The direction of meltwater channels on the High Central Plateau (Fig. 3-1 and Glacial Map, Chapter V) compare favourably with the orientations of the eskers. The channel patterns indicate topographic flow (a) to the northwest near Sheffield Hill, and (b) into the Barney's Brook drainage system further east. Thus the zone of eskers is indicative of late topographically controlled ice flow from the High Central Plateau.

Other features analyzed in the vicinity of Foretopsail are crevasse fillings similar to those described by Lundqvist (1965). They are highly dissected, associated with kettles and ablation moraine, trend at various angles within a specific deposit and are less than 1 mile (1.6 kms.) in length.

CHAPTER IV

THE KITTY'S BROOK - CHAIN LAKES MORAINES

Introduction

The Kitty's Brook - Chain Lakes valley system contains a series of large southeast-northwest oriented ridges. The field area extends towards the southwest to include these features. Although dominant ice flow considered in the total study was to the northeast, it is from the Kitty's Brook - Chain Lakes area of the High Central Plateau that late topographic flow was directed down-valley to the southwest, and then northwest into Sandy Lake (Plate 20). Thus, analyzing the Kitty's Brook - Chain Lakes features may be considered an important step in synthesizing the deglacial sequence of the field area.

Several early researchers made note of the general area. Coleman (1926) decided that the High Central Plateau had not been glaciated during the Wisconsin:

> The general tableland does not suggest glaciation since it is a plain covered with great bowlders (SIC) of granite and gneiss just like the underlying bedrock which shows as low bare ridges in places but is usually hidden by coarse and fine granitic debris which seems to have originated in place. . . . The greatly weathered surface of the mountains (Topsails) and the tableland . . . suggest that glaciation was probably of Kansan or Jerseyan age. (pp. 205-206)

Coleman's mistake in dating the Topsails area glaciation was in assuming that if the area had been covered by Wisconsin ice

PLATE 20.

THE KITTY'S BROOK - CHAIN LAKES AREA.

N.A.P. UNCORRECTED MOSAIC NO. RE-5992

APPROXIMATE SCALE

1 INCH = 4 MILES

1 CM. = 5.6 KMS.

the degree of periglacial and postglacial weathering of the "Topsails granite" would have been far less than it in fact is.

MacClintock and Twenhofel (1940) make specific mention of the Kitty's Brook area:

> From Kitty's Brook Station to the top of the Plateau at Gaff Topsail [there are] morainal hills 50 to 200 feet (15-60 meters) high composed of gravel and till. Interspersed are kettle holes of equivalent dimensions, many of which contain lakes.
>
> The Kitty's Brook moraines were built when tongues of the upland ice cap projected part way down the valley. This stand . . . was either a halt in recession or possibly a re-advance. (p. 1745)

Prest *et al.* (1967) have mapped the ridges as ribbed moraine, large scale features with a transverse linear pattern giving a ribbed effect to the land surface:

> The individual ribs consist of bouldery ridges up to a mile (1.6 kms.) or more in length; 30-90 feet (9-12 meters) high with crests 300-1000 feet (90-300 meters) apart (Prest, 1968, p. 6).

Lee (1962) attributes the formation of ribbed moraine to an overriding of basal till. The moulding process is described as occurring during re-advance when the ice slipped over unfrozen till with quantities of the material being built up or undercut at the ice edge by a bulldozer effect. As the material became more compact and resistant, ice moved up and over the ridge, continuing its advance by repeating the process.

Ribbed moraine has been associated with drumlins and fluted ground moraine; the latter may be linked to an increase in altitude and a change in certain factors of formation, such as flow from high to low pressure areas (Cowan, 1968).

The uncertain origin of the features and the importance of the zone in the sequence of deglaciation of the field area necessitated a traverse in the Kitty's Brook - Chain Lakes area. Several samples were collected for later textural analysis and a series of till fabric diagrams were plotted.

Morphology

The southwest Chain Lakes area deposits are from 700-1500 feet (210-450 meters) wide in a north-south direction, span 1-1.3 miles (1.6-2.1 kms.) across the valley and are spaced 2000-2500 feet apart (Fig. 4-1, Plate 21). In the northeast, towards Sheffield Hill, spacing between the features increases to 3500-5000 feet (1.1-1.4 kms.) while central lake system ridges are discontinuous. Heights of the lineaments in the southwest area range from 50-90 feet (15-27 meters); at the northeastern extremity of the lake-chain heights increase to 130-140 feet (39-42 meters). The major northeasterly trending trough in which the features are located is 1.0-1.4 miles (1.6-2.1 kms.) wide and 150-200 feet (45-60 meters) deep. Many of the lineament crests coincide in elevation with the High Central Plateau at 1250 feet (375 meters) to the east and with a narrow planar remnant west of the valley.

Towards the southwest, the slopes of the deposits are very smooth with slope angles approximately equal; (Plate 22) at the northeastern end of the valley system slopes are steeper, and concave in plan and profile towards the southwest, suggesting ice contact features. Lakes in the center of the valley are elongate while at either end of the system they are rounded.

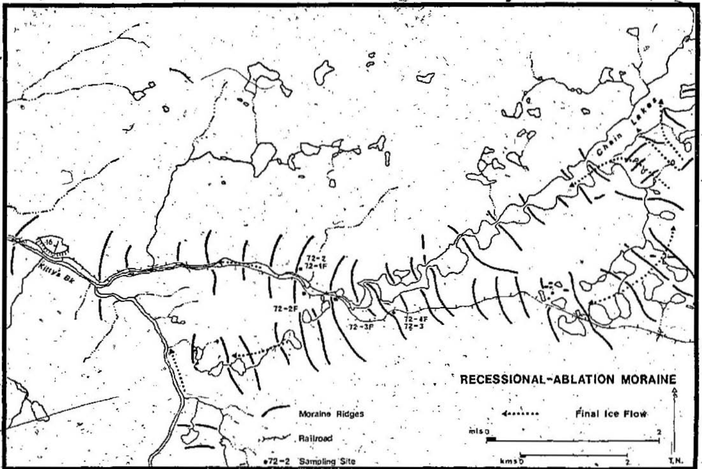

Chain Lakes
Kitty's Bk
16
72-2
72-1F
72-2F
72-3F
72-4F
72-3
RECESSIONAL-ABLATION MORAINE
Moraine Ridges
Railroad
•72-2 Sampling Site
Final Ice Flow
mls 0
2
kms 0
2
T.N.

Figure 4-1

PLATE 21. THE CHAIN LAKES RECESSIONAL-ABLATION MORAINES PHOTOGRAPHED FACING SOUTHWEST.

PLATE 22. CHAIN LAKES MORAINE 72-3. NOTE THE LOBATE CREST AND SHALLOW SLOPE ANGLE.

Since the deposits are concave up slope at both ends of the valley system, orientations of 285–350° represent only a trend normal to the structural trough. Moraines on the east side of the plateau (middle-east, Fig. 4-1) are oriented in a northeast-southwest direction; their heights and slopes are similar to those previously described.

Textural Analysis

The purpose of the textural analysis was to ascertain if the deposits are glacial or glaciofluvial, that is, whether the material is a glacial till shaped by a final ice thrust or outwash deposited by meltwater around stagnant ice bodies. Normally the latter is stratified. No stratification was visible in the deposits, therefore, in order to confirm the materials' origin, two samples were collected from cuts near the southwest end of Chain Lakes (Fig. 4-1). It was felt that these would be representative of sediment contained in the transverse deposits.

A wet sieve analysis was completed on the samples at whole ϕ intervals and the results were plotted on Arithmetic Ordinate Cumulative Curves (Fig. 4-2) and Frequency Curves (Fig. 4-3). Calculations of the mean, inclusive graphic standard deviation, kurtosis and inclusive graphic skewness were completed as outlined in Appendix 1. The results are presented in Table 4-1.

CUMULATIVE CURVES

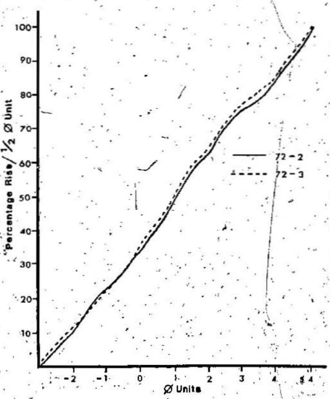


Figure 4-2

FREQUENCY CURVES

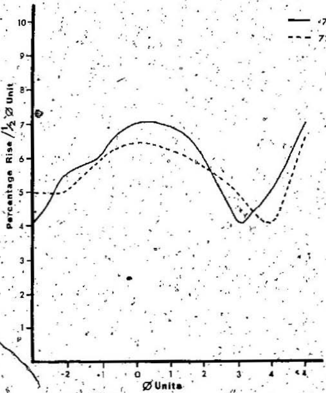


Figure 4-3

Results

TABLE 4-1

CALCULATED DATA FOR CHAIN LAKES
SAMPLES 72-2 - 72-3

Sample	Mean	Inclusive Graphic Standard Deviation	Kurtosis	Inclusive Graphic Skewness
72-2	1.13ϕ	2.54ϕ Very Poorly Sorted	0.80 Platykurtic	0.04 Near Symmetrical
72-3	1.10ϕ	2.52ϕ " "	0.66 Very Platykurtic	0.08 " "

The above results are indicative of a glacial till. The poor sorting and symmetrical Frequency Curves suggest the material has not been exposed to significant glaciofluvial action. The kurtosis values of .80 and .66 describe the bimodal quality of the sediments (Fig. 4-3). Both samples have a lack of material in the 3-4ϕ range. This conforms with the parameters for a glacial till described by German (1964), which show a flattening of the Cumulative percentage Curves at 5-3ϕ for various European till samples. While the ϕ range used in the Cumulative Curves (Fig. 4-2) in this report is not as broad as that used by German, a similar 3-4ϕ trough is visible on the Frequency Curve (Fig. 4-3).

Stereo Microscope Analysis

From a stereo microscope analysis of the 2ϕ segments of the till samples, it was ascertained that the grains are angular to very angular (.17, Powers (1953)) with a low degree of sphericity. There is little polish to the quartz content of both samples. This is indicative of a till and of glacial abrasion which results in tiny angular irregularities or fresh fracture surfaces (Folk, 1968).

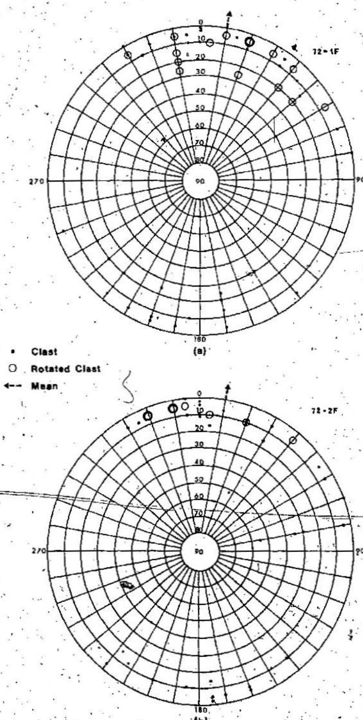
Till Fabrics

To further test the various theories of the origin of the Kitty's Brook - Chain Lakes features, several till fabric analyses were completed on selected deposits (Fig. 4-4, a,b,c,d). If the features were ribbed moraine or recessional features, one would expect a primary mode normal to ridge crests since both features are derivatives of ice flow.

Cowan (1968) describes the orientation of straight-ridged ribbed moraine clasts as "appearing in all cases to fall close to the direction of a glaciation" (p. 1150). For curved ridges he found that fabrics indicated movement related to "both the direction of glaciation and to some attribute of the ridge itself" (p. 1153).

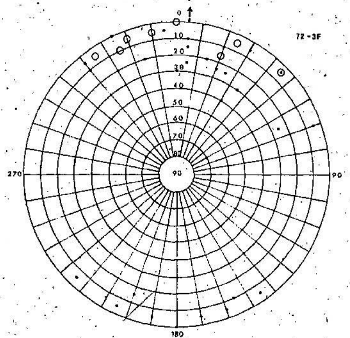
Recessional moraine is a resultant dump of ground moraine by stagnating ice but since it has been carried along during advance it would show some clast orientation paralleling final flow.

Railway cuts were used as sites where possible, and where not, fabric pits were dug to a depth of 36-48 inches (90-120 cms.) in an attempt to avoid zones affected by frost heaving and weathering. Feature trends were noted in the field while primary and secondary modes were visually interpreted from Rose diagrams of the data, (Fig. 4-5, a,b,c,d). Means and standard deviations were obtained from

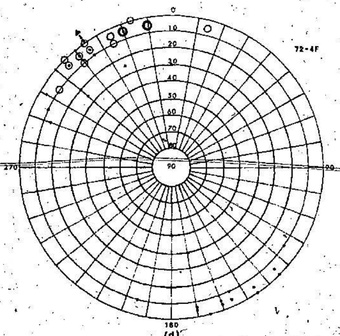


72-1F
0
10
20
30
40
50
60
70
80
90
270
90
180
(a)
Clast
Rotated Clast
Mean
72-2F
0
10
20
30
40
50
60
70
80
90
270
90
180
(b)

Figure 4-4


0
10
20
30
40
50
60
70
80
90
270
90
180
72-3F

(c)


0
10
20
30
40
50
60
70
80
90
270
90
180
72-4F

(d)

Figure 4-4

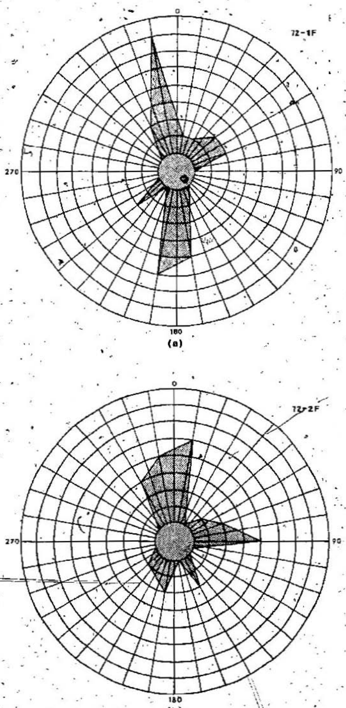


Figure 4-5

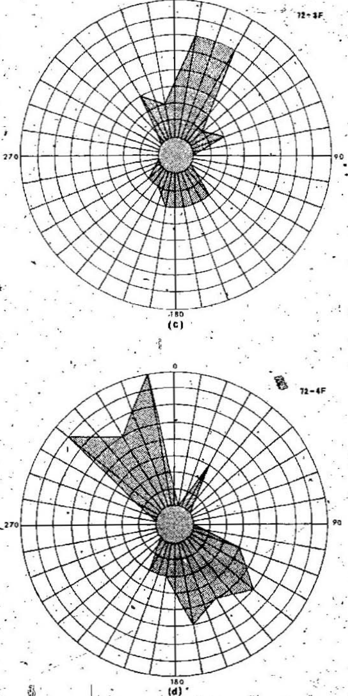


Figure 4-5

the till fabric diagrams and application of the relevant calculations outlined in Appendix 1. The results are presented in Table 4 - 2.

Results

TABLE 4-2

TILL FABRIC DATA, CALCULATED AND INTERPRETED

Sample	Mean	Standard Deviation	1° Mode	2° Mode	Feature Trend
72-1F	010	30°	350	090	010
72-2F	010	42°	355	055	010
72-3F	005	27°	020	160	345
72-4F	325	22°	330	200	320

Primary orientations for 72-1F and 72-4F are approximately parallel to feature elongation. Fabric 72-2F has a weakly developed primary mode with a strong secondary mode normal to the ridge crest.

Primary mode orientation for 72-3F is 180° from the assumed ice flow direction, that is it shows a marked plunge towards 010°. This probably occurred because the till fabric diagram was constructed from clasts on the northerly or up-valley slope of the ridge; all other samples were obtained from central positions or down-valley slopes. Otherwise the till fabric orientation at 72-3F has a primary mode sub-parallel to ice flow and a secondary mode parallel to feature elongation. In all cases two fabric modes have been observed; one parallel and one transverse to assumed ice flow from Kitty's Brook valley. If one is to explain the features either as ribbed moraine or recessional moraine as previously discussed, the bimodal aspect of the till fabric diagrams need clarification.

Discussion

Glenn, Donner and West (1957) note that in till fabrics where there is a secondary mode, it is usually at right angles to the primary mode and may exceed it in magnitude. In this instance the authors are assuming that a primary mode is parallel to ice flow rather than being the dominant orientation. They suggest that there are significant correlations between prolateness of clasts and a tendency to transverse modes, which they account for by collisions between more elongate stones.

Harris (1969) explains the relation of secondary modes to roughness of terrain. In areas of high relative relief he found that till fabrics had a high M.S.O.C. (Appendix 1) and poor modal orientation in the direction of ice flow. With a relative relief of 100–200 feet (30–60 meters) a notable development of transverse modes was observed.

Similarly, Andrews and Smith (1970) describe the occurrence of a dominant mode at right angles to ice flow. They interpret the phenomenon with the idea that as ice ascends a bedrock slope, clast rolling and thrusting becomes the main orientation-producing process; that is, a transverse mode is produced by changes in local flow conditions.

Rutter (1964) studied clast orientations in surging and normal glacier moraine. He found that normal glacier deposits have strong preferred orientations in the approximate direction of ice flow.

In surging glaciers stone orientations are weak, and, where they are apparent, are not necessarily parallel to flow. One fabric site in normal glacier moraine showed a definite transverse orientation. This he explains by observing that the sample site was on a steep slope and may have suffered post-depositional slump or alternately, consist of ablation debris deposited at the ice margin. While his ideas are worthy of note, it would be unwise to place too much emphasis on them since the Kitty's Brook - Chain Lakes deposits are unlike those in Rutter's area.

Dreimanis (MacClintock and Dreimanis, 1964) describes a series of till fabrics with two maximum orientations separated by an angle of 60°. One represents the penultimate glacial movement, the other defines the latest, which re-oriented at least half of the elongate pebbles parallel to the fabric maximum of the overlying till.

It is felt that the process described by Dreimanis is not applicable to the Kitty's Brook - Chain Lakes area, since here orientations were obtained near the surface of a contiguous till unit. One might suggest that the transverse modes were obtained from penultimate ice flow over the ridge north of Chain Lakes towards White Bay, however, it is unlikely that such an orientation would survive later re-working in a near-surface till unit.

The following mechanisms may be responsible for the strong transverse secondary modes in the Kitty's Brook - Chain Lakes area deposits:

- Re-orientation of prolate clasts during final flow. Unfortunately this cannot be tested since no record of individual clast shapes and their orientation was taken.

- Height above the valley floor. This is probably the most likely reason since all till fabric sites were 100-150 feet (30-45 meters) above the valley floor and relatively near the bedrock walls. No pits were dug on the lower central remnants of the features.

Andrews and King (1968) state the writer's view in the following:

> A till fabric is a sample of a larger unsampled set of pebbles and since fabrics may vary markedly within the same till exposure, single sample, single site results should be used with caution. (p. 458)

Obviously many more till fabrics analyses of the Kitty's Brook - Chain Lakes ridges need to be completed before one can conclusively interpret their dominant fabric orientations.

<u>The Kitty's Brook Glaciofluvial Deposit</u>

At mile 343 on the C.N.R., on the north side of Kitty's Brook valley there is a small outwash delta or fan (Plates 23 and 24). Fore-set bedding in the deposit strikes 020°, dips 16° E and contains large stones 1-3 feet (0.3-0.9 meters) in diameter. On the valley floor (Plate 25) and in the topset material, large well rounded to sub-rounded boulders 2-4 feet (0.6-1.2 meters) in diameter are visible. These are indicative of large volumes of water that must have poured down the valley late in deglaciation.

Air photo analysis of the feature indicates several melt-water channels that may have contributed to its formation. The deposit appears to be a delta formed in a small glacial lake, dammed up between two of the morainal features (Fig. 4-1), and since emptied by incision of Kitty's Brook. The deposit is presently

PLATE 23. C.N.R. MILE 343, THE KITTY'S BROOK DELTA.

PLATE 24. VIEW OF THE KITTY'S BROOK DELTA PHOTOGRAPHED FACING NORTH. BEDS ARE ORIENTED 020°, 16° L .

PLATE 25. KITTY'S BROOK VALLEY, (NOTE LARGE WELL-ROUNDED BOULDERS). PHOTOGRAPHED FACING NORTHWEST.

being used by Canadian National Railways as a borrow pit and it is impossible to determine the former extent of the delta, though since it is nearly 60 feet (18 meters) thick deposition probably continued for a considerable period of time.

Conclusions

Several features of the ridges prohibit their classification as ribbed moraine. Clast orientation is not well enough defined to meet the parameters outlined by Cowan (1968); also their morphological dimensions and spacing are greater than described by Prest (1968). From their morphology and the textural analyses, the following system is proposed for their construction.

The High Central Plateau was an ice dispersal centre in the late Wisconsin. During deglaciation, ice flow may have been towards the north or northwest as evidenced by eskers and meltwater channels (Chapter III). Ice pouring off the plateau flowed north-northeast towards Sheffield Lake and southwest down Kitty's Brook valley (Plate 20). The large northeast-southwest oriented till ridges east of Chain Lakes (Fig. 4-1) may be related to topographic flow from the plateau into the valley system. Ice contact slopes in the lower northeast sections of Chain Lakes valley suggest that rather than forming a series of true recessional moraines, ice stagnated in large blocks behind the deposits, giving them their elongated, concave-convex forms. Hence the deposits may be classified as recissional-ablation moraine.

The delta in Kitty's Brook valley was deposited just before a final glaciofluvial stage which connected the individual ponds and formed a complete drainage system.

CHAPTER V

GLACIAL MAP COMMENTARY

This chapter serves to explain the classification and symbols used on the glacial map of the field area (pocket, back cover). While the preceding chapters of the thesis deal with specific geomorphic problems, it is hoped that the map will present a more complete picture of glacial events. Both drift prospecting and geochemical sampling require such an interpretation as a starting point. Since the field area is part of the Central Mineral Belt and heavily drift covered, the following explanations used in conjunction with the map may provide a useful tool for future mineral exploration. It is recommended that the map be used with reference to Figure 6-1 since the features are not all contemporaneous and ice flow direction changes with stages of deglaciation.

Initially, a genetic terrain classification devised by Fulton *et al.* (1971) and used by the Geological Survey of Canada was planned as a mapping code. Unfortunately the system has several disadvantages. It does not focus on glacial landforms and events but rather presents a consolidated view of the landscape within defined boundaries. Also since the classification consists of a genetic category, morphological modifier and textural modifier, it is not easy to interpret the system unless one is completely familiar with the code. For example, $s\,F^{A}\,pK$, is interpreted as a fluvial environment where the geologic process responsible for the category is still actively affecting the area.

The modifiers state that the zone is a sandy thermokarst plain. Consequently, a modified form of the Glacial Map of Canada (Prest, Grant and Rampton (1967)) and Fulton's classifications has been attempted.

Unlike either of the terrain classifications mentioned, morainal zones have not been bounded; rather gradational symbols have been used that connote densities or marginal zones of specific features. The following list presents some of the terms used with brief explanations; others are self explanatory.

Delta Surface

The delta surface describes the raised deposits in a modern context. No differentiation is made under this heading for terrace levels in evidence on the main scarp. Landward boundaries were constructed at bedrock outcrops or distinct breaks in slope.

Erosional Terrace

A well defined terrace has been mapped at the 50 feet (15 meters) level. Other erosional features exist (Chapter II) but are not continuous ~~on all delta deposits~~ and for reasons of scale have not been included.

Kettles

Kettle holes have only been indicated when they are located on or near delta surfaces. Numerous kettles occur in several areas, but again because of scales and densities of the features they have not been mapped.

Outwash

Included within this denotation are materials deposited proglacially and derived specifically from meltwater as ice retreated inland. Essentially these are cross-bedded sediments of varying grain sizes deposited in valley trains.

Major Meander Scar

The symbol has been used at only one location and describes a feature that might be mistakenly interpreted as a raised delta remnant.

Ribbed Moraine

Ribbed moraine has been described with some detail in Chapter IV. Within the field area it is confined to shallow valleys and associated with elongate lakes which visually amplify the ridges. Prest (1968) describes the moraine as occurring on the flanks of drumlinoid ridges and eskers or on the low ground between them. In west-central Newfoundland ribbed moraine is generally associated with drumlinoid ridges.

Drumlins and Drumlinoid Ridges

True drumlins with steep stoss end and tapered distal slope are thinly distributed in the field area. Features mapped as such may or may not be rock-cored but their external morphology is similar to the classical dome-shaped till structure.

Drumlinoid ridges are more numerous and include narrow elongate rock-cored ridges tapered at either end, though the stoss end may be more blunt than the lee (Prest, 1968). Where defined by a stoss and lee form, direction of flow has been indicated, however several of the drumlinoid ridges are not well developed and are located where the sense of ice flow is not immediately certain.

Flint (1971) observes the following for drumlin forms and ice flow:

> 1. The presence of such forms establish the existence of an actively flowing glacier at the time of formation in contrast with ice-contact drift which indicates comparatively inactive ice.
> 2. The long axis of the streamline forms are a more reliable indication of the general direction of movement of a former glacier than are striations because they are less influenced by local topography (p. 106).

Hummocky Disintegration Moraine

Lundqvist (1965) classifies such a deposit as an irregular hummocky ablation moraine. Prest (1968) refers to an original work by Gravenor and Kupsch (1959) when he describes the features as "high relief, irregularly mounded and deeply pitted type of non-oriented hummocky moraine which is believed to form as a result of glacier desintegration or stagnation" (p. 11). In the field area deposits are from 75-100 feet (23-30 meters) high though Prest reports extreme cases of 200 feet (60 meters) in other locations. The deposits near Gaff Topsail are not extensively pitted but rather are "equidimensional mounded surfaces," (Prest, 1968) on a plateau. The lowlands around the moraine are boggy and contain numerous shallow lakes.

Ridged Ablation Moraine

More prevalent is a type of disintegration moraine described by Hoppe (1952). Areas of such deposits contain:

> 1. ridges up to 100-115 feet (30-35 meters) in height. (In west-central Newfoundland ridge heights are in the range of 50-60 feet (15-18 meters).

2. dead ice hollows.

3. moraine plateaus.

In the above study the ridges are regarded as being formed underneath the ice through the squeezing of water-soaked morainal material into basal cavities. The dead ice hollows indicate areas of residual ice, while the moraine plateaus are considered to be secondary features. Hoppe alternatively suggests the plateaus might represent original elevations of material below the ice. Ridged ablation moraine is confined to valleys and has little value for determining ice direction (Hoppe (1952), Lundqvist (1965)). Stalker (1960) notes that the moraine does not necessarily represent former ice sheet margins, but rather may denote changes in the rate of, or even halts in, the lowering of the surface of an ice sheet.

Recessional Moraines

The category includes the recessional-ablation moraine described in Chapter IV and other marginal and lobate recessional feature remnants. The designation may include interlobate moraine or kame terrace remnants without differentiation, since many of the features were mapped without field analysis.

Structural Lineations

Structural lineations are not to be confused with drumlinoid ridges. They indicate the orientation of outcrop ridges and bedrock trends. For the central section of the field area, elongation of the symbols indicates the limbs of major synclinal troughs (Neale and Nash, 1963).

Glacial Striae

Striae have been plotted near Halls Bay and include only those mapped by the writer. Others have been recorded by Neale and Nash (1963) and Lundqvist (1965).

Striations plotted on the map are:

1. Lower Wolf Cove, Springdale - 070°
2. Roche moutonnee south-southeast of South Pond - 035°, 020°
3. East of Burnt Berry Pond - 090°, 110°, 115°
4. North of South Brook town - 020°
5. Roberts Arm Road - 315°, 330°

CHAPTER VI

CONCLUSIONS AND DISCUSSION

From the air photo interpretation and analyses applied to specific glacial features, it is possible to suggest a sequence of events for the late glacial and postglacial of west-central Newfoundland. The field area is more of a transect than an entity, thus some correlations are implied with surrounding areas, based on the research of others and current field evidence for the "Halls Bay – Topsails" area. Ice fronts (Figure 6-1) are approximations only and were plotted from ice-marginal deposits where possible and where not, were implied from the general terrain. The figure should not be considered as a spatially exact chronological sequence, but rather as an indication of the manner in which ice retreated.

Glaciation

During the late Wisconsin maximum, ice flow in the field area was to the northeast (Fig. 6-1) and north towards White Bay from an ice cap centered south of the field area on the High Central Plateau. The orientations of drumlinoid ridges are evidence of this flow, as are the zones of ribbed moraine which are small and confined to valley bottoms where late flow would have been strongest. Multi-directional striae indicate late flow during which ice changed direction as it moved around outcrops and off minor plateaus into valleys.

It is considered that there was at no time an invasion of

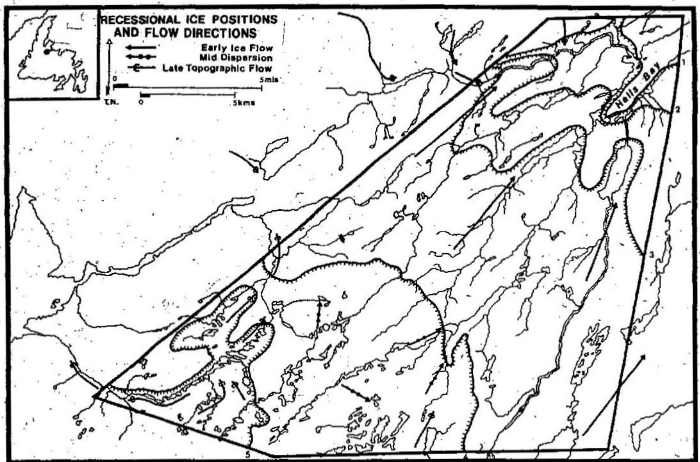

RECESSIONAL ICE POSITIONS
AND FLOW DIRECTIONS
Early Ice Flow
Mid Dispersion
Late Topographic Flow
T.N.
0
5mls
0
5kms
Halls Bay
1
2
3
5
6

Figure 6-1

Labrador ice either in the Halls Bay area or on the Burlington Peninsula to the northwest (See Introduction). Grant (1969) states that:

> Laurentide ice from Labrador advanced southward over at least the lowland portion of the Northern Peninsula and perhaps 1000 feet (300 meters) up the flanks of the Long Range mountains as evidenced by unidirectional grooving, prominent roches moutonnees, Labradorian erratics on the uplands near Roddickton and St. Anthony and a shelly drift that was spread widely over the area (p. 124).

Following Grant's analysis, if Lauentide ice had in any way affected the Burlington Peninsula, one would have to assume ice wrapping around the tip of the Northern Peninsula with a southerly component of flow as it crossed the Grey Islands (Fig. 6 - 2) and moved towards White Bay and east. There is no evidence for this hypothetical southeasterly onshore flow in the Burlington Peninsula or Halls Bay areas.

Deglaciation

Shortly before 12,000 B.P. ice retreated from Halls Bay, (as well as Green Bay), and within the field area, a set of raised deltas was deposited at Springdale and lower Halls Bay. Kettles and ablation moraine indicate that ice fronts were near the deltas during deposition. This may be the assumed outer drift zone boundary outlined by Lundqvist (1965). The writer feels however, that if a coastal area is deglaciated quickly by calving ice fronts in the major bays and fjords with ice remaining just inland as in position 1 (Fig. 6 - 1), deltas would obviously demarcate the ice margin. This does not imply inner-outer drift zones but rather describes ice retreat sub-paralleling a land-sea margin. In the Halls Bay area a total of 440 feet (133 meters) of postglacial uplift has occurred since 12,000 B.P. and is represented by 250 feet (75meters) net emergence after a eustatic rise in the same period of 192 feet (58 meters).

During the delta-building stage, ice retreated from the coast by stagnating in the valleys and lowlands between positions 2 and 3 (Fig. 6 - 1). Ridged ablation moraine is found in the middle and upper sections of the valleys where ice was thick enough to cause basal squeezing necessary for its formation. In the area northeast of Sheffield Lake, ridged ablation moraine partially overlies an earlier zone of ribbed moraine. Radial meltwater channels around the hills are further evidence of stagnant lowland ice and general thinning in early deglaciation.

At position 4 (Fig. 6 - 1) a still stand is indicated. The zone is delimited by a group of eskers just inside an abrupt steepening to the High Central Plateau from 800 feet (240 meters) to an 1100 feet (330 meters) level. Although ice stagnated in this zone, as evidenced by the ridged ablation moraine and eskers, several minor stages of recessional moraines near Barney's Brook and Little Sandy Pond suggest earlier active flow. The features are probably related to the Kitty's Brook - Chain Lakes recessional-ablation moraines and a topographically controlled flow from the High Central Plateau. Crevasse fillings in the area post-date the ridged ablation moraine and may be considered a final constructional form in the sequence of deglaciation.

On the lower Halls Bay-Gull Pond level, the northeasterly trending valley trains derived much of their material from this stage and final deglaciation. No climatic causes are envisaged for the still-stand, rather it is assumed that the event was a result of ice clearing the lowland and leaving the higher plateau ice as an independent body.

Final ice within the field area stagnated *in situ* just south of the Gaff Topsail, as denoted by hummocky disintegration moraine and a zone of thick drift. Meltwater from this stagnant zone and ice remaining on the hills west of the Kitty's Brook - Chain Lakes trough cut large channels in the valley system and constructed the postglacial delta noted in Chapter IV.

The plateau just south of the field area and north of Hinds Lake may be considered as one of the last ice areas in Newfoundland. Another was probably located on the Buchan's Plateau further south, from which ice flowed radially (Murray, 1955).

No date has been obtained for the two final glacial events in the field area, (positions 4 and 5). Andrews (1972) describes average marginal recessions of 860 feet (260 meters) per year between 12,000 and 7,000 B.P. for south and northwest margins of the Laurentide ice sheet. For the northeast corner he applies a retreat value of 66 feet (20 meters) per year. The northeast coast of Newfoundland was probably not affected by warm air masses similar to those at the continental ice margin, rather, the cold Labrador current was a more likely influence. Ice marginal positions for Newfoundland as speculated by Prest (1970) take account of this. Thus, Andrews' northeastern values are most applicable to conditions on the northeast coast of the island.

Retreat rates of 66 feet (20 meters) per year and a distance of 19 miles (30 kms.) from the coast to the edge of the plateau (position 4, Figure 6-1) yield a value of 1500 years for deglaciation conditions. Re-applying the method to the distance from the coast to Gaff Topsail, (34 miles, 55 kms.), a time span of 2750 years is calculated for ice retreat to reach the area, though final ice probably remained at this position for some considerable time. If radiocarbon date, G.S.C.-1733 is used for coastal deglaciation (12,000 ± 220 B.P.) then it would be expected that deglaciation of the area around Gaff Topsail occurred at about 9,250 B.P.

Grant (1969) dates the Ten Mile Lake readvance on the Northern Peninsula at 10,900 B.P., so it is logical that ice remained on the south High Central Plateau at this time. The dates calculated by Andrews method are speculative, however it seems that a more exact chronology will not be obtained in the immediate future. Macpherson (1973) suggests reasons for a considerable lag in postglacial vegetative colonization in Newfoundland which might rule out the possibility of accurately dating non-marine inland events in the field area.

Further Research

The field area and zones peripheral to it offer much scope for future glacial investigations. More detailed research is required on the recessional-ablation moraines in the Kitty's Brook - Chain Lakes area. Analysis of the northeastern end of the valley complex near Sheffield Lake would further help in interpreting the deposits, since the present study includes only a small area at the southwest end of Chain Lakes.

Ice retreat in Indian Brook Valley and the probable lacustrine deposits related to this stage of deglaciation should be given further attention. It may be that final topographic flow into the valley was from the plateau areas to the north and south and that residual ice remained in the upper part of the valley for a considerable time after ice retreated from the coast.

2. A major glacial study should be undertaken directly to the east of the field area in the Twin Lakes - Botwood vicinity (Figure 6-2). An analysis of the Botwood delta complex and glaciofluvial deposits along the coast further north might provide additional data to the inner-outer drift zones theory.

Lundqvist (1965) has supported the Jenness (1960) argument by constructing a "supposed line of retardation" from just east of Bishops Falls on the Exploits River to Kings Point in Green Bay. It appears however that the boundary should be much further northeast than its present position immediately north of the Twin Lakes area. The writer has noted raised glaciofluvial terraces on the northeast coast of Notre Dame Bay, which may be further evidence of ice retardation sub-paralleling the coast.

Grant (1972) describes an easterly flow in the Twin Lakes-Notre Dame Bay area. In addition to the north to northeasterly flow, he suggests radial flow from a remnant ice mass south of Frozen Ocean Lake similar to the last ice centers of the Topsails and Buchans Plateau. Dated samples from the Botwood complex or the more northerly raised glaciomarine deposits would add credence to the possibility that the lower north coast of Newfoundland from Green Bay to Bonavista Bay was deglaciated at approximately the same time; an idea that cannot as yet be substantiated.

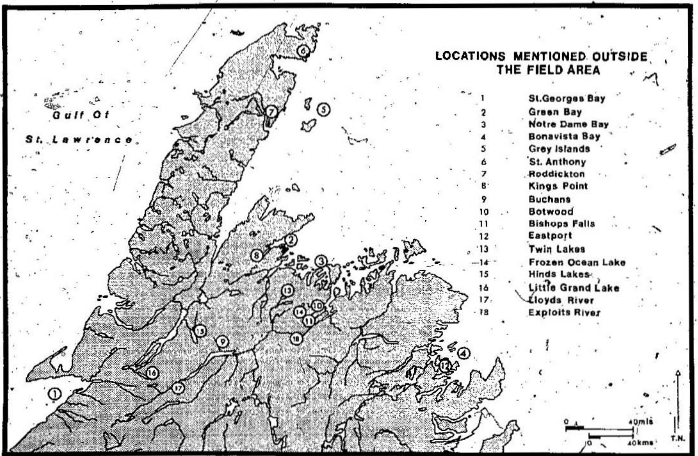

LOCATIONS MENTIONED OUTSIDE THE FIELD AREA
1 St.Georges Bay
2 Green Bay
3 Notre Dame Bay
4 Bonavista Bay
5 Grey Islands
6 St. Anthony
7 Roddickton
8 Kings Point
9 Buchans
10 Botwood
11 Bishops Falls
12 Eastport
13 Twin Lakes
14 Frozen Ocean Lake
15 Hinds Lakes
16 Little Grand Lake
17 Lloyds River
18 Exploits River
Gulf Of
St. Lawrence
0
40mls
0
40kms
T.N.

Figure 6-2

3. Expansion of the field south, to the Buchans Plateau would be a worthwhile venture in terms of describing another possible last ice center. It has been concluded that within the field area the "Gaff Topsails" was an area of last ice. Additionally, certainly the higher Buchans Plateau just southwest and northeast of Hinds Lake might be considered a last ice refuge since it is from this point that the terrain starts to slope away to the south and west. A study of the plateau with emphasis on the Lloyd's River valley, the Little Grand Lake valley and the lower Hinds Lake Plateau, would fill a large void in the glacial history of the island.

In the field of glacial geomorphology, the island of Newfoundland is one of the least studied areas in Canada. With increasing demands being placed on environmental understanding derived from such research, it is hoped that further studies on the island will receive the financial and logistical support which they deserve.

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APPENDIX 1

TECHNIQUES, INSTRUMENTS AND ANALYSES

Various field and laboratory methods were used in preparation of the thesis. While most are standard techniques, a list is provided with descriptions where necessary.

Sampling Techniques

Unconsolidated drift subjected to the various analyses was obtained by a standard procedure. Generally, 5 pound (2.5 kgms.) samples were acquired from cuts and packaged unsieved in polyethylene sample bags. Where good cuts were not available, pits were dug to a depth of 2-2.5 feet (0.62-0.76 meter) to avoid zones of weathering.

Silt samples obtained from a large deposit near Indian Brook (Chapter II) were sliced from a sedimentary section that had been removed intact from the field area and mounted on a metal retainer. Other silts analysed were procured in a manner similar to the drift samples.

Field Instruments

Various pieces of apparatus were in use throughout the field season. In addition to the standard field equipment, a Wallace and Tierman barometric altimeter was used. The instrument was zeroed at high tide level and field readings were interpolated to the nearest 2 feet (0.6 meters). Corrections for atmospheric temperature variations were applied using a sling psychrometer and a graphic scale provided with the altimeter. Most coastal elevations and those within two hours walking distance of datum were obtained by this method.

A hand level was used to determine heights above the general surface of remote features and deposits.

Till Fabric Analysis

Till fabric analysis was attempted on several deposits in the Kitty's Brook - Chain Lakes area. Each fabric analysis consists of orientation and dip measurements which were plotted on polar equidistant projections (Chapter IV, Figure 4-4), with orientations on a series of radii spaced at 10 degree intervals and dips on concentric circles indicating the angle of slope from the horizontal. The circles were also spaced at 10 degree intervals. Data was measured to the nearest 5 degrees and all bearings were corrected for magnetic declination. Pebble size was generally from 1-2 inches (2.5-5 cms.) with a long to short axis ratio of not less than 2.5:1.

A measure of probability as to whether the clasts sampled were preferentially oriented or not was calculated automatically in the field using Harris' (1969) method based on the conventional chi square test, in which the number of pebbles in a specified class is compared with the number of pebbles there would be if all the classes were equally filled. By following the graphic results one is able to determine exactly how many pebbles are required in the primary mode out of a total number counted to achieve a 95% level of confidence or the minimum significant orientation count (M.S.O.C.).

To calculate the mean and standard deviation of the fabrics without the negating effect of a 360 degree diagram, points included in an arbitrarily decided minor half of the projection were rotated 180 degrees. The means and standard deviations were calculated for a range of 0-180 degrees using a 20 degrees class interval. The results were then converted to azimuthal bearings relative to true north.

Size Analysis

A dry sieve analysis was completed on all sediment samples. An upper limit of -3ϕ (phi) and lower limit of 4ϕ were used at whole ϕ intervals. Each 100 gms. (3.5 oz.) sample was oven dried and then sieved for 15 minutes on a Ro-tap vibrator. It is acknowledged that whole ϕ units are too large for detailed sediment work, however the objective was to present a general quantitative description of various features and not a detailed sedimentological analysis.

Several samples containing large amounts of silt and clay were analysed for textural variations using a method of pipette analysis outlined by Folk (1968). The technique is based on the settling velocities of particles computed with reference to Stokes Law, $V = \frac{2}{9}(ds-dw)\frac{g}{n}r^2$, where: V = fall velocity in cms/sec., ds = density of the sphere, dw = density of the fluid, g = acceleration due to gravity, n = viscosity of the fluid and r = the radius of the sphere. Folk re-arranged the equation and provided a constant "A", dependent upon g, ds, and n, which is a function of temperature. By knowing the water temperature and particle density, the time required for any particle to fall any depth through a column of water can be calculated, and thus, the amount of a specific size of sediment contained in a given sample.

Prior to pipette analysis, the sediment samples were wet sieved and the material finer than 4ϕ was treated with H_2O_2 overnight to remove organic impurities. Samples were dispersed with .1N sodium hexametaphosphate (Calgon) and the analysis completed as outlined by Folk.

From the various textural analyses, cumulative and individual percentage weights were calculated for the samples and the results plotted on Cumulative (arithmetic ordinate) Curves and Frequency Curves. The following statistical parameters were determined from Folk (1968):

$$\text{Mean} = M_Z = \frac{\phi16 + \phi50 + \phi84}{3}$$

$$\text{Inclusive Graphic Standard Deviation} = \sigma_1 = \frac{\phi84 - \phi16}{4} + \frac{\phi95 - \phi5}{6.6}$$

$$\text{Inclusive Graphic Skewness} = Sk = \frac{\phi16 + \phi84 - 2\phi50}{2\ (\phi84 - \phi16)} + \frac{\phi5 + \phi95 - 2\phi50}{2\ (\phi95 - \phi5)}$$

$$\text{Kurtosis} = K_G = \frac{\phi95 - \phi5}{2.44\ (\phi75 - \phi25)}$$

X-ray Analysis

To test the variations in composition of certain samples an X-ray analysis of the sections finer than 8ϕ was attempted (outlined by Carroll, 1970). Oriented samples were prepared for analysis by coating glass slides with suspensions of the material to be tested. Three slides of each sample were made. They were air dried and the process was repeated to assure a thick coating. The procedure allowed the clay particles to settle with the 001 face parallel to the slide, the orientation necessary for scanning.

An initial X-ray pattern using a Phillips diffractometer and a proportional counter was run from 2–30 degrees 2θ (theta) at the following instrument settings: 2 degrees 2θ scanning speed, 40 KV., 20 MA., TC = 4, 200 c.p.s. and a chart speed of 20 mm. per minute. The results in degrees 2θ were converted to d- spacings in angstroms and the clay minerals present were determined. To test for montmorillonite, a second slide of each sample was treated overnight in a dessicator with ethylene glycol at a temperature of 80°C. As soon as possible after removing the slide from the dessicator a pattern was run from 2–15 degrees 2θ at the settings used previously. A final slide of the samples was analysed to determine whether kaolinite or chlorite was present. The samples were first placed in a preheated muffle furnace at 600°C for one hour. Upon removal they were scanned at the above settings.

Stereo Microscope Analysis

A stereo microscope was used to analyse the 2φ fraction of all sediment samples. From the study, particle roundness and sphericity were described using Powers (1953) criteria. The degree of polish on the quartz fractions was also noted and a search was made of specific samples for foraminifera and diatoms.

APPENDIX 2

TEXTURAL ANALYSES COMPOSITES

The purpose of the following appendix is to present graphical composites of all samples analysed, plotted in various statistically descriptive combinations.

Mean size and skewness are plotted in Figure A-1. A good separation is obtained between the silt samples (s) from Indian Brook valley and the esker (e) and till (t) samples. One esker sample is grouped with the tills. Although near symmetrical, its mean size does not vary substantially from the other esker samples, which are fine skewed.

In plotting skewness against standard deviation, Figure A-2, a well defined separation occurs between the sediment types. The till samples have a broad standard deviation which is a result of the glacially derived poorly sorted texture. Esker samples are sorted to a greater degree and generally finer skewed than the till; the silts although not as well sorted as the esker samples are strongly fine skewed.

A poor definition of water laid samples was obtained when skewness was plotted with kurtosis. From the results obtained it would be difficult to describe a specific hydrological environment. The tills are well separated from the esker and silt samples, since all water laid material was finely skewed.

It would be premature to explain the variances more than superficially based on so small a sample number. With a greater quantity of samples, boundaries should be defined more exactly, though deviations from the norm would still be present.

MEAN VERSUS SKEWNESS

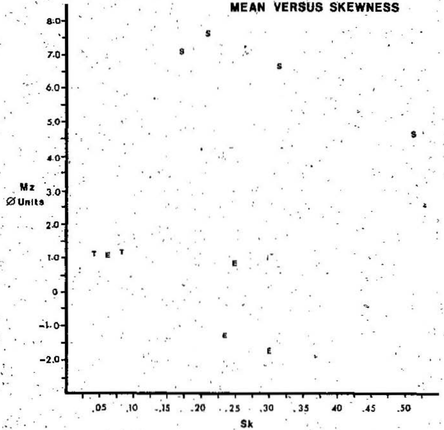


Figure A-1

SKEWNESS VERSUS STANDARD DEVIATION

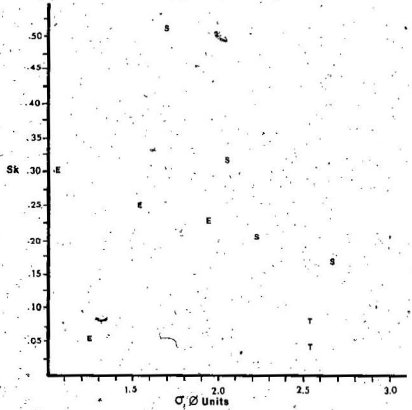
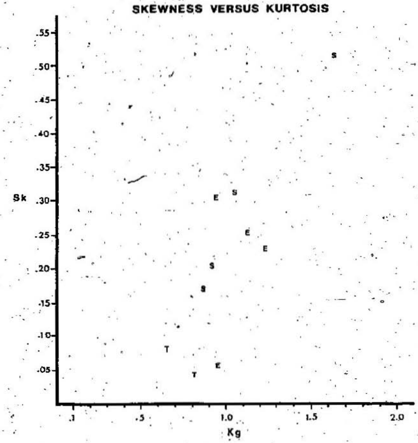


Figure A-2


SKEWNESS VERSUS KURTOSIS
Sk
.55
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
.1
.5
1.0
1.5
2.0
Kg
S
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T
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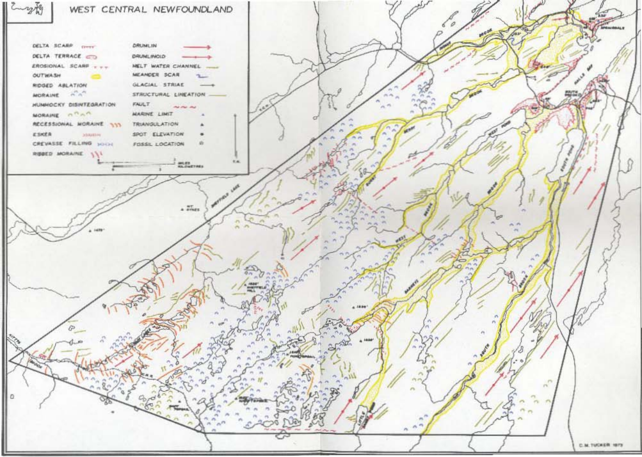
Figure A-3

APPENDIX 3

ABBREVIATIONS

C.N.R.	Canadian National Railways
D. M. A. R.	Department of Mines, Agriculture and Resources, Government of Newfoundland and Labrador.
D.R.E.E.	Department of Regional Economic Expansion, Government of Canada.
M.S.O.C.	Mean standard orientation count.
N.A.P.	National Air Photo Library, Government of Canada.
T.C.H.	Trans-Canada Highway.



WEST CENTRAL NEWFOUNDLAND
DELTA SCARP
DELTA TERRACE
EROSIONAL SCARP
OUTWASH
RIDGED ABLATION
MORAINE
HUMMOCKY DISINTEGRATION
MORAINE
RECESSIONAL MORAINE
ESKER
CREVASSE FILLING
RIBBED MORAINE
DRUMLIN
DRUMLINOID
MELT WATER CHANNEL
MEANDER SCAR
GLACIAL STRIAE
STRUCTURAL LINEATION
FAULT
MARINE LIMIT
TRIANGULATION
SPOT ELEVATION
FOSSIL LOCATION
MILES
KILOMETRES
SHEFFIELD LAKE
SOUTH BROOK
WEST BROOK
SOUTH POND
HALLS BAY
SPRINGDALE
C.M. TUCKER 1973